WOODY PLANT ESTABLISHMENT
AND
MANAGEMENT PROGRAM
FOR
OIL SANDS MINE RECLAMATION

Prepared
for

The Reclamation Research Technical Advisory Committee
and
The Oil Sands Environmental Study Group

by

Techman Engineers Ltd.

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Introduction

Techman Engineering Ltd. was commissioned by the Reclamation Research Technical Advisory Committee (RRTAC) of Alberta Environment and the Oil Sands Environmental Study Group (OSESG) to prepare a report entitled "Woody Plant Establishment and Management Program for Oil Sands Mine Reclamation." This study is being funded jointly by RRTAC and OSESG and is designed to provide information for essential long term planning for oil sands reclamation research.

Objectives

The objectives of the study, as identified in the terms of reference, are to:

- conduct a review of readily available information on the establishment and management of woody plants on level and gently sloping (less than 15 percent) amended tailings sand and other similar sites; and

- to prepare a critical evaluation of the information and provide recommendations on the most suitable methods for establishing and maintaining self-sustaining and productive plant communities in the Alberta tar sands area.

Scope of Study

This study identifies the woody plant establishment and management procedures used in the reclamation of amended tailings sand and other similar sites, and how these procedures affect the rate and level of establishment of the species planted.

The report will highlight, where information was available, the use of the following trees and shrubs as selected by the OSESG-RRTAC committee.

Alnus crispa	Green Alder
Amelanchier alnifolia	Saskatoon
Caragana arborescens	Caragana
Elaeagnus commutata	Silver-berry
Prunus pensylvanica	Pin cherry
Rosa acicularis/woodsii	Prickly rose
Salix bebbiana	Beaked willow
Shepherdia canadensis	Canadian buffalo-berry
Picea glauca	White spruce
Pinus banksiana	Jack pine
Populus tremuloides	Trembling aspen
Populus deltoides x P. balsamifera Bartr. cv. 'Northwest'	Northwest poplar
Populus deltoides Bartr. x (P. balsamifera Petrowskyana Scheid.)	Walker poplar

The information reviewed covers the time span from planting until the end of the tenth growing season. Included are considerations of stock quality and rearing, site preparation, planting and the procedures necessary to ensure the survival of the plant material throughout the establishment and growth phases.

Techman Engineering Ltd. relied extensively upon its own library and reprint files. Additional information was provided by RRTAC and OSESG, and publications available in local libraries and from recognized specialists in the field of woody plant production and reclamation (see Acknowledgements).

Method

Literature from a variety of sources was reviewed for information pertinent to this study. These sources included:

- federal and provincial government reports and files;
- industry reports and files; and
- existing field trials and experiments (as identified by RRTAC and OSESG).

In addition, personal and telephone interviews were made with specialists in the fields of woody plant production and reclamation and field trips were made to tree nurseries and to the Suncor Inc. and Syncrude Canada Ltd. site operations at Fort McMurray, Alberta.

INTRODUCTION

The major oil sands deposits in Alberta are located in the Athabasca, Cold Lake and Peace River regions. Of the three areas, the Athabasca deposit, located in Northeastern Alberta, is at present the only one with commercially active extraction facilities. Development of the Athabasca oil sands necessitates the disturbance of large tracts of forested land, most of which will have to be rehabilitated to an accepted end land use with an ecological productivity equal to, or better than that which existed prior to mining. The acknowledged end land uses for disturbed land in the Athabasca oil sands are forestry, wildlife habitat and recreation.

The soils of the area are of the Brunisolic, Gleysolic, Luvisolic and Organic orders (Fedkenheuer 1979). The vegetation is characteristic of the Boreal Forest Region with Pinus banksiana - Populus tremuloides and Picea glauca - P. tremuloides assemblages dominant on Luvisolic soils, Salix spp. and Alnus tenuifolia communities dominating areas along the water courses and a Picea mariana - Ledum groenlandicum community dominant on the Organic soils (Peterson and Levinsohn 1977).

The climate of the region is cool - temperate with long, cold winters and short summers (with only brief periods in excess of 24°C). An extended period of daylight occurs during June and July. The total annual precipitation is approximately 44 cm with 30 cm falling as rain. The growing season for the area is approximately 95 days from June through August (Longley and Janz 1978).

Tailings sand (both in the dikes and mine area) is the largest single type of material which will have to be reclaimed. Based on available data, there is insufficient rainfall from April through May for the vegetation in the area to realize its full potential on tailings sand. During the growing season, the potential evapotranspiration rate exceeds precipitation, resulting in a water deficit. Studies have shown that in July and August, the available soil moisture levels in sand are lowered to near the permanent wilting point (Monenco 1980). To ensure the survival of plants, in particular the shallow rooting species, beyond July, it is necessary to incorporate amendments into the tailings sand to increase the available moisture.

Inherent in most reclamation programmes is the desire to create an ecosystem that is self-perpetuating and maintenance free. In an attempt to achieve this goal, reclamation research in the area has emphasized the utilization of native species. Although there are a number of potentially useful introduced trees and shrubs as indicated by their inclusion in this study, the native woody species have already demonstrated the ability to establish themselves in the area under the pre-mining environmental conditions and are therefore, worthy of consideration.

Under the present reclamation guidelines, an erosion controlling cover must be established on a disturbed site within one year after disturbance has ceased, as a control against surface water and wind erosion (Fedkenheuer 1979). Subsequent to this, shrubs and trees are planted to satisfy the proposed end land uses of forestry, wildlife habitat and recreation. In order to identify the shrub and tree species with the greatest potential for reclaiming the tailings sand, a relatively large number have and are being examined through propagation, greenhouse and field trials. The selection of individual species has been based in part on the following criteria:

- native or naturalized;
- easily produced in large quantities;
- ability to regenerate on and stabilize disturbed land;
- nitrogen fixing ability;
- high value for specific end land use objectives; and
- proven effective in reclamation elsewhere.

The species highlighted in this study represent the culmination of much of this work.

1.0 PLANT PRODUCTION

Direct seeding or insertion of unrooted cuttings of woody plant species in areas of low precipitation has generally failed (Bleak et al. 1965; Clarke and Depuit 1980; Shaw 1980). However, some shrubs and trees can be successfully established on disturbed arid sites as either bareroot or container-grown stock sown from seed or from rooted cuttings. Successful establishment is related to plant size, site preparation, planting and management procedures as well as site-matched characteristics of the species selected. Planting stock presently being used in tailings sand reclamation is both bareroot and container-grown, depending in part on the nursery management system of the supplier, the germination or rooting characteristics of some of the species used and the reclamation techniques used by the operators. The use of properly selected species coupled with correct cultural practices will enhance the establishment, productivity and species diversity of a reclaimed area.

Successful establishment is influenced greatly by planting stock production methods. These involve the selection and collection of propagating material, scheduling, propagation and rearing, shipping and holding facilities.

1.1 Species Selection

Species adaptability is the major determining factor to be considered when selecting species for reclamation purposes. Plants must be adaptable to 'engineered' soil conditions, local temperatures, elevation, slope, aspect, wind conditions and natural precipitation levels for the area.

Availability of propagating material, general vigour of the plant and suitability for the desired end land use are also important considerations. Baseline data for the area detailing plant productivity characteristics at different successional stages on a variety of site conditions may be of assistance in selecting species with the greatest potential for adapting to the new site conditions.

Plantings of several species are recommended as they tend to offer a greater range of adaptation to environmental extremes. Indigenous species usually possess a genotype that ensures long term survival and thus represent the preferred pool of propagating material (Penrose and Hansen 1980).

The Manual of Species suitability for reclamation in Alberta (Watson, Parker and Polster 1980) details the potential for reclamation of many of the species highlighted in this report.

1.2 Availability of Planting Stock

Federal and provincial tree nurseries are presently producing a number of native and introduced woody plant species for use in landscaping and shelter belt programs. In some cases, these nurseries have arranged to produce both 1-0 and 2-0 bareroot and container-grown stock for use in reclamation programmes on non-government reclamation projects.

In order to avoid possible conflicts of interest, privately owned nurseries have been encouraged to start production of native and introduced species for use in reclamation programs. Several nurseries are currently in the process of developing the techniques necessary for the production of stock material suitable for revegetation purposes.

1.3 Seed and Cutting Collection

Reclamation programs must be planned to include all phases of work. Prior arrangements must be made with the nursery (on-site or elsewhere) to ensure that acceptable seed or cutting supplies are received in time for processing or planting. Most seeds or cuttings of native woody plants are presently collected from stands in the immediate area (up to an 80 km radius is suggested) of the disturbed site (Klym 1982 - personal communication). The cost and availability of seed varies from year to year due to the erratic nature of seed production in terms of quality and quantity. Selection of sound, mature fruits is essential as the collection of immature fruits or damaged seeds can increase production costs.

The collection of seed or fruits from local stands can be contracted to commercial seed collectors. Seeds can be collected by the grower or by employees of the operator, remembering that in most instances seeds or fruits need to be processed before they can be planted. Scheduling of seed collection is critical; however, a number of reports are available which indicate the approximate dates of seed maturation for individual species (USDA 1974; Vories 1980).

An alternative source of seed material is through commercial seed companies. Some carry seeds of a limited number of native woody plants but care must be taken when purchasing to ensure that the resulting plants are adaptable to the site to be reclaimed. Each seed lot purchased should contain a detailed description of the seed source and the results of seed tests indicating stratification requirements, vigour and viability, although the application of standard germination tests to seeds of native species may produce misleading results (Shaw 1980).

1.4 Nursery Practices

1.4.1 Bareroot Planting Stock

Since growth is difficult to control under outdoor conditions, bareroot production requires more time and space than container grown stock grown under controlled environment conditions. Two years for pine and three years for spruce are required to produce bareroot stock suitable for planting (King 1982 - personal communication). Therefore, up to two year advance orders for bareroot planting stock are often necessary to guarantee supply.

Since specific cultural requirements are still being developed for individual native species, the techniques involved in bareroot production of deciduous native shrubs and trees are, in the main, based on the techniques developed for conifer tree production (Novlesky 1982 - personal communication). Information on the production of bareroot planting stock of the species highlighted in this report can be found in Appendix A.

Seeding rates are dependent upon the number of seedlings to be reared per linear metre, the number of seeds per kilogram, germination and purity of the seed lot, expected seedling mortality, the culling rate and the desired size of the planting stock.

Current production techniques involve sowing the seed into four or six row nursery beds with conventional seeders modified to handle seeds of diverse shapes and sizes at precise rates. Following sowing, the beds are covered with a layer of sharp sand to provide protection overwinter, to prevent soil crusting and to act as a mulch to conserve soil moisture. Seeds are usually planted in the fall as this will normally satisfy stratification requirements of most species (Schroeder 1982 - personal communication). If planting is delayed until spring, seed dormancy may have to be broken by artificial stratification or other pre-germination treatments (USDA 1974).

Germination and seedling emergence of fall planted seeds occurs from late April through to early June, depending upon the species. Similarly growth rates vary from species to species with maximum root and shoot growth occurring during late June to mid-July. Rosa woodsii continues to grow vigorously into early fall in some areas (Shaw 1980).

At present, trials are underway to identify optimum spacing, the effect of root and shoot pruning, nutrient requirements, response to herbicides, time of harvesting and the effect of irrigation on the quality of planting stock (Schroeder 1982 - personal communication).

At the PFRA Tree Nursery in Indian Head, Saskatchewan, most bareroot stock is lifted in the fall and stored through the winter at temperatures between 1°C and 4°C in readiness for early spring planting.

Observations indicate that some native species are more capable of surviving storage than others and more work is required in this area (Schroeder 1982 - personal communication).

1.4.2 Container Grown Planting Stock

Under controlled greenhouse conditions, a favourable root-to-shoot ratio can be achieved with container-grown stock in some three to four months. This ratio is an important factor when considering planting stock quality as it has a great bearing on transpiration loss and the reaction to moisture stress once the material is planted out (Penrose and Hansen 1980). These ratios are achieved by a combination of controlled day and night temperatures, nutrient applications, watering, growth medium and container characteristics and optimal light requirements.

Detailed information on cultural techniques involved in rearing suitable container grown stock are available from a number of reports or articles (Carlson 1979; Tinus and McDonald 1979; Alberta Agriculture 1980). Although much of the information deals with the containerized production of conifer seedlings, the principles involved are directly applicable to other species. Syncrude Canada Ltd. use Carlson (1979) as their reference source with cultural recommendations for white spruce production being applied to deciduous shrub and tree production.

1.4.2.1 Container Design

The design of all containers is intended to minimize root exposure and disturbance so that there is less transplanting shock leading to higher survival and growth rates. Two basic planting strategies are currently in use:

- the container is planted with the tree or shrub; root egress can occur because of the biodegradable nature of the container or through holes, slots and expandable seams built into the container; or

- the seedling or rooted cutting and its plug of rooting medium held together by the roots is removed from the container which is often discarded (but is reusable).

The shape of the container controls root system development and configuration and can affect the future growth of the seedling in the field. Containers can produce malformed root systems that can lead to windthrow and breakage long after the tree or shrub has been planted out in the field (Ben Salem 1971). The Spencer-Lemaire type containers incorporate rigid plastic walls with vertical ribs or grooves and rounded horizontal corners and a bottom hole which serve to prevent root spiralling leading to strangulation. Further, the design allows for root egress without the danger of plugging and causing the growing medium to waterlog, provided the plant is outplanted on schedule.

The use of containers designed to be planted with the tree or shrub is not as popular. Due to the variation in the degradation rate of the biodegradable containers, roots often penetrate the wall and become intertwined with those of the plants in the adjacent containers which makes separation difficult during handling. Degradation rate and root penetration are dependent upon the availability of moisture and therefore, these containers are not recommended for use in dry sites. With the other types of plantable containers which rely on mechanical expansion or holes for root egress, similar problems can occur with roots of adjacent plants intertwining and also restriction of root development can occur after planting out in the field. Pines are particularly prone to this (Tinus and McDonald 1979).

Container size and configuration have a bearing on both the quality and quantity of planting stock produced as these factors dictate the density of containers on a given area of greenhouse bench space. In general, for any species, the larger the container the larger the plants will be that are grown in them. Shoot growth will be much more prolific so containers must be spaced further apart, otherwise the seedlings will be competing for light resulting in plants with spindly growth.

There is no ideal container, but there is usually one which best fits the production and planting systems developed for any particular project. The size and type can be selected on the basis of production and planting costs, plant survival and desired growth parameters.

In 1970, the Montana Agricultural Experiment Station initiated some research to increase plant survival in dryland conditions. Their work led to the development of a technique known as the 'dryland tubeling planting technique' (Jensen and Hodder 1979). The technique involves establishing seedlings or rooted cuttings in a growth medium enclosed in a long paper tube reinforced by a plastic mesh sleeve called a "tubeling'. These long, small diameter tubes are designed to encourage the development of a narrow but extraordinarily deep root system. When planting, the undisturbed root system is placed within deep soil moisture reserves negating the need for irrigation and reducing other maintenance procedures during the period of establishment. Besides eliminating the need for irrigation during the establishment period, this system has the potential of increasing plant survival rates and is adaptable to mechanized planting.

1.4.2.2 Growth Media

The choice of a suitable growth medium is an important step in the production process as it can exert a great deal of influence over rearing costs and planting stock quality, which in turn will have a bearing on the rate and level of establishment. Materials which have been used include sand, peat, compost, sphagnum moss, bark chips, topsoil, perlite, sawdust and vermiculite. For functional and economic reasons, peat and vermiculite mixes are the most popular as they best satisfy the physical, chemical and biological requirements of a good medium.

Hellum (1975) indicated the variability that exists in commercially available peat and the danger it poses where bulk quantities of seedlings have to be grown to specific dimensions in a certain length of time. Sphagnum peat moss is recommended over all other types of peat. Sedge peat is not recommended because of its high pH (7.0-8.0) and its fine fibre content which may cause compaction in the container (Carlson 1979). Dry peat should be avoided as it is difficult to moisten evenly and does not flow freely when containers are being filled, resulting in uneven moisture distribution and large air spaces that will cause erratic seedling growth.

Vermiculite comes in a variety of grades. Horticultural Grade Vermiculites (Nos. 2 or 3) are the most popular in that they function to improve and maintain aeration and drainage in a growth medium. Finer vermiculite (No. 4) should be avoided as it settles quickly affecting both drainage rates and aeration (Tinus and McDonald 1979).

Perlite is often used in growth media instead of vermiculite or as a seed covering medium. The high temperature (760°C) used in the processing of perlite from volcanic lava flow material creates a sterile product. Horticultural grade perlite has a particle size diameter of 1 to 3 mm. It will hold up to four times its weight in water. The pH of perlite ranges from 6.0 to 8.0, but with no buffering capacity; unlike vermiculite, it has no cation exchange capacity and is devoid of mineral nutrients (Hartmann and Kester 1959). Perlite does not compress and is, therefore, most useful in increasing the drainage and aeration of growth media. However, it may make it more difficult to extract root plugs from their containers at planting time (Tinus and McDonald 1979).

The most widely used growth medium is a 1:1 mix of sphagnum peat moss and vermiculite. Other ratios are used depending on species requirements or the personal preference of the nursery operator. The Provincial Tree Nursery at Oliver, Alberta is presently using the following mixes for their container-grown stock:

Conifers	75 peat	
	15 vermiculite	
	10 perlite	
		(percent by volume)
Deciduous	50 peat	
	25 vermiculite	
	25 perlite	
		(percent by volume)

Successful seedling production has been obtained by some nurseries with straight peat without any vermiculite or perlite. Maintenance of optimum moisture levels is a key factor with this approach.

A number of commercially prepared growing media are available. These include 'Redi-Earth', 'Jiffy-Mix', and 'Micapeat'. A few growers use them, but they do not give the flexibility that 'home-mixes' give in terms of production requirements. Their use is not recommended unless the source and preparation of the components is identified.

The degree of aeration and drainage required is the determining factor involved in the selection of a growth medium (Tinus and McDonald 1979). In general:

- as more vermiculite or perlite is added, the drainage and aeration increases; too much may result in a loose medium which falls out of the root egress hole or affects the cohesiveness of the plug upon removal from the containers;
- more drainage is required as containers get larger and deeper;
- the higher the humidity in the greenhouse the better drained the medium should be;

- more drainage is required if water is not distributed evenly as there is a tendency to overwater some plants while ensuring others get the required amounts; and

- if waterlogging persists over a period of time, then drainage should be increased; conversely, if frequent waterings are required, then drainage can be reduced.

Aeration and drainage in a growing medium can be measured as a percentage of the macropore space in the medium (Hellum 1975). For a peat only medium, a 25 percent macropore space is recommended for optimal root development. The macropore space for peat-vermiculite mixes can range between 10 and 50 percent depending on the depth of the container (50 percent for deep containers). On-going comparisons between the condition of the plants and the growth medium is the best way to judge whether the medium characteristics are the best for the container, species and growing conditions.

Common problems with media are (in part from Tinus and McDonald 1979):

- TOO COARSE (too well drained and aerated): medium falls out of root egress hole, root plug not cohesive - falls apart when removed from container, needs watering frequently, plants often stunted, root fibrosity reduced; and

- TOO FINE (poorly drained and aerated); medium always waterlogged, medium quickly compacts, rarely needs watering, difficult to wet when dried out, fungal diseases prevalent, algal and bryophyte growth on medium surface, high electric conductivity (EC) leachate readings, plants stunted, chlorotic, root-rot evident.

Although some growers incorporate fertilizers into their growing media it is not recommended as it tends to interfere with the control of growth patterns which are necessary to achieve the desired planting stock quality. Control is achieved by adjusting the watering and fertilizer regimes together with other environmental factors at certain stages of the plant's growth.

Most native woody plants in their natural habitats live in association with soil borne actinorrhizal or mycorrhizal fungi (Wilcox 1980). These symbiotic fungi tend to increase a plant's tolerance to disease and drought and enable them to better utilize the nutrient pool in the soil. The lack of these fungi on disturbed sites where relatively infertile soils may occur is thought to be one of the limiting factors in plant establishment. A considerable amount of work has been done on the addition of mycorrhizal fungi to the growth medium as it is believed that inoculated container-grown plants perform better. Once planted out, they can serve as reservoirs of fungi that can inoculate other non-inoculated species since many mycorrhizal fungi are non-host specific (Penrose and Hansen 1980).

Although greenhouse conditions are controlled to such a degree that healthy non-inoculated seedlings can be grown quite easily, studies have shown that inoculated material is often more robust and healthy. Consequently during unexpected stress conditions such as waterlogging due to a poorly drained and aerated medium, they are not as susceptible to root- rot as their non-inoculated counterpart. Research is on-going at the Syncrude Canada Ltd. site to look at the effect of inoculating <u>Pinus banksiana</u> in terms of enhancing survival and establishment on amended tailings sand sites (Fung 1982 - personal communication).

Some producers add forest litter (duff) to their growing medium based on the assumption that the material contains mycorrhizal fungi. Although this is often the case, the duff can also contain harmful fungi, nematodes, insects and weed seeds. Of the woody plant species highlighted in this report, <u>Alnus crispa</u>, <u>Caragana arborescens</u>, <u>Elaeagnus commutata</u>, <u>Shepherdia canadensis</u>, <u>Prunus pensylvanica</u>, <u>Picea glauca</u> and <u>Pinus banksiana</u> are known 'actinorrhizal or mycorrhizal species' (Fessenden 1979; Malloch and Malloch 1982).

1.4.2.3 Greenhouse Conditions

The following sub-section outlines a number of greenhouse conditions which have a direct bearing on the quality of planting stock. Details of growth conditions for the production of the species highlighted in this report are included in Appendix A to this report.

Temperature

Bio-chemical activities within the plant, culminating in growth, increase as temperature increases to an optimum level above which any increase in temperature decreases the growth rate. The optimum daytime temperatures for pine and spruce are 25°C and 22°C, respectively with a 16°C nighttime temperature for both species (Carlson 1979). The temperature limits between these and most other species differs slightly and because optimum ranges overlap, most species can be grown successfully in the same greenhouse.

A greater differential between day and night temperatures is necessary when hardening seedlings. Lower night temperatures will stimulate root growth but slow top growth so that the shoot material is more resistant to cold injury. Hardening plants in the greenhouse over winter, in preparation for spring planting, requires a gradual lowering of the temperature to near freezing over a four to six week period (Carlson 1979).

Humidity

Humidity is extremely difficult to regulate in most greenhouses as it quickly equilibrates to that of the surrounding atmosphere. Humidity levels usually increase quickly during irrigation but drop almost at the same rate. Little information is available on optimum humidity levels for individual species due mainly to the difficulty in regulating it.

If the growth medium in the containers is drying out rapidly it may be necessary to increase humidity. This can be achieved by double glazing the greenhouse with plastic, adding steam to greenhouse air, evaporative cooling, humidifiers or sprinklers. Maintaining high humidity (about 90 percent R.H.) over a prolonged period of time can lead to problems with fungal growth, especially damping-off and grey mold on the foliage, and excessive bryophyte growth on the surface of the growth medium.

Low humidity levels are in some respects advantageous for container-grown plant production as they serve to slow down root egress by air-pruning of roots below the containers. Most greenhouse benches are designed to allow the free movement of air below the trays of containers. This facilitates handling of the containers and separation of the individual plants just prior to planting (Carlson 1979; Novlesky 1982 - personal communication).

Light

Both the rate of photosynthesis and dormancy are affected by photoperiod, light intensity and saturation, and wavelength. Of these three factors, photoperiod is the most critical as poor control can induce a state of dormancy which cannot be broken. The minimum photoperiod for conifers is 18 h/day which will maintain continuous growth for white spruce and intermittent growth for pines. When conifer seedlings are being hardened, the day length should be reduced gradually to 12-14 h/day (Carlson 1979).

Most juvenile stock grows best with light intensities of approximately 30 klx (Carlson 1979). As the plants mature, the intensity should slowly be raised to the saturation level (a point at which the rate of photosynthesis no longer increases). Intensities greater than the saturation point can restrict growth, reduce chlorophyll content and in extreme cases kill the seedling.

In conifers, high light intensity interacts with the photoperiod to induce lateral branching. This is especially important in rearing containerized plants which are normally grown close together. The upper needles tend to shade the lower ones thereby reducing light intensity at that point to a level where branching will not occur. Supplementary lighting may be necessary to alleviate this situation.

When artificial lighting is being considered, the light source used should have maximum output in the red (600-700 nm) part of the visible spectrum and none in the ultraviolet, as it is the 600-700 nm wavelengths which promote the maximum rate of photosynthesis (Tinus and McDonald 1979).

Nutrient Requirements

Both the pH and cation exchange capacity (CEC) of the growth medium will affect the availability of mineral nutrients to the plant. The pH of the medium is initially determined by the nature of the peat material in the mix; preferably, the range should be between pH 4.5 to 6.0 (sphagnum peat moss satisfies this criteria) (Tinus and McDonald 1979).

The CEC level is affected by the texture and make-up of the growth medium. The finer the material the higher the CEC; although this indicates that more nutrients are available to the plant, problems with drainage and salt accumulation can be expected.

When a fertilizer program is being developed, the interactions amongst the environmental variables existing in the greenhouse, together with the growth stages of the individual species must be considered. Table 1.4-1 lists recommended nutrient regimes for optimum growth of containerized conifer seedlings in the Prairie Provinces. Levels recommended for white spruce can be successfully applied to the production of deciduous tree and shrub stock (Genovese, 1982 - personal communication).

Good drainage is essential if optimum seedling growth is to be maintained. If growth media are barely moistened, then the rate of drainage is not sufficient to remove the accumulation of salts and organic wastes from the root system. As these salts accumulate, there is an increase in the pH level which may limit the availability of nutrients to the

Table 1.4-1

Recommended nutrient regimes for optimum growth of some containerized conifer seedlings in the Prairie Provinces[1]

Species	Early growth stage (28-35 d)[2] N-P-K (ppm)	Rapid growth stage (42-112 d) N-P-K (ppm)	Hardening stage (112 d+) N-P-K (ppm)
Jack pine	229-29-154	229-29-154	44-101-150
White spruce	112-55-156	112-55-156	44-101-150
Pine-spruce mixture	125-60-159	125-60-159	44-101-150

(from Carlson 1979)

1 The fertilizers should be applied at weekly intervals to be most effective. These regimes may vary with the time of the year; e.g., the rapid growth regime should cease 6 weeks before the seedlings are expected to be in the final hardened or dormant state.

2 Age of plant in days

plant. These accumulations invariably result in plants with reduced shoot growth and stunted root production. This potential problem can be eliminated by nutrient flushing with large volumes of nutrient solution once a week or by using a peat-only growth medium (Carlson 1979). Syncrude Canada Ltd. flushes with water only, in an attempt to eliminate the accumulation of salts (Fung 1982 - personal communication).

Recognizable deficiency symptoms develop when an essential element is lacking. The literature contains little information as to specific deficiency symptoms for the plant species under discussion. Although there is some variation in the appearance of deficiency symptoms from one species to another, certain characteristic indicators can be used. Early identification is essential so that remedial measures can be implemented to return a plant to its normal growth pattern. Appendix C lists some of the indicators which may be useful in identifying specific nutrient deficiencies.

Irrigation

In a containerized system, the growth medium exerts a great deal of control over moisture availability. The medium should have sufficient water holding capacity to maintain plant growth between waterings but at the same time drainage rates should be sufficient to leach out accumulated salts.

During germination and early seedling growth, moisture loss through evaporation is critical. A crushed granite grit covering over the surface, and frequent misting is recommended at this stage to prevent the surface from becoming hydrophobic and affecting the infiltration rates of future waterings (Novlesky 1982 - personal communication).

Once the seedling is established, loss of water by evaporation declines and transpirational loss increases. As the root system develops, water loss occurs throughout the growth medium, and waterings should be aimed at replenishing this loss. Wilting usually indicates an excessive loss of water and with deciduous stock this can be quickly rectified before permanent damage occurs. In conifers, however, wilting should not be used as an indicator of moisture demand as the visible wilting point of many conifers occurs just prior to death (Carlson 1979).

Frequency of watering is difficult to determine. Soil moisture tensiometers or weighing devices can be used but the skill of the greenhouse manager is still the best determinant. By lifting the trays, checking the temperature, feeling the growth medium, randomly inspecting the plugs and by the general overall appearance of the plant, watering requirements can be determined.

1.4.2.4 Hardening

Once the rapid growth phase is complete, the plants must be hardened-off so that they can better withstand the adverse conditions outside the propagation facility. Hardening of plant material can take up to three months or more depending upon the nursery operation, the time of year and the species involved (Carlson 1979).

Greenhouse conditions are controlled to encourage maximum growth of plants by protecting them from such stresses as temperature change, moisture and nutrient availability and fluctuating light conditions. Once the seedling has reached the desired size it must be placed in an area for hardening before planting out. In most situations a shadehouse will satisfy the hardening requirements. The shadehouse provides sufficient shade and wind protection to prevent dessication. Although there is little control over day and night temperatures or photoperiod, moisture and nutrient availability is ensured by the provision of some system of irrigation and fertilizer application.

Seedlings should be hardened 28 to 42 days before being planted out or prior to the onset of the winter period (Carlson 1979). Plants should be placed in a shadehouse only after there is a minimum chance of frost injury. There are also restrictions on how late material can be put out for hardening. The Fort McMurray, Alberta area falls within Plant Hardiness Zone 1 of the Prairie Provinces. Based on this information, Carlson (1979) recommends that plants can be put out safely between May 24 and August 6.

Following removal to the shadehouse, nutrient application to the plant is adjusted to promote root growth but restrict shoot growth. This is achieved by reducing the amount of nitrogen and increasing phosphate and potassium levels (Table 1.4-1); fertilizer applications can be reduced to once every two weeks. Watering is carried out on demand. Any material that is not fall-planted may have to be stored outside during the winter. If this is the case, plants should be covered with an insulating layer of snow, loose straw or hay to protect them from the extreme cold (Carlson 1979).

If the nursery conditions differ significantly from those at the planting site, planting stock should be site-hardened for a number of weeks prior to planting-out. It must be remembered that hardening is a multi-faceted physiological process which cannot be achieved by merely withholding water completely for a few days in an effort to acclimatize plants to semi-arid conditions, such as occur on the amended tailings sand sites.

1.4.2.5 Shipping and Holding Facilities

In the event that planting stock is reared a considerable distance away from the planting site, flexibility in the actual shipping date should be written into any contract between grower and planter. This will enable healthy plant material to be delivered on-site just prior to planting time. Temperature controlled trucks or trailers (reefers) are preferred over other forms of transportation as they are capable of delivering material in good condition (Smith 1979).

These trailers are normally equipped with up to three tiers of adjustable or removable shelves on which the material is packed. The efficiency of the shipping operation is dependent upon the adequacy of the air circulation in the trailers. This can be achieved by leaving spaces at each end of the trailers and placing the packages in such a way that air movement is achieved throughout the load. With bareroot material, if the transplants are not packed in fully enclosed containers (plastic bags), moisture lost from the plants will condense on the refrigeration coils, reducing their efficiency, and at the same time the plant material will rapidly dry out. During a defrost cycle, this condensed water is drawn off and the plants will have to be watered. The reefer vans are able to transport from 100,000 (2-2 white spruce) to 700,000 (younger stock) seedlings under refrigerated conditions. For spring shipping, temperatures of 1°C for bareroot stock and 4°C for container-grown stock are recommended (Smith 1979).

If planting is delayed, plants can be kept in the trailer for a couple of days. A longer delay would necessitate moving the planting stock to temporary holding facilities designed to protect the plants from exposure to excessively high temperatures and dessicating winds. A structure similar to a lathhouse would be suitable.

Following delivery, all plants should be carefully inspected and dried out material dealt with accordingly. Water loss differs from species to species, so a careful assessment of each type is recommended. Plants toward the outside edge of any shipping or holding facility tend to dry out much faster than those towards the centre.

1.5 Planting Stock Characteristics

The survival of transplants, whether bareroot or container-grown is dependent, in part, on the size and quality of the material used. There is little precise information available as to what constitutes an acceptable product in terms of suitability for revegetating amended tailings sand. The information available indicates that widely varying descriptions of the 'ideal' planting material exist. There appears to be a tendency to relate the preferred quality (especially in terms of size) to a particular site, type of site preparation, stock production methods, stock handling, planting method or previous personal success with planting.

In general, small transplants may possess a root system that is incapable of deep enough placement and fast enough penetration to avoid moisture deficits as the season progresses. Small transplants are more susceptible to soil movement, competition from grasses and/or legumes established for initial erosion control, damage by small rodents and insects and wind dessication. Conversely, too large a transplant may have a root system that requires more moisture to keep it alive than is available from the soil.

In May 1981, Syncrude Canada Ltd. initiated a stock-size planting trial designed to examine the relationship between seedling size and outplanting performance on amended tailings sand (Fung 1983 - personal communication). A total of 26 combinations of seedling species and size were planted on a tailings dyke amended with 10 cm clay, 15 cm muskeg peat, 336 kg/ha of Triple Superphosphate (0-45-0) and 112 kg/ha of Potassium Chloride (0-0-60) incorporated to a depth of 30 cm. Sizes were differentiated by age, class and the size and type of containers the seedlings were raised in. Individual species were planted in rows of 20 seedlings spaced at 1.5 m apart with 1.0 m between rows.

Notable changes in the ground cover composition occurred in 1982. The predominant Chenopodium album L. had completely disappeared. The grasses, however, were still present. Assessment showed that 66 percent of the experimental area remained vegetation free. The vegetation components were mainly grass species with a trace amount of legumes and native weeds.

No erosion was observed over the two year period. It is apparent from this trial that vegetation cover as low as 34 percent is sufficient to resist soil erosion on tailings dyke of 4:1 slope.

Seedling survival and growth for all species and sizes has been exceptionally good over the two seasons. A summary of the mean percent survival and the mean annual height growth are shown in Table 1.5-1. A slight drop in percent survival (97.1 to 92.8 percent) was recorded in fall 1982. Mortality occurred mainly on the extremely "pot bound" jack pine where new roots failed to egress out of the root ball. Sand deposition accounted for some of the missing small seedlings while shoot die-back was the main cause of alder mortality.

Excellent survival and growth to date could be attributed to the very scanty ground cover distribution. Seedlings did not have to compete vigorously for the available soil moisture and nutrients.

For most shrub species, a transplant 10-15 cm in height should be satisfactory; tree species can be somewhat taller (20-40 cm). The literature suggests that the shoot to root ratio is a critical factor in woody plant establishment. Further, Ferguson and Frischknecht (1980) suggest that in container-grown shrub production, the containers should be 15 cm to 20 cm deep with a volume of 250 to 400 cc to achieve the desired ratio. For certain federally funded revegetation projects, the Federal Government (Public Works Canada) require that all plants grown from seed are grown in 7.5 cm wide by 15 cm deep commercially used containers that will permit plant removal without damage to root or crown growth. Coniferous stock has to be a minimum of 15 cm in height, with a well developed crown and root system. Minimum heights for specific deciduous stock are:

Rosa woodsii	25 cm
Elaeagnus commutata	35 cm
Shepherdia canadensis	35 cm

The stock measurements are taken from the natural ground level of the plant to the growing tip (Government of Canada 1982).

In order to accurately evaluate planting stock quality, morphological and physiological characteristics should be documented (Bunting 1980). Morphological analysis involves the measurements used to describe the physical qualities of the stock and would normally include height,

Table 1.5-1

Mean percent survival and growth of the various stock sizes after two growing seasons

SPECIES	AGE CLASS: REARING PERIOD	AGE CLASS: CONTAINER SIZE & TYPE	MEAN % SURVIVAL: 1981 FALL	MEAN % SURVIVAL: 1982 SPRING	MEAN % SURVIVAL: 1982 FALL	MEAN ANNUAL HEIGHT GROWTH (cm)
Aspen	June 1980 - May 1981	SB (7)	97	97	97	8.8
J. pine	June 1979 - May 1981	SL (T)	100	100	100	-2.9
J. pine	June 1979 - May 1981	SB (20)	100	100	77	1.4
J. pine	Feb. 1980 - May 1981	SL (5)	100	100	100	7.7
J. pine	Feb. 1980 - May 1981	SL (H)	100	100	100	12.5
J. pine	Feb. 1980 - May 1981	SL (T)	100	100	100	10.8
J. pine	Feb. 1980 - May 1981	SB (8)	100	100	100	9.2
J. pine	Feb. 1980 - May 1981	SB (20)	100	100	100	4.1
Larch	June 1979 - May 1981	SB (8)	100	100	87	4.8
W. spruce	June 1979 - May 1981	SL (H)	100	96	93	2.3
W. spruce	June 1979 - May 1981	SB (8)	100	100	100	3.1
W. spruce	Feb. 1980 - May 1981	SL (5)	100	100	100	9.1
W. spruce	Feb. 1980 - May 1981	SL (H)	100	100	97	4.3
W. spruce	Feb. 1980 - May 1981	SB (8)	93	90	86	6.1
W. spruce	June 1980 - May 1981	SL (5)	80	74	74	5.4
W. spruce	June 1980 - May 1981	SL (H)	100	100	100	11.7
B. berry	June 1980 - May 1981	SL (5)	100	100	100	7.2
B. berry	Feb. 1981 - May 1981	SL (H)	90	90	88	12.1
Caragana	June 1980 - May 1981	SL (5)	93	90	83	6.2
Caragana	June 1980 - May 1981	SL (H)	100	100	90	8.4
Dogwood	June 1980 - May 1981	SL (5)	100	100	97	5.6
Dogwood	June 1980 - May 1981	SL (H)	100	100	100	9.6
G. alder	June 1980 - May 1981	SL (5)	97	97	79	5.6
G. alder	June 1980 - May 1981	SL (H)	100	100	85	6.5
Saskatoon	June 1980 - May 1981	SL (5)	97	95	95	10.1
Saskatoon	June 1980 - May 1981	SL (H)	97	97	90	6.9

SL = Spencer Lemaire
(H) = Hillsons
(T) = Tinus
SB = Styroblock

(Fung 1983 - personal communication)

number of stems, branching, root-collar diameter, shoot/root ratio, root size or absorptive area and dry weight.

Physiological analysis is much more difficult and time consuming as a number of measurements have to be taken over a period of time and often on a destructive basis. Attempts have been made to estimate physiological quality by measuring such parameters as internal moisture relationships, root regeneration capacity, dormancy, foliar colour, nutrient content, electrical impedance and nodulation of species with nitrogen fixing capability.

Table 1.5-2 indicates the range of planting stock characteristics of some of the woody plant material presently being used in the afforestation of amended tailings sand sites.

Table 1.5-2

Characteristics of some of the planting stock currently being used in the afforestation of amended tailings sands sites

Species \ Characteristics	Container (C) or Bareroot (B)	Age at Harvest (wks)	Habit Tree (T) or Shrub (S)	Shoot height (cm)	Root collar diameter (mm)	Shoot/root ratio	Actinorrhizal or mycorrhizal activity
Alnus crispa	C	16	S	21.0	3.0	1.80	Yes
Amelanchier alnifolia	C (Tinus/ Paper pot)	16	S	24.0 - 34.8	3.6	0.73 - 1.74	No
Caragana arborescens	C	16	S	19.0	1.9	1.53	Yes
Elaeagnus commutata	C	16	S	N/A*	N/A	N/A	Yes
Prunus pensylvanica	C	16	S	N/A	N/A	N/A	Yes
Rosa acicularis/ woodsii	C (Tinus)	16	S	13.3	3.3	1.49	No
Salix bebbiana	C	16	S	9.0	1.95	0.69	No
Shepherdia canadensis	C	16	S	12.0	1.55	0.39	Yes
Picea glauca	C (Fives)	16	T	9.1 - 12.0	1.9 - 2.65	1.90 - 2.33	Yes
Pinus banksiana	C (Paper pot)	16	T	8.5 - 12.0	1.85 - 2.6	1.5 - 1.94	Yes
Populus tremuloides	C (Tinus)	16	T	19.0 - 22.0	2.2 - 3.1	0.45 - 1.57	No
Poplar 'Walker Hybrid'	C	N/A	T	N/A	N/A	N/A	No
Poplar 'North Western Hybrid'	C (Tinus)	N/A	T	21.9	12.9	1.53	No

* N/A - information not available

SUMMARY

Successful establishment is related to plant quality, site preparation, planting and management procedures as well as site-matched characteristics of the species selected.

The quality of planting stock is influenced primarily by production methods which include the selection and collection of propagating material, scheduling, propagation and rearing, shipping and holding facilities.

Most seeds or cuttings of native woody plants are currently collected from stands in the immediate area (up to an 80 km radius is suggested) of the disturbed site. Baseline data surveys for the area detailing the location and probability characteristics of the selected species are recommended.

Since growth is difficult to control under outdoor conditions, production of bareroot planting stock requires more time and space than container grown stock grown under controlled environment conditions. Specific cultural requirements for the bareroot production of deciduous native shrubs and trees are still being developed. Current production techniques are, in the main, based on the techniques developed for conifer tree production.

Much of the planting material being used for oil sands mine reclamation is container-grown under controlled greenhouse conditions. A favourable root-to-shoot ratio can be achieved in some three to four months. This ratio is an important factor when considering planting stock quality as it has a great bearing on transpiration loss and the reactions to moisture stress once the material is planted out. These ratios are achieved by a combination of controlled day and night temperatures, nutrient application, watering, growth medium and container characteristics and optimal light requirements.

Once the seedling has reached the desired size it must be placed in an area for hardening before planting out. In most situations, a shadehouse will satisfy the hardening requirements. If the nursery conditions differ significantly from those at the planting site, planting stock should be site hardened for a number of weeks prior to planting out.

Where planting stock has to be shipped over a considerable distance, flexibility in the actual shipping date should be written into any contract between grower and planter. This will ensure healthy plant material is delivered on-site just prior to planting time. Temperature controlled trucks are preferred to other forms of transportation.

Following delivery, all plants should be inspected and any dried out material dealt with accordingly. If planting is delayed, plants can be kept in the trailer for a couple of days. A longer delay would necessitate moving the material to temporary holding facilities, such as a lathhouse.

2.0 SITE PREPARATION

Revegetation of tailings sands represents the major reclamation problem for operators of the oil sands' extraction facilities. To aid in the separation of oil from the sand, sodium hydroxide is included in the extraction process with the result that the pH of the sand coming from the extraction plants is in the range of 8.0 to 8.5 (Lesko 1974). In addition, the levels of nitrogen, phosphorous and potassium in this material are inherently low (Massey 1973; Takyi et al. 1977). Measures need to be taken both to reduce the alkalinity and to increase the nutrient reserves and water-holding capacity of the medium before vegetation can be successfully established.

2.1 Amendment Materials

Materials available in the immediate area for use in soil reconstruction include overburden, peat and tailings sand (Rowell 1977). Information on amendment materials included in this section is based on studies carried out by Monenco (1980).

The overburden has high silt and clay contents (29-41 percent), high field capacity moisture content (23-39 percent) and a saturated hydraulic conductivity of 10^{-3} cm/sec.

Besides being important sources of organic carbon (35-46 percent) the fen and bog peats found in the area have a high water-holding capacity and relatively large amounts of total nitrogen (1.3 percent) - factors which make them important amendment materials in the reclamation process. The peat materials can hold up to eight times their dry weight in water, thereby improving the moisture holding capacity of the tailings sand material. Peat materials can also be used in conjunction with the overburden material as a means of attaining the nutrient levels necessary for plant establishment. The low bulk density of peat (0.04

to 0.10 gm/cm^3) further enhances its use for the effective rehabilitation of the higher density sands (>1.4 gm/cm^3) and overburden materials.

The physical, chemical and biological characteristics of the tailings sand limits its use in soil reconstruction. The characteristic high sand content (>95 percent) leads to a rapidly draining medium with an even higher saturated hydraulic conductivity level (10^{-2} cm/sec) than either peat or overburden. A low cation exchange capacity, a deficiency of nutrient elements, biological sterility, reduced amounts of available water and low concentrations of soluble salts further restrict the use of this material as a growth medium.

2.2 Plant Communities and Starter Soils

The information on starter soils and their associated plant communities presented in this section is based on studies carried out by Monenco (1980). These studies looked at the potential for re-establishment during the reclamation of the disturbed oil sands areas of three plant communities, namely, grasses (associated with the dike slopes), jack pine and mixedwood forests.

The minimum physical, chemical and biological characteristics for successful plant establishment on 'starter' soils are summarized in Table 2.2-1 for the three vegetational types identified above. Soil-water relationships, peat-organic matter transformations and erosion potential are based on assumptions affecting the reconstruction of all soils in the disturbed areas. The water-holding capacity and the plant-available water in the sand have yet to be identified. The permanent wilting point of 15 bars suction is applicable to all soil conditions. Field capacity, however, is probably better estimated at 0.06 bars suction rather than the 0.3 bars suction normally applied to agricultural soils. Sand loses large amounts of water at low suctions and therefore, measurements using 0.06 bars result in available water contents of 10-25 percent as opposed to levels of less than two percent

Table 2.2-1

Summary of the minimal physical, chemical and biological characteristics for starter soils for three vegetational types

Soil Property	Horizon(s) Depth or Element	Vegetation Type		
		Grasses	Jack Pine	Mixedwood
PHYSICAL				
- Silt & clay (%)	Surface 15 cm	5	5	20
- Avail. H_2O (%)	Profile	5-15	5-10	10-20
- Drainage	Profile	mod-excess	mod-excess	imp-mod
- Slope	Profile	2:1	5:1	5:1
CHEMICAL				
- CEC (meg/100g)	Surface 15 cm	5	2.8	12.0
- Exch. cations:	Ca	-	0.5	3.0
(meg/100g)	Mg	-	0.15	0.8
- Nutrients:	P_2O_5	15	15	50
(ppm)	K_2O	30	15-50	150
- pH	Surface 15 cm	8.5	4.8-7.0	4.7-6.5
BIOLOGICAL				
- Organic matter (%)	Surface 15 cm	2	1	3
- Total N (%)	Surface 15 cm	0.05	0.04	0.12
- Peat (kg/ha D.W.)		60×10^6	31×10^3	12×10^3

(Monenco 1980)

when 0.3 bars is used. By using 0.06 bars, soil amendments are not necessary, initially, to enhance water availability for jackpine or mixedwood communities.

It is assumed that peat incorporated into the tailings sand will function in a manner similar to organic matter formed in situ in terms of providing nutrients, increasing the cation exchange capacity of the medium, increasing the moisture retention capacity and acting as a source of micro-organisms necessary for soil microbial activity. It is expected that as the peat breaks down in the developing soil complex it will be replaced by the residue of some of the established vegetation.

Field studies and calculations using the Universal Soil Loss Equation (USLE) have indicated that exposed tailings sand is highly susceptible to water erosion. Of the factors used in the USLE, the rainfall (R) and the soil erodability (K) factors must relate to the specific conditions in the oil sands area. The rainfall factor (R) is a measurement of the erosive power of a specific rainfall or an average years's rainfall. It is normally based on the effect of a 24 hour rainfall; in the case of exposed tailings sand, it is recommended that erosion potential could be predicted more accurately if the effect of a 15 minute rainfall were assessed. The erodability factor (K) is a measure of the erodability of a soil determined by measuring sediment loss during simulated rainfalls. The K-value for sands (0.03) indicates a material with a very low erosion potential because of the high infiltration rate. However, a K-value of 0.26 for tailings sand is more realistic due to the hydrophobic nature of the residual oils and slimes.

Erosion of more than 37 tonnes soil loss/hectare signifies serious environmental damage. To maintain levels below this for two consecutive years, it is assumed that a combination of grass establishment and peat application is necessary. However, where this treatment may give good control of rill erosion, undercutting resulting in gully erosion could occur.

2.2.1 Grass Community (Dike Slopes)

The incorporation of overburden and peat into the tailings sand is recommended to create conditions conducive to vegetation establishment, to provide surface erosion control and to stabilize the plant nutrient supply. Since the tailings sand are in excess of 95 percent sand, amendments are necessary to achieve a minimum five percent silt and clay content in the surface 15 cm of soil. An organic matter content of two percent in the surface 15 cm is recommended, and can be achieved by incorporating 15 cm of peat (approximately 60 x 10^3 kg/ha dry weight) into 15 cm of soil. A maximum 2:1 slope is recommended for the tailings dikes.

2.2.2 Jack Pine Community

In areas where jack pine is to be established, slopes of less than 4:1 and available water contents of five to 10 percent are suggested. A cation exchange capacity of 2.8 mEq/100 g together with exchangeable calcium and magnesium (0.5 mEq/100 g and 0.15 mEq/100 g, respectively) are recommended. These levels can be met by maintaining the minimum texture (five percent silt and clay) and organic matter (one percent or 31 000 kg peat/ha dry weight) requirements. Potassium (25-50 ppm) and phosphorus (15 ppm) are necessary for jack pine establishment. The pH of the growth medium can vary between 4.8 and 7.0 without seriously affecting tree growth.

2.2.3 Mixedwood Forest Community

Initial soil requirements for establishing mixedwood forests are more stringent than those for jack pine stands. Of all the species within a mixedwood community, white spruce has the most exacting requirements. The following criteria are those deemed necessary for the successful establishment of white spruce. A minimum of 20 percent silt and clay together with a three percent organic matter content in the surface 15 cm of 'soil' is recommended and available water content should be 10 percent. A minimum exchangeable cation capacity of 12.0 mEq/100 g together with exchangeable calcium and magnesium of 3.0 and 0.8 mEq/100 g, respectively, is recommended; 40 kg P_2O_5 and 300 kg K_2O per hectare in an available form are needed. White spruce will tolerate pH levels of between 4.7 and 6.5 before growth is seriously affected. Peat applications of 112 x 10^3 kg/ha dry weight are necessary to achieve optimum cation exchange capacity, organic matter and nitrogen levels for white spruce establishment.

2.3 Materials Handling for Soil Reconstruction

The incorporation of the amendment materials into the tailings sand material is one of the most critical stages in the reclamation of tailings sand sites. The depth and uniformity of mixing has a great bearing on the survival and establishment of woody plant transplants (Klym 1982 - personal communication) The more distinct the boundary at the amendment/tailings sand interface, the more negative the effect on establishment (Shopik 1982 - personal communication).

Two types of amendment mixing procedures are possible:

- Off-Site Mixing. At Suncor Inc., the procedure for handling the muskeg and overburden material results in a blending of the mineral overburden (usually clay) and the organic soil (usually peat) to produce the desired growth medium. The stockpiled material is approximately 40 percent (by volume) clay overburden (Suncor 1981).

- On-Site Mixing. At Syncrude Canada Ltd., muskeg and overburden are salvaged and stockpiled seperately. These materials are then mixed into the tailings sand as specified (Techman 1980).

Final seedbed or transplant site preparation involves spreading and mixing the amendment materials into the tailings sand. The depth and uniformity of incorporation is dependent upon the type of tillage machinery used.

A number of approaches are employed at the two operating oil sands sites at Fort McMurray, Alberta for the mixing of amendment materials and/or till into the tailings sand substrate:

- using a dozer to work materials into the substrate;
- using a tractor driven rotovator to mix amendments into the substrate (Suncor); and
- using conventional and modified agricultural equipment to mix the amendment materials into the substrate (Syncrude).

Track-mounted dozers are used to both spread the amendments as they are dumped and, in part, to mix them into the tailings sand.

At Syncrude Canada Ltd., the dumping of alternate loads of overburden and muskeg material at the top of the slope serves to enhance the mixing process. As the material is pushed down slope with the dozer, the materials are blended together.

Suncor Inc. uses a rotavator drawn by a D-6 Cat to mix amendment materials into the tailings sand substrate to a depth of approximately 25-30 cm. It can be pulled up and down or across slopes. Desired tillage depth is a factor limiting the use of rotovators; equipment development and/or modifications would be required to achieve mixing to greater depths.

The overburden material at Syncrude Canada Ltd. has proved too stony for efficient rotovator operation and a heavy duty agricultural cultivator is used, although this equipment is apparently easily damaged (Fung 1982 - personal communication).

The 'Extra Heavy Duty Brushland Plow' is designed for terrain with scattered rock that would damage a standard disc plough. This particular piece of equipment is more suited to the on-site mixing approach where muskeg with a high stone and rock content is more likely (Techman 1980).

The agricultural rototiller has been used for mixing amendments into the tailings sand. This machine requires only one pass over an area to mix the materials to the desired depth and uniformity.

Following mixing, compaction of areas with a crawler tractor or 'Land Imprinter' is recommended (Klym 1982 - personal communication). Not only does this type of equipment compact, but it also serves to manipulate surface materials so that erosion control is improved and microsites are created which will enhance seedling survival and establishment.

SUMMARY

The physical, chemical and biological characteristics of the tailings sand limits its use in soil reconstruction. The characteristic high sand content (>95 percent) leads to a rapidly draining medium with a saturated hydraulic conductivity level of 10^{-2} cm/sec. A low cation exchange capacity, a deficiency of nutrient elements, biological sterility, reduced amounts of available water and low concentrations of soluble salts further restricts the use of this material as a growth medium. Amendment materials available in the immediate area for use in soil reconstruction include overburden and peat.

Three vegetation types, namely grasses (associated with the dike slopes), jackpine and mixedwood forests, have been identified as the desired post-reclamation plant communities. Soil reconstruction activities are designed to satisfy the minimal physical, chemical and biological characteristics of the soils necessary to support these vegetation types (Table 2.2-1).

The handling and incorporation of the amendment materials into the tailings sand is one of the most critical stages in the reclamation of tailings sand sites. The depth and uniformity of mixing has a great bearing on the survival and establishment of woody plant transplants. Both off-site and on-site mixing are used to blend the overburdened and peat material together before mixing into the tailings sand. The depth and uniformity of incorporation is dependent upon the type of tillage machinery used.

Following mixing, compaction of areas with a crawler tractor or "Land Imprinter" is recommended. This not only provides a firm planting bed, but tends to improve erosion control and creates microsites which will enhance seedling survival and establishment.

3.0 PLANTING

3.1 Planting Alternatives

Under the guidelines controlling the development of the oil sands area, operators are required to establish an erosion controlling cover immediately following the disturbance (Fedkenheuer 1980). In many instances, however, the presence of an initial ground cover has had a detrimental effect on the establishment of subsequent plantings of woody plant species. This is due in part to the competition between the grasses and legumes and the shrubs and trees for available moisture and nutrients (Fedkenheuer 1979; Vogel 1973) and also to the increase in rodent populations associated with a dense ground cover (Green 1982). To encourage the establishment of shrubs and trees on the amended tailings sand, it may be necessary to develop a reclamation program whereby competition from grasses and legumes is eliminated or reduced to compatible levels while at the same time reducing the wind and water erosion potential.

Several alternatives exist which might alleviate this problem.

3.1.1 Without An Initial Vegetative Cover

3.1.1.1 Planting Woody Plant Species Only

The key factor which can affect the successful establishment of shrubs and trees planted in isolation in the tailings sand areas is the overall stability of the planting medium, particularly on the dike slopes. Without any initial ground cover, the amended tailings sand is exposed to the erosional effects of wind and water.

3.1.1.2 Planting Woody Plant Species and Ground Cover Concurrently

Where it is necessary to establish both types of vegetation, it is recommended that they should be planted at the same time (Vogel 1973).

Competition from herbaceous vegetation can also be lessened by encouraging certain legumes and avoiding the selection of strongly competitive grasses.

Species included in the initial erosion control ground cover mixes and their application rates should be selected with the objective of enhancing woody plant establishment and native plant invasion while at the same time providing an acceptable level of erosion control. Continuous monitoring of seeded sites and test plots will identify suitable species, optimal seeding rates and plant densities necessary to achieve this objective. Seed mixtures used at Syncrude Canada Ltd. have undergone a number of changes in species and percentage composition. Dropped from seed mixtures in 1978 were Festuca ovina (hard fescue), Elymus junceus (Russian wild rye), Agrogyron riparium (streambank wheatgrass), Alopecurus pratensis (meadow foxtail), Agropyron trichophorum (pubescent wheatgrass), Trifolium hybridum (alsike clover), Melilotus alba and Melilotus officinalas (mixed blossom sweet clover). The mixed blossom sweet clover and hard fescue were thought to be overly competitive with both the other species in the mixtures and with the woody plants used, while the others performed below expectations (Fedkenheuer and Langevin 1978). Table 3.1-1 outlines the composition of the seed mixture used by Suncor Inc., Oil Sands Division, Fort McMurray, Alberta in 1981 on their permanent amended tailings sand sites. The highly competitive nature of bromegrass has led to its removal from the seed mixtures used at the Suncor operation during the 1982 seeding program (Klym 1982 - personal communication).

Lowering seeding rates or adjusting the proportions of the different species in the seed mixture may alter the competitive effect of the herbaceous material. Eliminating fertilizers or lowering application rates, especially of nitrogen, may also reduce the competitive nature of seeded grasses. Over time, this initial ground cover may also deteriorate to the point where invasion by native grasses, shrubs and trees can take place.

Table 3.1-1

Seed mixture composition: 1981 seeding program, Suncor Inc., Fort McMurray, Alberta

Species and cultivar	% content by weight
Slender Wheatgrass (Revenue)	21
Pubescent Wheatgrass (Greenleaf)	21
Bromegrass (Carlton)	3
Creeping Red Fescue (Boreal)	15
Alfalfa (Canada No.1)	24
White Dutch Clover (Canada No.1)	16

(from Suncor Inc. 1981)

Note: a. All legumes pre-inoculated at 10 times recommended agricultural rates.
b. Rate of application was 56 kg/ha.
c. Mixture hydroseeded in July, 1981. All slurry mixtures included Conwed 2000 Hydromulch (1450 kg/ha).

Syncrude Canada Ltd. initiated a drill-seeding study in 1981 to evaluate the use of seeding techniques, seeding rates and fertilizer rates for controlling the density and species composition of ground cover on the tailings sand dykes. The effects of ground cover density on the establishment and performance of woody species are also being evaluated (Fung 1983 - personal communication).

In this study, the tailings dyke slope of Cell 24 was subdivided into six large blocks, each approximately 0.5 ha in size. Each block was seeded with grasses and legumes, either hand-broadcasted or drill-seeded, at one of three seeding rates, in June 1981. Four shrub species, namely, Alnus crispa, Shepherdia canadensis, Caragana arborescens and Cornus stolonifera were planted in October 1981.

Ground vegetation cover was assessed in late July, 1982 for species composition and percent cover. All blocks have established a heavy vegetative cover. Among the seeded species, slender and crested wheatgrasses were the dominant grasses. It is interesting to note that crested wheatgrass had a higher percent cover than slender wheatgrass on the drill seeding blocks, while the broadcast blocks showed the reverse trend. Alfalfa was the dominant legume in all blocks.

The biomass of herbaceous plants ranged from 2000 to 3400 kg/ha on the drill seeding blocks and from 1100 to 2300 kg/ha on the broadcast seeding blocks. Drill-seeding produced a more uniform vegetative cover with more vigorous plants than broadcast-seeding despite the lower seeding rates used.

The survival of woody plant seedlings was assessed in early June and late September, 1982. C. arborescens had the best survival among the four species planted followed by S. canadensis, C. stolonifera and A. crispa. As of the fall of 1982, one year after planting, C. arborescens had a greater than 70 percent survival rate, while survival of the other three species was less than 20 percent in most treatments. After two growing seasons, several trends are developing:

- grasses and legumes have become well established resulting in a heavy cover density in all blocks. Even at the lower rates of seeding the ground cover is more than enough for surface erosion protection. Therefore, the seeding rate for broadcasting could be below 11 kg/ha while drill-seeding rates could be less than 6 kg/ha to produce sufficient ground vegetative cover;

- drill-seeding produced a better and more uniform vegetative cover than broadcast-seeding; and

- the survival of woody plant seedlings was generally very low due to the heavy ground vegetative cover. The herbaceous species depleted great amounts of soil moisture during the growing seasons, consequently the woody plant seedlings suffered drought stress with resulting low survival rates.

Sims and Mueller-Dombois (1968) have also indicated that the rooting habit of certain trees has an effect on the level of competition between certain grasses and trees. Further work is required in this area, however, before definitive statements can be made.

3.1.1.3 Ground Cover Configuration and Strip Seeding

Strip seeding of ground cover material may be a means of reducing the competition between grasses and woody plants. The method involves establishing bands of ground cover between which the land surface is left clear for shrub and tree plantings.

In 1982, Syncrude Canada Ltd. initiated a strip seeding project which was designed and set up to evaluate woody plant survival on various herbaceous cover seeding patterns over an area of relatively flat tailings sand. The four seed treatments were: (1) No seeding (control); (2) one metre strip (drill-seed one metre strip of grass and legume and leave a one metre strip unseeded); (3) three metre strip-seeding (drill-seed one metre strip of grass and legume and leave three metre in between unseeded); and (4) drill-seeded (the entire plot drill-seeded with grass and legume). Drill-seeding was done at the end of May 1982 using the Rangeland drill.

Vegetation percent cover and biomass were assessed in August 1982. The percent cover assessment showed a large number of invading plant species, since peat from the muskeg storage pile that was used for topsoiling contains numerous weed seeds. Fireweed (Epilobium angustifolium), Canada bluegrass (Poa compressa), and stinging nettle (Urtica dioica) are the most common species found on the plots. Of the seeded species, slender wheatgrass and alfalfa appear to be the most abundant. Bromegrass and timothy were seeded at very low rates resulting in low percent cover values.

Pinus banksiana and Alnus crispa seedlings are to be planted in both the seeded and unseeded strips so that a direct comparison between survival and herbaceous cover can be made. One half of the area was planted in the fall; September 20-23, 1982. The other half will be planted in the spring (i.e. mid-May 1983). The split planting was designed to compare survival rates between spring and fall planting.

The survival of woody plant seedlings along with ground vegetation cover, biomass, soil nutrients, moisture conditions, erosion status and rodent activity will be assessed annually for several years.

There is some indication that on slopes, the presence of strips of ground cover, parallel to the contour of the land, help to maintain soil stability by acting as a physical barrier to the down-slope movement of water.

3.1.2 With an Initial Ground Cover

The establishment of an initial ground cover as soon as possible after the cessation of operations is considered an essential part of most reclamation programs. Subsequent to this, shrubs and trees can be planted in the area but as was indicated earlier, successful establishment is affected by both the competitive nature of the grasses and legumes and the increase in small rodent populations as a result of a dense ground cover.

Planting of shrubs and trees into an established ground cover can be approached in two ways.

3.1.2.1 Minimal Disturbance of the Ground Cover Material

Only the disturbance necessary to facilitate planting is involved in this method. Competition for light, available moisture and nutrients is unavoidable, but the degree of impact can be lessened by controlling the density and composition of the ground cover and by avoiding the selection of strongly competitive legumes and grasses in the initial seed mixture. Selection of woody plants that can compete with legumes and grasses as well as the density at which the woody species are planted will affect the potential for establishment.

3.1.2.2 Removal of Some or All of the Ground Cover Material

The removal of some or all of the ground cover can be accomplished by mechanical or chemical means, or by controlled burning of undesirable vegetation, or by any combination of these.

In 1978, Syncrude Canada Ltd. initiated a programme designed to establish woody plants in a dense grass-legume cover which had developed over a number of years (Fedkenheuer 1979). The treatments included the use of herbicide ('Round-Up') applied in strips, strip ploughing, strip herbicide plus strip ploughing, burning or burning plus strip ploughing. Following treatment application, the cleared areas were planted with *Picea glauca*, *Picea mariana*, *Pinus banksiana*, *Pinus contorta*, *Populus tremuloides*, *Alnus crispa*, *Amelanchier alnifolia* and *Shepherdia canadensis*. Preliminary results indicate that the ploughed areas showed the greatest decrease in small rodent damage with only 15 percent of deciduous material and less than one percent of coniferous material displaying any visible signs. This is considerably lower than the 83 percent of deciduous material and 25 percent of coniferous material showing damage on the control and herbicide only plots.

Further to this study, Syncrude Canada Ltd. initiated, in 1982, a trial to evaluate the effectiveness of two herbicides as tools for creating clear strips on revegetated tailings dykes. An area was pre-seeded with a standard grass and legume mix at 34 kg/ha on June 9, 1982. The herbicides used were Afolan-F and Glyphosate. These were applied in strips 20 m long by two metres wide at different times to determine at what stage of growth vegetative cover can be effectively controlled.

Seven treatments were implemented on three replicates: a control where no herbicide was applied; Afolan-F as pre-emergence vegetative control applied at 5.0 and 10.0 L/ha on June 14 just prior to seed germination; Glyphosate as early post-emergence at 4.75 and 9.5 L/ha applied on August 5; and Glyphosate as late post-emergence at 4.75 and 9.5 L/ha applied on September 1.

Two weeks after the last herbicide application, <u>Pinus banksiana</u> and <u>Alnus crispa</u> seedlings were planted in the centre of the strips at one metre spacing in alternate order.

No seedling assessment was done in 1982. Ground cover assessment showed no significant difference between treatments for the first year. Seedlings performance and ground vegetative cover will be monitored in 1983.

Mechanical disturbance of the ground cover by scarification, discing, ploughing or rototilling is advantageous as plant material is incorporated into the soil, thereby helping to improve its overall fertility. However, the incorporation of large volumes of plant material into the soil may in fact be detrimental to plant establishment in that the root/soil contact is reduced to a point where root dessication becomes a problem (Klym 1982 - personal communication). Excessive disturbance, however, may also increase the erosion potential of that area. The use of herbicides to remove ground cover material is advisable where actual disturbance of the soil may lead to erosion problems. Unfortunately, much of the residual nutrient value and potential organic matter of the plant material is lost as it is not usually incorporated into the soil until at a later date.

The density and composition of the ground cover may not be as critical, as the removal of large areas of ground cover is going to significantly reduce the problem of competition between herbaceous and woody plants. Clearing large areas prior to planting in a highly competitive ground cover will provide at least two seasons with relatively low levels of vegetative competition. However, if sweet clover is nearby, this period of low competition might be reduced to only one season. With relatively large areas of land being disturbed and exposed to the elements, increased planting densities of woody species with a vigorous spreading habit would be beneficial.

3.2 Planting Techniques

After proper species selection, there are two means of establishing woody plants in disturbed areas: direct-seeding and transplanting.

3.2.1 Direct-Seeding

Direct-seeding may be accomplished using a mixture of several growth forms which can include species of woody plants, grasses and forbs. This technique has been used in rehabilitating rangelands and lands disturbed through strip-mining (Clarke and Depuit 1980). However, only limited success has been reported with regard to shrub establishment (Frischnecht 1978). Very few shrub species produce seedlings which are capable of withstanding competition from perennial grass seedlings. The developmental pattern of grasses is such that they are more vigorous than shrubs and tend to mature earlier with the result that they establish themselves as the dominant species in most situations. In addition, the apical meristems of shrub seedlings are usually above ground, which exposes them to inclement weather and grazing animals, whereas the apical meristem of grass seedlings is below ground and is, therefore, protected.

An alternative to using a grass-woody plant seed mixture, is to seed woody plants and grasses in alternate rows, thereby reducing competition (Frischknect 1978). Although some success has been experienced with shrubs that possess low seedling vigor, inter-specific competition is not entirely removed. Seeds of forbs and grasses may be present in the seedbed, especially when overburden material and peat are used as they invariably serve as a seed reservoir of volunteer plant species. Elimination or control of these plants may be necessary to reduce competition. Attempts have been made to establish shrubs by direct seeding without the associated grass and legume cover (Ferguson and Frischknecht 1980). However, this is not recommended as woody plants are not as effective as grasses in preventing erosion in sensitive areas (slopes). Direct-seeding of shrubs in strips or patches may be, therefore, a viable alternative.

There are four major considerations to be made when direct seeding of woody plants is being contemplated (in part from Stevens 1980):

- competition must be reduced;
- only seed with acceptable purity, viability and vigour should be used;
- seeds have to be sown at a time that provides optimum conditions for germination and seedling establishment; and
- correct seedbed preparation and seeding is necessary.

When an initial ground cover has become established, its removal is necessary before seeding can occur. This can be achieved by a scalper preceding the seeder (Giunta et al. 1975), with herbicides or with summer fallowing. Seedlings of most woody plants, whether aggressive or not, do not appear capable of establishing themselves in swards of grasses and legumes (Stevens 1980).

When seed is broadcast, 11 to 20 kg of seed mix (grass, forbs and woody plants) per hectare is sufficient. Less seed is required, generally 9 to 16 kg/ha, when seed is drilled. Grass seed should not make up more than one half the total seed mixture (percent content by weight) (Stevens 1980). Use of too much seed is not only expensive but can also result in seeded species competing with each other, especially during the critical seedling stage. Reducing seeding rates will allow for volunteer species to invade the area. Rates are dependent upon the species selected, the seedbed conditions, and the viability and size of the seeds.

Seeds of woody plants should be sown in the fall or winter as many woody plant species possess a dormancy mechanism which can only be broken by exposure to a prolonged period of cold, moist conditions; overwintering in the soil usually satisfies this requirement. In addition, seedbed preparation in the spring disturbs the soil to such a degree that accumulated soil moisture may be lost through evaporation. If planting is delayed until the spring, artificial stratification or other seed pretreatments may be required to break dormancy.

Seeding in fall and early winter also helps reduce seed loss due to a reduction in mammal, insect and bird activity. Early winter seeding is preferable to fall, because the danger of precocious germination as a result of moist soil conditions and unseasonable warm temperatures is virtually eliminated.

Seeds of woody plants can be sown directly with a variety of drills, seed dribblers and seeder-scalpers (Stevens 1980) or by aerial-seeding, hydroseeding and cyclone-seeding.

Hydroseeding is used on areas not suitable for drill or broadcast seeding. Such areas include steep slopes, and areas requiring chemical stabilizing prior to plant establishment.

Cyclone-seeding is carried out either by hand-held cyclone seeders or machine mounted units on small and inaccessible areas.

On steep slopes and areas with a high erosion potential, the use of soil stabilizers and/or mulches may prove useful. A mixture of an adhesive binder and a fibre mulch applied after sowing helps to conserve moisture, reduce wind and water erosion and acts as a protective blanket for frost-sensitive seedlings. Care should be taken to ensure that the mulch layer is not too thick as subsequent compaction of the mulch can be detrimental to seedling emergence. If alternate forms of mulch are used (hay, straw, etc.) there is always a danger of introducing weed seeds that will germinate and compete with the selected species.

Soil moisture is probably the most important factor to consider when direct seeding of woody plants is contemplated. If there is insufficient available soil moisture to initiate good germination, some initial irrigation may be necessary followed by an occasional watering during the first growing season to ensure plant survival. The economics and practicality of irrigation are of great concern and many reclamationists will argue it has no place in a reclamation program. The selection of site-matched species is considered much more important in ensuring successful plant establishment.

It is essential that seeds be covered to encourage germination and establishment. As a general rule-of-thumb, seeds should not be buried more than two to four times their own thickness (of the smallest dimension). If seed is drilled, care should be taken to adjust the depth rings correctly.

Following broadcasting, the seedbed should be dragged with a chain or pipe-harrow to ensure that seed is covered. Although hydroseeding has distinct advantages in seeding steep slopes or areas not conducive to aerial application, it does not place the seed in a situation where it can readily take advantage of the available soil moisture. Establishment in an area that has to be hydroseeded can be improved by operating a crawler tractor or 'Land Imprinter' over the site to provide moisture-trapping microsites.

3.2.2 Transplanting

The potential for successful woody plant establishment can be improved by using bareroot or container-grown transplants. Although transplanting is much more expensive than direct-seeding, the more severe the soil and climatic conditions of the site, the greater the need for transplanting. The following points should be considered when selecting transplant material (Shaw 1980):

- bareroot stock can be stored more compactly and is easier to handle than container-grown stock. The excessive bulk of containerized seedlings adds to transportation, handling and planting costs;

- both types of stock must be handled carefully prior to planting; bareroot stock must be held at temperatures slightly above freezing which can include refrigerated containers, portable coolers or snow banks; containerized plants must be held in a lathhouse or shaded and watered periodically;

- the cost of container stock is somewhat higher than that of bareroot; in addition, planting costs are greater;

- certain species perform poorly when transplanted as bareroot stock; and

- establishment of bareroot stock on extremely stony sites is poor due to the difficulty of ensuring good soil/root contact; as well, nursery growth media dry at different rates than most soils, thus reducing survival of container-grown stock.

Table 3.2-1

Summary of percent seedling survival and percent soil moisture at various planting times - 1982.

SPECIES	June 7	June 23	July 5	July 19	Aug. 3	Aug. 19	Aug. 31	Sept. 13	Sept. 23	Oct. 12
Pinus banksiana	100	100	100	100	100	100	100	100	100	100
Picea glauca	100	100	100	100	100	100	100	100	100	100
Populus tremuloides	100	100	100	100	100	100	100	100	100	100
Alnus crispa	100	87	93	100	100	100	100	100	100	100
Amelanchier alnifolia	100	100	100	100	100	100	100	100	100	100
Cornus stolonifera	100	100	100	100	100	100	100	100	100	100
Shepherdia canadensis	93	93	93	93	93	100	100	100	100	100
Caragana arborescens	93	100	100	100	100	100	100	100	100	100
MEAN	98.2	97.5	98.2	99.1	99.1	100	100	100	100	100
% Soil Moisture	42.5	17.7	39.4	41.5	38.7	39.4	33.6	35.4	12.0	28.1

(Fung 1983 - personal communication)

The time at which woody plant seedlings are outplanted is crucial to their ultimate survival and growth. Success or failure depends very much on the seedlings' root regeneration potential and the amount of soil moisture present at the time of planting. These two factors are both seasonally variable. Area-specific meteorological data is useful in identifying times of the year when the greatest precipitation can be expected. Ideally, transplanting should be done in the early spring when plants are dormant, soil moisture is usually relatively high, temperatures are low, the chances of precipitation are high and frost heaving has stopped.

Syncrude Canada Ltd. initiated a planting-time trial in 1982. The objective of the study is to determine the best time span in the season to outplant seedlings in the Athabasca oil sands area for optimum survival and growth. Since precipitation around Mildred Lake varies from year to year, one season's data may not represent the true soil moisture availability at a given time. Therefore, planting will be carried out five consecutive years (1982 - 1986) from April to October. In 1982, ten plantings were carried out at two-week intervals from June 7 to October 12 on near level tailings and dyke amended and incorporated with 10 cm of clay and 15 cm of muskeg peat.

Available soil moisture was determined at each planting time using the gravimetric method (Table 3.2-1). The precipitation trend deviated from the 30 year recorded average, i.e. high precipitation in the spring, lowest in mid-summer with a slight increase in the fall. In 1982, soil moisture was relatively high in mid-summer with low points recorded on June 23 and September 23. However, this low amount of soil moisture availability had no detrimental effect on the seedling survival rate.

A summary of seedling survival by species at the various planting times is also shown in Table 3.2-1. Excellent survival was due to sufficient soil moisture available throughout the season, good planting stock quality and the lack of competition from ground vegetation.

When transplanting container-grown or bareroot stock, the following guidelines are important (Stevens 1980):

- keep plants cool;
- never allow plants to dry out;
- plant at a depth slightly deeper than the depth in the nursery bed or container;
- compact soil around the roots to ensure good soil/root contact; and
- always plant into sites with adequate soil moisture.

The use of bareroot stock has a number of advantages over the use of container-grown stock. When correctly planted, bareroot stock has a higher rate of survival and establishes more quickly (McKell and Van Epps 1980) because the stock is usually bigger than container-grown material. Bareroot stock is generally older (1 to 3 years old) with strong woody stems and well developed root systems.

Container-grown stock, however, has often been grown under 'forcing' conditions with the result that some of the material delivered for planting is young, weak and spindly. Having been grown in outside beds (or as wildlings), bareroot stock is truly hardened thus increasing its chances of survival. Bareroot stock is much easier to handle because of the lack of bulky packaging and soil but because the material is somewhat larger than container-grown stock, a larger planting hole must be dug. The cost of container stock is generally two to 10 times greater than that of bareroot stock (Stevens 1980).

The use of container-grown stock does have its advantages over bareroot stock. Roots are already established in a growth medium and the material is available and plantable over a longer period of time.

Correct planting of both types of material is one of the key factors in ensuring successful establishment. Proper planting requires both preparation and training of planting crews and timing. To avoid any problems, the operator should instruct the crews in the principles and practices of planting techniques and should also be prepared to supervise the actual planting operations.

Correct tillage and control of competing plant species are the most important considerations to be made when preparing the site for planting into amended tailings sand. Proper tillage using appropriate equipment (Section 2.3, Materials Handling for Soil Reconstruction) should result in a growth medium that is loose, friable and well aerated, and which will intercept and retain precipitation over a period of time. However, particular care should be taken to ensure that the amendment layers and the underlying tailings sand are mixed as much as possible.

Volunteer species, or grass and legume species seeded for initial erosion control, represent the greatest competition for successful woody plant establishment. To reduce the level of competition, some form of control is recommended which will result in optimal planting locations. As indicated previously control techniques which can be used include reduced seeding rates of initial erosion control species, seeding in strips, spot applications of herbicides, or scalping of established vegetation by hand or mechanical means.

Both bareroot and container-grown material can be planted by hand or by machine. The technique chosen will depend on the size of the area to be planted, the topography of the area, the moisture content of the soil, quality and size of the planting material and the availability and reliability of planting personnel and equipment.

Although hand planting is labour intensive, it does have its advantages especially on steep slopes. In addition, it does allow the operator a certain amount of leeway in selecting microsites with favourable conditions for survival and where random planting patterns are desirable (Penrose and Hansen 1980).

Planting by hand involves digging a hole large enough to accept the root system of the plant. The terrain and soil conditions dictate the type of tool that can be used for this part of the operation. The mattock is used extensively as a planting tool as it enables the planter to quickly clear away any debris in order to create a favourable planting site and then to insert the planting material. In using a mattock, however, a planter tends to dig a hole on a slant rather than perpendicularly. The entire plug is then closer to the surface and is more susceptible to drought conditions than if it were planted vertically. This method of planting tends to induce root development to one side of the seedling or rooted cutting which could cause problems with plant survival at a later date (Walker 1978). However, planting deciduous trees and shrubs on a slant can stimulate branching along the stem.

If a mattock is to be the major planting tool, then more time and care should be taken in hand scalping, and planting at oblique angles should be avoided. Studies have shown that woody plant mortality as a result of competition occurs where scalping of existing vegetation has been inadequate. Where mattocks are used, the area scalped is often not much wider than the mattock blade and surrounding vegetation can quickly invade the cleared area and overlap the transplant (Fung 1982 - personal communication).

A number of alternatives exist for efficient 'patch' scarification. The Bracke scarifier can be used for site preparation prior to planting. With two metres between passes, 2250 patches/ha are made. This scarifier clears a scalped spot approximately 80 cm long, 63 cm wide and 24 cm deep (Smith 1979). A Bracke scarifier has been used with moderate success on a slope of between 2:1 and 2.5:1. This machine must be towed perpendicular to the slope to minimize the potential of channel erosion. While towed in this direction, the scarifier can "crab" and place the dozer operator in an awkward, and sometimes dangerous situation.

Suncor Inc. have used two types of rototillers, a light-duty garden variety and a heavy-duty tiller towed by a D-3 Caterpillar tractor, to clear patches of similar dimensions but care must be taken when operating this type of machinery on steep slopes as they can easily roll. In both cases, the tillers did not cut and mulch the vegetation but only mixed the soil and vegetation together producing a highly aerated planting medium which caused excessive moisture loss. These areas are readily susceptible to invasion by sweet clover. Scarifying in this manner frees the planter from the time-consuming job of hand scalping and also permits increased use of dibbles and the 'Pottiputki' for more efficient planting. Gasoline powered augers (back-pack type) are recommended for large projects as one operator can dig enough holes for a planting crew of three to four persons (Penrose and Hansen 1980). When used at Suncor Inc., augers work poor to adequate if the ground cover is not dense and soil is not too compacted or contaminated with stones.

At present, no specialized mechanical planters are used at oil sands reclamation sites. In part, this is due to the relatively small areas reclaimed to woody plants and the nature of the dike slopes. As larger expanses of flat tailings sand sites become available for permanent reclamation, utilization of equipment of this type may become feasible (Techman Ltd. 1980).

Many non-portable seedling planters can only function efficiently on level terrain or benches. The 'Steep Slope Tree/Shrub Planter' can be adapted for sloping dyke surfaces and other difficult terrain associated with tailings sand sites. The 'Mara Planter' warrants further study as it has the potential for planting seedlings on open swamps and wet fields, with swamp tracks that can operate in muskeg-sand conditions (Techman Ltd. 1980).

Most bareroot stock cannot be planted successfully using the automatic pickup and planting systems found on many tree transplanters. This is because most transplants have multiple-branching, fibrous and/or long root systems that continually get intertwined in the finger and chains of the automatic planting mechanism.

Sodding equipment, such as the 'Dryland Sodder', maybe useful where 'islands' of native vegetation stands can be recovered in advance of mining and transplanted to nearby reclaimed areas. Variations of this equipment, involving improvised dozer blades, can be mounted on front-end loaders or caterpillars. Suncor Inc. have had a certain amount of success with this method in establishing native species at the base of overburden waste dump slopes and they feel that similar success should be possible on amended tailings sand sites (Klym 1982 - personal communication).

Both container-grown and bareroot material should be planted as soon as possible after being taken into the field, in order to prevent dessication. Roots of bareroot stock can dry out in a matter of minutes, particularly on hot, windy days; roots should be kept damp at all times. Roots of container-grown stock, once out of the container, will tolerate longer periods of exposure (Stevens 1980).

Bareroot stock is generally packaged and transported to the field in plastic bags, whereas, container-grown material is usually handled in cardboard boxes. When placed in direct sunlight, both plastic bags and cardboard boxes soon heat up to temperatures that quickly lead to plant damage or mortality. Care should be taken to keep plants as cool as possible until the time they are required for planting (Stevens 1980).

Once the hole is made, the root system should then be inserted as nearly vertical as possible in the hole. In the case of container-grown stock, the plants should be inserted so that the top of the root plug is approximately 2 cm below the soil surface once the soil has been firmed around the plant. If the root plug is at (or slightly above) the soil surface, it will tend to act like a wick resulting in water loss from the plug.

During planting of bareroot material, care should be taken to ensure that roots are not bent upwards or kinked. Initially, such treatment may seriously affect the type of root system the plant develops, which in turn will affect the rate and extent of establishment as the plants will be more susceptible to improper nutrition, root disease and wind damage (Penrose and Hansen 1980). Bareroot stock should be planted at a depth that is slightly deeper than the depth of the plant in the nursery bed.

After the plant has been inserted into the hole, the soil should be firmed around the plant roots to eliminate air pockets and to ensure an adequate soil/root contact necessary for water uptake but not too firm so as to impede root penetration. In rocky material, care should be taken to prevent any crushing of the delicate root mass. Planted shrubs should always have a small basin formed around them to catch natural precipitation, run-off or supplemental water (Penrose and Hansen 1980).

3.2.3 Planting Considerations

Spacing of transplants is dictated by a number of factors:

- species to be used;
- availability of soil moisture;
- survival rate;
- reclamation guidelines pertaining to end land use, stocking rate and diversity; and
- objectives regarding aesthetics, competition or erosion.

On sites where soil erosion is a problem and anticipated losses are high due to adverse conditions, close spacing intervals are recommended (one metre square). On more hospitable sites where species diversity or maximum species growth may be desired, much larger spacing intervals can be used (Penrose and Hansen 1980). Suncor Inc. uses a planting density of 2470 stems per hectare (Klym 1982 - personal communication).

The meteorological conditions at planting time can have a significant effect on plant survival. This is most important when planting both conifers and deciduous stock which has leafed-out. The rate of water loss from an exposed seedling is a function of the moisture gradient between the seedling and surrounding air. When moisture gradients are high, planting should be postponed. The exposure of planting material to drying conditions during transportation and handling prior to planting compounds the problem further.

Air temperatures of between 0°C and 18°C with continuous wind speeds of less than 30 km/hr are desirable at planting time (Penrose and Hansen 1980).

Planting into frozen ground or during hot, dry periods is not recommended as juvenile stock is highly susceptible to wind dessication under these conditions.

Tailings sand deposits are characteristically areas of low soil moisture where supplemental water for irrigation purposes is presently unavailable. However, the development of new dryland planting techniques for woody plants virtually eliminates the need for irrigation during the plant establishment period. These techniques involve the use of black polyethylene soil surface covers which serve to conserve soil moisture, recycle water vapour, control weed competition and reduce diurnal and seasonal fluctuations in soil temperature (Carpenter, et al. 1978). The condensation trap (Figure 3.2-1) is perhaps the most commonly used and is also the most successful as it is capable of converting water vapour into irrigation water which, by virtue of the design of the trap, is

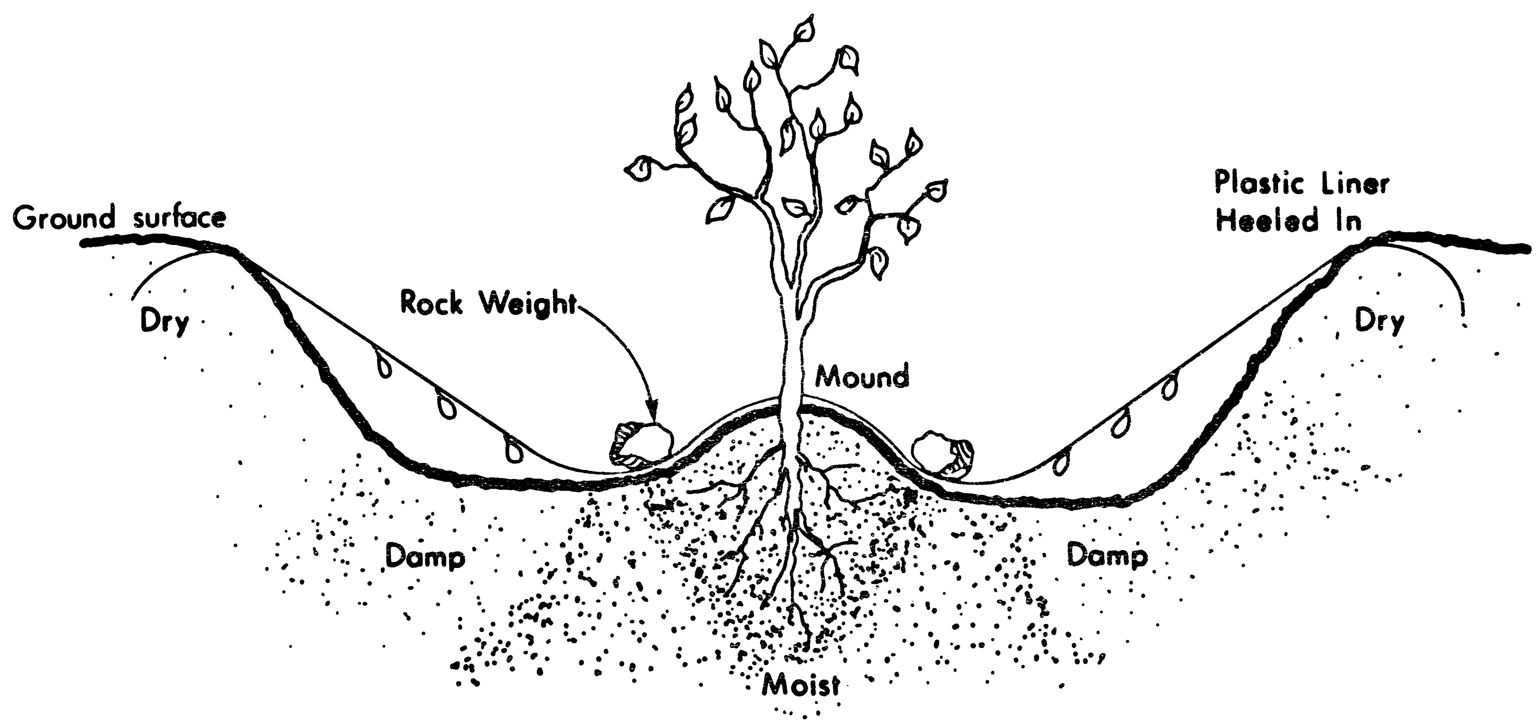

FIGURE 3.2-1

A CROSS SECTIONAL VIEW OF THE FIRST TYPE OF CONDENSATION TRAP.

deposited near to the plant (Jensen and Hodder 1979). Figure 3.2-2 shows a prefabricated type of condensation trap which allows for easy installation and a consistently functional condensation trap.

Besides the use of the condensation trap, other forms of individual tree mulches involving the use of fibreglass mats, straw collars, bark chips or latex rubber sprays have increased the survival rate (Jensen and Hodder 1979). Mulching of individual trees, although extending planting time and increasing planting costs, can be used effectively on steep and rough terrain to significantly increase the survival rate of tree and shrub plantings.

An alternative to mulching could be the application of antitranspirants which serve to lower evapo-transpiration rates of individual plants. Chemicals such as Stom-Seal (phenyl mercuric acetate) cause the stoma of leaves to close and Wilt Pruf (beta pinene) coat the surface of leaves with a thin latex film (Carpenter et al. 1978).

Although irrigation of woody plants on amended tailings sand sites is not presently being considered, it may well be the only technique capable of ensuring establishment on particularly sensitive sites. Aldon, Cable and Schol (1977) outline three experimental systems used to revegetate steep slopes of a uranium tailings dam in a semi-arid area of New Mexico. A modified, scaled down version of their submatic system would ensure survival of most woody plant species. The system consists of 12.7 mm polyethylene hose with 0.5 mm drip orifices which would be spaced in accordance with the planting distances chosen.

The irrigation lines run on the ground surface across the slope and are fed from 5.1 cm feeder lines running down the slope. The water supply system consists of a 7.6 cm plastic pipe running the length of the dam face, along the top, to which the feeder lines are connected. A filter, pressure regulator and pressure valves are necessary on the incoming line to filter the water and control the line pressure at about 1 kg/cm^2 (15 psi).

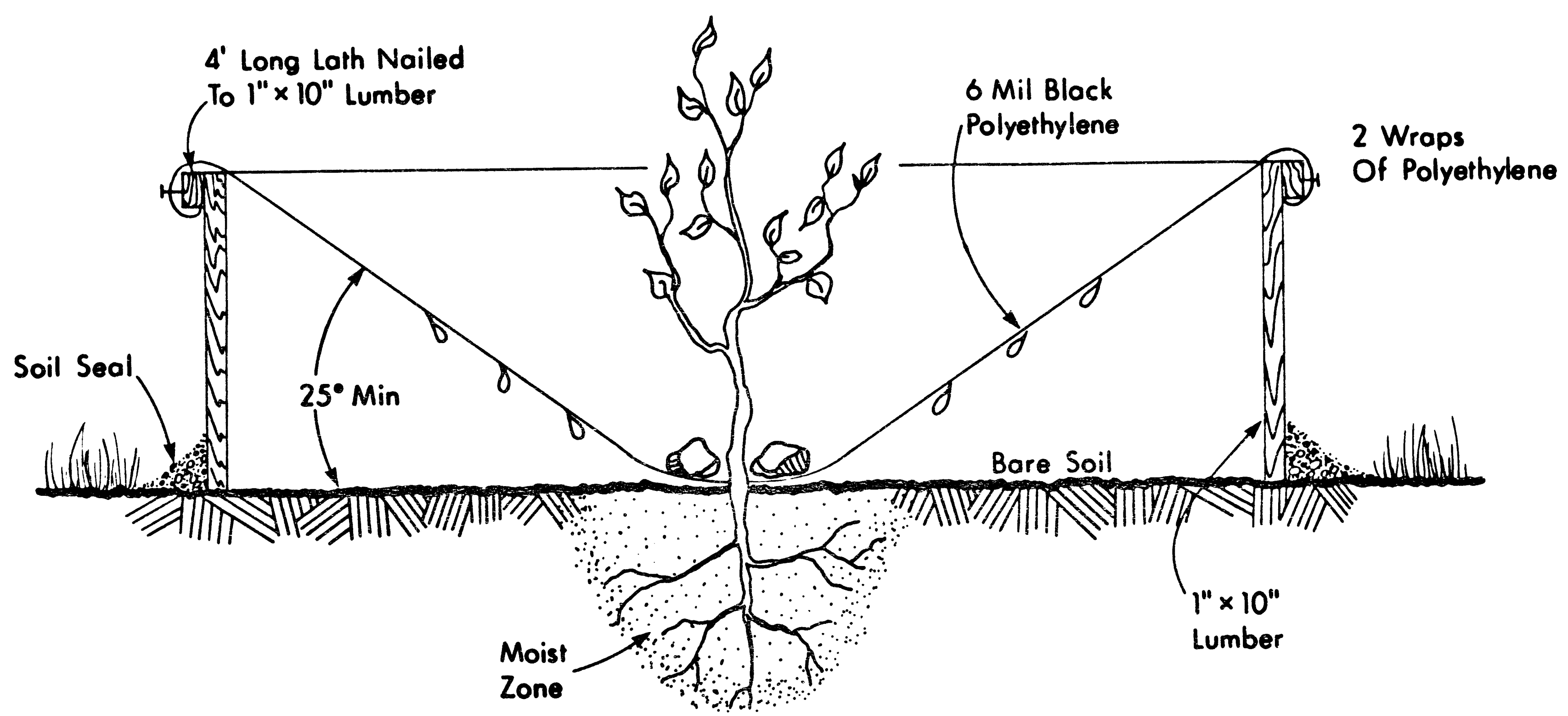

FIGURE 3.2-2

A CROSS SECTION OF A CONDENSATION TRAP CONSTRUCTED OF LUMBER. THIS TYPE MAY BE PREFABRICATED WHICH RESULTS IN EASY INSTALLATION AND A CONSISTENTLY FUNCTIONAL CONDENSATION TRAP.

Penrose and Hansen (1980) suggest that 'watering-in' of plants should be considered if soil moisture levels are critically low, especially in sandy textured soils. Increases in planting costs, as a result of 'watering-in', can usually be justified if a 10 to 20 percent increase in survival is obtained. Application rates of two to four litres per plant are recommended.

Little is known about the nutrient requirements of specific woody plants. Generally, fertilizers are not recommended for woody plants in arid and semi-arid areas as applications can significantly increase the moisture stress levels. If soil analyses indicate that nutrients may be a limiting factor in plant growth, it is recommended that slow-release fertilizers be used. These can be obtained in tablet form ('Agriform Planting Tablets') and be inserted in the bottom of a hole prior to planting. Nutrients are gradually released by soil bacterial action over an extended period of time (up to two years), thereby minimizing moisture stress produced by the soluble salts contained in the tablet. An equivalent amount of ammonium nitrate in its normal form would result in almost 20 times the moisture stress created by the slow-release tablet form (Penrose and Hansen, 1980). The slow-release fertilizers are useful during fall plantings as late applications will not encourage soft, new, frost- sensitive growth.

Animals may be attracted to newly planted and seeded areas because of the lushness and palatability of the vegetation and the habitat it creates. During the establishment phase, damage can be expected from small rodents, in particular. Controlling the amount and proximity of the ground cover vegetation to the individual woody plants coupled with the use of repellants or rodenticides may help to increase tree and shrub survival rates. Monitoring of rodent populations in the immediate area may indicate population cycles which can be used to advantage. Planting at the low point of a cycle would give the woody plants a two or three year rodent-free period during which time they would hopefully develop to point where they would be able to withstand rodent damage more easily (Green 1982).

During the establishment phase, the plants should be periodically inspected to observe their reaction to the ever-changing site conditions. Moisture stress, as indicated before, is the factor which tends to over-ride all others in terms of survival of planting stock. Reaction to this condition manifests itself in a variety of forms such as leaf-curl, yellowing, leaf-drop, premature dormancy or death (Klym and Shopik 1982 - personal communication).

In areas where frost-heave is a problem, detection of affected plants following the spring thaw and run-off may allow for correction before dessication can occur. At the same time, newly formed rills and gullies can be identified and corrected before severe erosion occurs which can damage or eliminate newly planted stock.

Survival and mortality rates should be monitored for each species planted, together with the vigor of surviving transplants. While planting, a record of the slope, aspect, soil conditions, planting method, quality and size of stock and presence of competitors should be made as this will prove invaluable when future revegetation programmes are designed and implemented (Penrose and Hansen 1980).

The information gained from examining dead plants is extremely useful where future planning is concerned. Dead plants should be dug up to determine if roots have grown into the surrounding soil and to determine the cause of death. Moisture stress is invariably the major cause of death but insect damage, leaf burn, wind damage, frost heaving, herbivore damage, soil compaction, unfavourable pH and flooding all take their toll (Penrose and Hansen 1980).

Planting on a large scale must be preceded with test plots to determine the appropriate species, planting techniques and maintenance procedures necessary to ensure establishment. Depending upon the species and site conditions, these plots may be required for more than 10 years.

SUMMARY

The presence of an initial ground cover has had a detrimental effect on the establishment of subsequent plantings of woody plant species. This is due in part to the competition between the grasses and legumes and woody plants for available moisture and nutrients and also to the increase in rodent populations associated with a dense groundcover. A number of planting alternatives exist which serve to reduce or eliminate the level of competition between the two vegetation types:

- planting woody plant species only;
- planting woody plant species and ground cover concurrently;
- strip seeding;
- disturbance of the ground cover material; and
- removal of some or all of the groundcover material.

Woody plant species can be established in an area by either direct seeding or as transplants. Direct-seeding may be accomplished using a mixture of several growth forms which can include species of woody plants, grasses and forbs. Very few woody plant species, however, produce seedlings capable of withstanding competition from perennial grass-seedlings. Sowing seeds of woody plants and grasses in alternate rows may be a viable alternative, although the presence of seeds of forbs and grasses in the amendment materials must always be expected. The four major considerations to be made when direct-seeding of woody plants is being considered are:

- competition must be reduced;
- only seed with acceptable purity, viability and vigour should be used;
- seeds have to be sown at a time that provides optimum conditions for germination and seedling establishment; and
- correct seedbed preparation and seeding is necessary.

The potential for successful woody plant establishment can be improved by using bareroot or container-grown transplants, particularly in areas with severe soil and climatic conditions. Current reclamation procedures in the oil sands area favour the use of container-grown stock. Roots are already established in a growth medium and the material is available and plantable over a longer period of time.

The time at which woody plant seedlings are outplanted is crucial to their survival and establishment. Success or failure depends very much on the seedlings' root regeneration potential and the amount of soil moisture present at the time of planting. Area-specific meteorological data is useful in identifying times of the year when the greatest precipitation can be expected.

Correct planting of transplant material is one of the key factors in ensuring successful establishment.

Tillage and control of competing plant species are the most important considerations to be made when preparing the planting site. The growth medium should be reconstructed in such a way that it is loose, friable and well aerated, and which will interupt and retain precipitation over a period of time. Particular care should be taken to ensure that the amendment materials are uniformly mixed into the underlying tailings sand as much as possible. Where necessary, the level of competition from the initial erosion control ground cover can be reduced prior to planting by spot application of herbicides or scalping/scarification of established vegetation by hand or mechanical means.

The terrain and soil conditions dictate the type of tool used in the actual planting of shrubs and trees. The mattock is used extensively as a planting tool as it enables the planter to create a favourable planting site and then to insert the planting material in the correct fashion. On sites where soil erosion is a problem and anticipated losses are high due to adverse conditions, close spacing intervals (one metre square) are recommended.

The meteorological conditions at planting time can have a significant effect on plant survival. This is most important when planting both conifers and deciduous stock which has leafed out. Air temperatures of between 0°C and 18°C with continous wind speeds of less than 30 km/hr are desirable at planting time.

The development of new dryland planting techniques, in particular the condensation trap, greatly enhances the potential for woody plant survival. Not only do they conserve soil moisture and recycle water vapour but they also assist in weed control and reducing fluctuations in soil temperatures. Besides the use of condensation traps, other forms of individual tree mulches involving the use of fibreglass mats, straw collars, bark chips or latex rubber sprays can increase the survival rate. Conventional irrigation of plantings on amended tailings sand sites is presently not considered feasible. However, it may be the only technique capable of ensuring establishment on particularly sensitive sites.

4.0 POST PLANTING MANAGEMENT PRACTICES

To date, woody plant establishment on amended tailings sand sites has only been moderately successful. Studies indicate that in general, a minimum of four to five years must elapse before plants can be said to be in a permanent survival condition (McKell and Van Epps 1980). However, on a species or site specific level, this period may be shortened or, more likely, may have to be extended. Soil reconstruction and other site preparation activities are designed to create a growth medium that is capable of ensuring a plant's survival throughout the period of establishment by satisfying its physical, chemical and biological needs (Table 2.2-1).

In theory, little post-planting management should be necessary. However, studies have shown that a number of field management practices can be incorporated into the reclamation program to increase the level of survival and establishment of woody plant species on amended tailings sand sites.

4.1 Control of Competition

Competition for soil nutrients and moisture from grasses and legumes used in the initial erosion control cover appear to have the greatest impact on survival and establishment of woody plant species. Effective long-term control of these competitive species is best carried out prior to planting and can be achieved by carrying out some of the measures outlined in Section 3.1, Planting Alternatives.

Subsequent to planting, control of competitive species is much more difficult and costly and may only be feasible on a small, site specific level. Regular monitoring of planted sites will allow for early identification of the effects of competition. Most noticeable will be the characteristic symptoms of reduced water availability, namely wilting, shrivelled leaves or premature defoliation (Klym and Shopik 1982 - personal communication). A number of control measures can be implemented to alleviate the situation:

- spot scalping around affected woody plants;
- use of post-emergence herbicides designed for use around nursery stock;
- maintaining the integrity of, or establishing, condensation traps around affected plants; and
- reducing and eventually discontinuing fertilizer applications as a means of reducing grass and legume productivity.

4.2 Maintenance of Soil Fertility

Failure of the plantings can be expected unless sufficient fertilizer is supplied to maintain the necessary nutrient pool in the amended tailings sand. This is particularly important during the period of establishment of the newly planted material, but once the plants have a fully developed root system, they should be able to survive without further attention by obtaining their nutritional requirements from the decay and breakdown of older plant material and from the developing soil complex (Weston 1973). Several applications of fertilizers over a four or five year period may be necessary on amended tailings sand sites to enhance the development of the desired self-sustaining vegetation cover. The frequency, rate and type of fertilizer should be based on a series of on-going soil analyses designed to monitor the nutrient status of the soil, the pH and moisture availability of the soil as well as the growth characteristics of the plant. It is of little use applying large amounts of fertilizers when the root systems of the plants are not sufficiently developed to handle the increased nutrient level or if moisture is insufficient to put the chemicals into solution.

Unfortunately, fertilizer applications not only benefit the plants for which they are intended but also will lead to increased growth of competitive species. Continuous high applications of fertilizers that are not incorporated into the soil at depth tend to encourage the competitive nature of grasses at the expense of woody plants, legumes and invading native species. For this reason, Suncor Inc. make an initial application of starter fertilizer just prior to seed bed preparation (6-24-24 at 392 kg/ha) and at seeding time (6-24-24/34-0-0 (1:1)) at 112 kg/ha. Over the next five growing seasons an application of a maintenance fertilizer (6-24-24 at 224 kg/ha plus 34-0-0 at 112 kg/ha) is made usually in late spring. Maintenance fertilizer rates are determined from soil tests, vegetation cover performance and cover objectives (Suncor Inc. 1982). Fertilizer applications are discontinued after five growing seasons.

Problems can arise with making only one application of fertilizer per growing season. Applications made in May usually will result in higher nutrient levels almost immediately but by the end of June these reserves may be depleted to the point where deficiency symptoms can be observed in the ground cover vegetation (Rowell 1977). The problem is due to the short period of time nutrients are available to plants on fertilized tailings sand sites; in some cases, only three to eight weeks of plant growth can lead to significant reductions in the available nutrient pool (Rowell 1977). Two applications per growing season, one in June and another in August, have been recommended to maintain a continuous supply of available nutrients for grassland sites (Takyi *et al.* 1977). Although the nutrient requirements of erosion control ground cover species on amended tailings sand is reasonably well documented, little is known about the nutrient requirements of the tree and shrub species highlighted in this report, especially in terms of their growth on engineered soils.

Information available on the nutrient requirements of *Pinus banksiana* indicate that the amount of nitrogen available is related directly to the amount of decomposible organic matter in the amended tailings sand.

Initially, organic matter levels may decrease due to the immaturity of the soil development process. The beneficial effects of nitrogen applications are thereby reduced and, therefore, the rates should go down and more frequent applications should be made (Monenco 1980).

Where P. banksiana is planted into already established erosion control ground cover, great care must be taken with the application of fertilizers as the vigorous growth pattern of fertilized grass and legume swards may affect the survival rate of this species. It may be that more successful establishment can be achieved by planting into a sward that has not been fertilized for two or three years by which time it should be nutrient deficient. As long as the major nutrients are balanced, jack pine can establish itself under these conditions (Monenco 1980).

During the initial establishment and growth period of mixedwood species, nutrient demand must be met by regular fertilizer applications as sufficient organic matter has not yet formed to ensure efficient nutrient cycling (Monenco 1980).

4.3 Maintenance of Soil Moisture

In the absence of irrigation, the level of moisture availability to woody plants is dependent upon the success of planting site preparation, soil reconstruction, the re-establishment of the water table and the density and type of ground cover.

Although available moisture in amended tailings sands is inherently low, further losses may occur through surface evaporation in areas where ground cover is sparse. Continued monitoring will identify these areas and remedial seeding may be necessary to counter the problem.

The intensity of competition will affect the availability of moisture to woody plants. A dense, vigorously growing grass cover will utilize or trap precipitation before it has a chance to reach the woody plant root zone. Control of competitive grasses (Section 4.1) will help conserve soil moisture. Condensation traps (Section 3.2.3) not only help to control herbaceous growth adjacent to woody plants, but by virtue of their design, are capable of maintaining and supplementing available moisture levels in close proximity to individual plants. Initial costs of constructing and fitting these traps may appear prohibitive, but in areas such as the tailings dikes, where moisture is at a premium, this may be an effective form of control.

An interesting phenomenon has occurred on certain reclaimed areas of the Suncor Inc. tailings pond slopes which may indicate a possible solution to the problem of moisture availability. Normally, growth of all types of vegetation is more vigorous at the base of the slope where moisture tends to accumulate. In certain areas, however, there is prolific growth of poplar and willow species near the crest of the slope where blowing tailings sand has accumulated and eliminated the grass and legume cover normally associated with these slopes. It is believed that this layer of tailings sand is acting as a mulch over the amended tailings sand layer leading to moisture retention in and around the root zone of the woody plants (Klym 1982 - personal communication).

4.4 Erosion Control

Tailings sand is very susceptible to surface wind and water erosion by virtue of its high sand content and hydrophobic characteristics. Once a vegetation cover has been established, erosion only becomes a problem when rill or gully erosion exposes the tailings sand underlying the amended layer. On steep slopes, continuous monitoring is necessary to identify areas where undercutting and rill erosion is occurring so that remedial action can be taken.

Peat used as a mulch or mixed into the surface has been used effectively on some areas as a means of controlling erosion. Rowell (1977) used stabilizers to combat erosion but soil loss was greater on the treated than on the control plots. Gravel application has been used with some success in controlling the spread of rills and gullies. Netting has been used on some eroded gullies, but where soil contact is not made, undercutting has developed (Klym 1982 - personal communication).

On more gently sloping (<4:1) areas, contour trenching and terracing appear to help control erosion and encourage vegetation establishment (Lesko 1974; Fung 1982 - personal communication) by providing microsites for seed germination, conserving moisture and reducing the rate of run-off (Curtis 1971).

In established areas, the need for erosion control measures will tend to decrease as the canopy, litter layer and root development provide greater protection against raindrop impact and water run-off.

4.5 Control of Small Mammal Damage

High mortality rates occurring in some woody plant species have been attributed to small rodent damage, particularly Microtus pennsylvanicus (Green 1982). Damage occurs in the form of partial or total girdling of the young plants.

Suncor Inc. have been assessing a number of different methods of control of small rodent damage on a number of their planted areas. On a small scale, the use of kill traps, 'Warfarin' bait and metal guards around the base of individual plants do not appear to offer the desired control. An extended study using 'Rozol' by Radvanyi demonstrated that in treated areas, there was a high kill factor but there was little attempt to correlate actual damage to animal density (Green 1982).

An experiment has been established at the Syncrude Canada Ltd. site involving the use of extended plastic net tubes. The plants are inserted in them at planting time and during planting the tubes are partially buried so as to anchor them in the soil. The stem portion of the plant is completely enclosed in the plastic net tube; growth is not restricted but at the same time small rodents are supposedly not able to feed on the stem (Fung 1982 - personal communication).

In a more recent study by Green (1982), three control methods were assessed - the application of an animal repellant ('Thiram') to plantings, the provision of supplementary food supplies (whole or crushed oats) throughout the winter and a reduction of ground cover around individual plants. The extent of damage varied from site to site, and from year to year, but in all cases the greatest amount of damage was observed in areas where a dense grass-legume cover was established and the least amount in areas where cover was reduced or eliminated. Of the trees and shrubs planted, willows and poplar appeared to be the most susceptible to damage, whereas caragana and white spruce were rarely touched. Based on these observations, the most effective form of control can be obtained by adjusting the seeded ground cover mixture so that the development of a dense ground cover and a thick accumulation of litter material is minimized. The seeding and maintenance of a reduced ground cover would provide a less attractive habitat for small rodents and consequently lead to less damage. In addition, a reduced ground cover would lessen the impact of competitive stress on the woody plants from grasses and legume and allow them to grow more vigorously so that they are less susceptible to small rodent damage.

An additional form of control may be possible by the provision of raptor nesting sites in reclaimed areas (Erlinge 1974).

A small number of trees in areas of dense grass cover have been browsed by snowshoe hares. Poisoning of hares is possible, but removal of any small mammal population nearly always leads to invasion of the controlled area by animals from adjoining habitats. Further, these poisons are not species specific resulting in the death of many non-target animals (Sullivan and Sullivan 1981).

4.6 Control of Large Mammal Damage

The amount of vehicular and personnel movement in the area together with the relatively juvenile state of reclaimed areas has resulted in limited damage from large mammals. A small number of trees have been browsed by ungulate species in fringe areas proximal to adjoining natural habitats (Klym 1982 - personal communication). As the canopy of tree and shrub cover develops, ungulate browsing of woody plants could become a problem. Unless the area is fenced or unpalatable species are used, control of large mammal movement in a reclaimed area is extremely difficult. Some damage is inevitable but excessive damage would indicate that a problem exists with the adjacent natural habitats in terms of food availability and consideration may have to be given to some form of habitat enhancement of these areas.

4.7 Control of Insect and Disease Damage

Insect populations, like vegetation communities, are affected by moisture levels. In the Fort McMurray area, in general, insect numbers, biomass and diversity are highest in the wet fen areas and lowest on the jack pine and non-vegetated sites (Ryan and Hilchie 1981). This would indicate that little widespread insect damage can be expected on the characteristically dry dike slopes although some damage may occur on fringe sites adjacent to undisturbed areas.

Baseline studies indicate that herbivorous insects are the most active insect group in the area in terms of observable damage, with carnivorous and saprovorous (soil dwelling) insects also present in the area (Ryan and Hilchie 1981). The study carried out over a two year period (1978 and 1979) indicated a general pattern of damage, although climatological conditions did vary from site to site. Virtually all leaves of *Cornus stolonifera* (dogwood) bore insect scars; the highest percent leaf area missing was in *Populus tremuloides* (trembling aspen) and *Salix* spp. (willow) with some damage on *Alnus crispa* (green alder) and *Shepherdia canadensis* (buffalo-berry) being noted.

Except for some willows, few stems of deciduous plants showed evidence of insect damage. Stems of conifers were much more heavily attacked; for spruce species, galls followed by bud damage were most prevalent. Scale insects were evident on stems of buffalo-berry, some willow species and *Ledum groenlandicum* (Labrador tea) with none being found on green alder or *Rosa acicularis* (prickly rose).

The study also assessed bark beetle attack on crowns of spruce, jack pine and poplar trees. No crowns were killed by beetle attack although leader terminal buds were often damaged by insect larvae, possibly cecidomyiid flies. Some spruce tree terminals were denuded, bore cancerous clumps or were abnormally spindly but the report gives no indication as to the cause(s).

Table 4.7-1 lists the specific insects and diseases known to attack the woody plant species highlighted in this report.

Control of insect and disease damage on shrubs and trees in reclaimed tailings sand areas is not widely documented, due to the fact that few established stands are available for study. Current observations indicate that damage, where it exists, is very localized and occurs in sites immediately adjacent to non-disturbed areas or where plants are in a weakened state because of the intense competition for soil moisture and nutrients from surrounding grasses and legumes.

In the initial stages of reclamation, the best approach lies not in control but in the maintenance of healthy woody plant stock throughout the period of establishment (Sections 3.0 and 4.0). Except in localized areas, the use of pesticides and/or fungicides could prove time consuming and costly as it would necessitate the spraying of large tracts of land adjacent to the disturbed site, as it is from these areas that most attacks will originate.

Table 4.7-1

Susceptibility of reclamation species to insect and disease damage

Woody Plant Species	Insects	Diseases	Comments
Alnus crispa	alder flybeetle, poplar and willow borers, striped alder sawfly, western tent caterpillar, large aspen tortrix	powdery mildew, leaf blisters, white rot	
Amelanchier alnifolia	fruit maggot, western tent caterpillar gall damage, sawfly (fruit), oyster shell scale	Monilinia amelanchieris, rust, mildew, damping off (seedlings only)	rusts cause defoliation, shoot dieback and fruit malformation; can be prevented by removing junipers growing near
Caragana arborescens	blister beetle, caragana seed chalcid, pea aphid, beet web-worm, grasshopper	Rhizoctonia solani, damping off (seedlings only)	
Elaeagnus commutata		leaf spot, leaf rust dieback and root rot (Peniophora cremea)	
Prunus pensylvanica	forest tent caterpillar, ugly nest caterpillar	black knot, western x disease, gummosis, blossom blight, twig blight, fire blight	
Rosa acicularis	crown gall	variety of leaf rusts, leaf spots, powdery mildew, stem canker	
Rosa woodsii	common gall	leaf spots, leaf rusts, gray mold, powdery mildew, stem canker	
Salix bebbiana	willow sawfly, willow borer, scale, large aspen tortrix		
Shepherdia canadensis	scale	leaf spot, leaf rust, powdery mildew, heartrot	
Picea glauca	spruce sawfly, spruce gall aphid, spruce budworm, spruce spider mite, pine needle scale, white pine weevil	needle rust, bad rust, snow blight, "Armillaria root rot", brown cubicle rot	adverse response to glyphosphate spray applications, symptoms can be confused with insect attack
Pinus banksiana	jack pine budworm, pine sawfly, white spotted sawyer beetle, red terpentine beetle, pine needle scale, white pine weevil	dwarf mistletoe, blue stain fungi	
Populus tremuloides	forest tent caterpillar, poplar borer, poplar bud gall mite, large aspen tortrix	leaf spot, leaf rust, shoot blight, sooty bark canker, "Armillaria root rot"	seedlings susceptible to mildew and damping off; susceptible to frost damage
Hybrid poplars	forest tent caterpillar, poplar borer, poplar bud gall mite, large aspen tortrix	cankers	Walker poplar moderately resistant to insect and disease attack; Northwest is susceptible to gall mites but shows some resistance to leaf rust and aphids; susceptible to frost damage

Note: Information provided by Watson, Parker and Polster, 1980; PFRA Tree Nursery, Indian Head, Saskatchewan; Techman Engineering Ltd. 1981. Alberta Provincial Tree Nursery, Oliver, Alberta

4.8 Encouragement of Invasion by Native Species

The level of invasion of disturbed areas by native woody plant species is dependent upon the extent and type of initial ground cover material established for erosion control purposes and the proximity of these sites to undisturbed areas, which act as the primary seed source for invasion.

On some of the older reclaimed sites, invasion by native species is sporadic because of the dense grass-legume ground cover. Invasion of these areas can only be achieved by reducing or eliminating the ground cover material through chemical or mechanical means. Selection of less vigorous erosion control species combined with reduced seeding rates would create sites more conducive to invasion by native species.

In areas where an erosion control ground cover has not been established prior to planting, invasion by native species is more prolific. Not only is there a ready source of native plant material in the form of the seed reservoir in the amendment material but the level of competition for space, moisture and nutrients is much less.

Correct fertilizer application in terms of rate and placement will have an effect on invasion by native species. Heavy, widespread applications will encourage the spread of the agronomic grass species at the expense of the woody plants. Continual soil analyses and vegetation surveys will assist in developing a management program that favours the invasion of disturbed sites by native species.

4.9 Stand Rejuvenation

Rejuvenation, or increasing stand density, through natural coppicing or seeding is dependent upon the general health and vigour of the planted stands. Prevention or control of competition, particularly from introduced grasses and legumes, will help ensure establishment of the woody plant species.

Some coppicing of trembling aspen and wolf-willow can already be seen on some older reclaimed dikes at the Suncor Inc. operations, particularly where some of the trapped construction water has found its way to the surface. Seed production from established caragana plants is apparent at some of the Syncrude Canada Ltd. and Suncor Inc. reclamation sites (established 1978). At Suncor Inc., seed germination is abundant in a number of areas.

Maintaining a suitable woody plant density will also enhance stand rejuvenation. Suncor Inc. uses a planting density of 2470 stems per hectare. When this density drops to below 50 percent replanting of affected stands is carried out (Klym 1982 - personal communication).

4.10 Zero Management

In sensitive areas, growing conditions are in a constant state of flux such that established vegetation can quickly deteriorate to a point where its survival is threatened. Hence, any reclamation activity should include a continual monitoring program designed to identify problems before they occur in order that remedial action can be taken.

As the depth of knowledge and level of expertise involved in the reclamation of amended tailings sand sites increases, the time taken for a reclaimed area to become self-perpetuating and maintenance free will diminish. Present woody plant survival and productivity rates (Section 5.0) on amended tailings sand indicate that, depending upon the desired end land use for a particular site, the management phase could well go beyond the initial ten year period.

SUMMARY

A number of field management practices can be incorportated into the reclamation program to increase the level of survival and establishment of woody plant species on amended tailings sand sites.

Subsequent to planting, control of competitive species is much more difficult and costly and may only be feasible on a small, site specific level. Monitoring of planted sites will allow for early identification of the effects of competition. Most noticeable will be wilting, shrivelled leaves or premature defoliation. Several control measures can be implemented to alleviate the situation:

- spot scalping around affected woody plants;
- use of post-emergence herbicides designed for use around nursery stock;
- mainting the integrity of, or establishing, condensation traps around affected plants; and
- reducing and eventually discontinuing fertilizer applications as a means of reducing grass and legume productivity.

During the initial period of soil development and plant establishment, failure of the plantings can be expected if sufficient fertilizer is not supplied to maintain the necessary nutrient pool in the amended tailings sand. Several applications of fertilizers over a four or five year period may be necessary. The frequency, rate and type of fertilizer should be based on a series of on-going soil analyses designed to monitor the nutrient status of the soil, the pH and moisture availability of the soil as well as the growth characteristics of the plant.

The level of moisture availability to woody plants is dependent upon the success of planting site preparation, soil reconstruction, the re-establishment of the water table and the density and type of ground cover. Many of the recommendations made for controlling competition

from ground cover material will also serve to conserve moisture. Surface evaporation of moisture may occur in areas where the ground cover is sparse, and remedial seeding may be necessary to alleviate this problem.

Once a vegetation cover has been established, erosion only becomes a problem when rill or gully erosion exposes the tailings sand underlying the amended layer. On steep slopes, regular monitoring is necessary to identify affected areas so that remedial action can be taken. Peat, used as a mulch, has been effective as has the use of netting on some eroded gullies. On more gently sloping areas (<4:1), contour trenching and terracing appear to control erosion and encourage establishment.

High mortality rates occurring in some woody plant species have been attributed to small rodent damage. Damage occurs in the form of partial or total girdling of the young plants. A number of control measures are currently being assessed and include the use of "Warfarin" and "Rozol" baits, metal guards around the base of the plants, plastic tube netting around individual plants, the use of an animal repellant ("Thiram"), the provision of supplementary food supplies and a reduction of ground cover around the plants. The extent of damage has varied from site to site, and from year to year, but in all cases the greatest amount of damage has been in areas where a dense grass-legume cover was established.

Ungulate browsing of a small number of woody plants has occurred in areas proximal to adjoining natural habitats. Unless the area is fenced or unpalatable species are used, control of large mammal movement in a reclaimed area is difficult. Excessive damage would most likely indicate that a problem exists with the adjacent, undisturbed natural habitats in terms of food availability and some form of habit enhancement of these areas should be considered.

In the Fort McMurray area, insect populations are highest in the wet for areas and lowest on the jack pine and non-vegetated sites. Little damage can, therefore, be expected on the characteristically dry dike slopes, although some damage may occur on fringe sites adjacent to undisturbed areas.

In the initial stages of reclamation, the maintenance of healthy woody plant stock throughout the period of establishment is recommended over actual control. Except in localized areas, the use of pesticides and/or fungicides could prove uneconomic as it would necessitate the spraying of large tracts of land adjacent to the disturbed site, as it is from these areas that most attacks will originate.

On some of the older reclaimed sites, invasion by native species is sporadic because of the dense grass-legume ground cover. Invasion of these areas can only be achieved by reducing or eliminating the ground cover material through mechanical or chemical means. Selection of less vigorous erosion control species combined with reduced seeding rates and reduced fertilizer applications would create sites more conducive to invasion by native species. In areas where an erosion control cover has not been established prior to planting, invasion by native species is more prolific.

Rejuvenation, or increasing stand density, through natural coppicing or seeding is dependent upon the general health and vigour of the planted stands. Prevention or control of competition, particularly from introduced grasses and legumes, will help ensure proliferation of the woody plant species.

In sensitive areas, such as recently amended tailings sand sites, growing conditions are in a constant state of flux such that even established vegetation can quickly deteriorate. Any reclamation planning should include a monitoring program designed to identify problems before they occur. Moisture stress brought on by extended periods of drought or by competition from the ground cover material is invariably the major cause of death, but rodent damage, wind damage, frost heaving, soil compaction and unfavourable pH all take their toll.

Present woody plant survival and productivity rates indicate, depending upon the desired end land use for a particular site, that the management phase could well go beyond the initial 10 year period.

5.0 SOIL DEVELOPMENT AND PLANT ESTABLISHMENT

In an attempt to predict the primary woody plant communities at the end of the first 10 year period and also to predict the plant productivity level, this section will focus on monitoring studies carried out by the two major operators in the Athabasca tar sands area following reclamation activities on their sites.

5.1 Soil Development

Fedkenheuer (1980) reported that studies at Syncrude Canada Ltd. to investigate the addition of amendments to tailings sand as a means of enhancing its development as a vegetation supporting soil are producing positive results and that the improvements obtained have been maintained for more than two growing seasons.

The following subsections are based in part on the studies carried out by Syncrude Canada Ltd. Except where indicated, all data used pertain to these studies. The results reported in Section 5.1.1, Chemical Characteristics, are an average of fertilized and unfertilized plots within treatments on a yearly basis as an initial base fertilizer application of 50 kg/ha of N, P and K fertilizers, respectively was made in 1977 on all plots and was believed to be still augmenting the nutrient pool in 1979.

In this study, tailings sand was amended with 10 cm of either native sand, lean tar sand or mineral fines (from overburden material), or 20 cm of mineral fines; all treatments included 15 cm of peat material. Following amendment incorporation and seedbed preparation, the plots were drill seeded at 10 kg/ha with a grass-legume mix and then planted with native shrub and tree seedlings. The performance of these seedlings is discussed in Section 5.2, Plant Establishment.

5.1.1 Chemical Characteristics

Monenco (1980) reported a drop in pH of amended tailings sand on dike slopes from 8.5 to 6.5 over a five year period. A decline of this magnitude indicates an extremely low buffering capacity due in part to the inherently low cation exchange capacity (CEC) and the rapid leaching of cations present.

Syncrude Canada Ltd. reports indicate that the incorporation of mineral fines and organic matter into the surface layer (15 cm) will stabilize the pH levels (Fedkenheuer 1980). The pH value for amended tailings sand in 1977 was 7.3 for all treatments described previously. By 1979, this level had dropped to 7.1 for the peat plus native sand and peat plus lean tar sand treatments but had risen to 7.5 with the addition of peat plus mineral fines.

In all treatments, electrical conductivity was substantially below the 4.00 mmhos/cm level normally considered an indicator of potential salt damage to actively growing plants (U.S. Salinity Laboratory Staff, 1954). The highest level occurred where peat plus lean tar sand was used as an amendment; a level of 1.41 mmhos/cm was recorded in 1977 with a decline to 1.11 mmhos/cm in 1979.

The sodium adsorption ratio (SAR) values for all treatments are below 2.0. The highest level occurred where peat plus 20 cm of mineral fines was used as an amendment. A level of 1.97 was recorded in 1977 with a substantial decline to 0.50 in 1979. An SAR value of 6.0 indicates the point at which the physical properties of the soil may be seriously affected (Alberta Department of Agriculture 1968).

The CEC of tailings sand is approximately 2.35 mEq/100g. Increases in the CEC level were recorded in 1977 for all treatments, from a low of 12.12 mEq/100g to a high of 16.24 mEq/100g for peat plus 10 cm of mineral fines (Note: the peat used in all treatments had a CEC of 47.95 mEq/100g). Levels of 7.0 to 10.0 mEq/100g are considered suitable for tree nurseries, indicating more than adequate levels for woody plant conditions.

In 1977, exchangeable sodium was highest on the tailings sand amended with the peat plus the 20 cm of mineral fines (0.66 mEq/100g); lowest levels occurred on the peat plus native sand treatment (0.28 mEq/100g). Although there was a slight increase in exchangeable sodium levels in 1978, the levels dropped substantially in 1979; peat plus the 20 cm of mineral fines was still the highest at 0.25 mEq/100g. Sodium concentrations in excess of 2.0 to 3.0 mEq/100g are considered detrimental to plant growth (U.S. Salinity Laboratory Staff 1954).

Exchangeable potassium levels ranging from 0.12 mEq/100g for the peat plus native sand to 0.21 mEq/100g for the peat plus 20 cm of mineral fines were recorded in 1977. These levels dropped substantially in 1978 for most treatments but increased in 1979 to levels ranging from 0.22 mEq/100g for the peat plus native sand and peat plus lean tar sand to 0.30 meg/100g for the peat plus 20 cm of mineral fines. Levels of approximately 0.06 mEq/100gm and 0.13 mEq/100g of exchangeable potassium are recommended for plantations of _Pinus banksiana_ and _Picea glauca_, respectively (Wilde _et al_. 1964).

Exchangeable calcium levels ranging from 10.87 mEq/100g for the peat plus lean tar sand to 19.73 mEq/100g for the peat plus 20 cm mineral fines were recorded in 1977. Levels increased dramatically in 1978, ranging from 18.64 mEq/100g for the peat plus lean tar sand to 28.23 mEq/100g for the peat plus 20 cm of mineral fines. These same levels dropped in 1979, ranging from 8.77 mEq/100g for the peat plus lean tar sand to 13.99 mEq/100g for the peat plus 20 cm of mineral fines. Levels of approximately 0.50 mEq/100g and 1.25 mEq/100g of exchangeable calcium are recommended for plantations of _Pinus banksiana_ and _Picea glauca_, respectively (Wilde _et al_. 1964).

Exchangeable magnesium levels ranging from 1.78 mEq/100g for the peat plus native sand to 3.67 mEq/100g for the peat plus 20 cm of mineral fines were recorded in 1977. These same levels increased during 1978 to 2.37 mEq/100g and 4.50 mEq/100g respectively. Levels of approximately 0.20 mEq/100g and 0.50 mEq/100g are recommended for plantations of _Pinus banksiana_ and _Picea glauca_, respectively (Wilde _et al_. 1964).

The addition of all amendments to the tailings sand greatly increased the percent of total nitrogen. The tailings sand had an initial total nitrogen level of 0.01 percent which was increased to a range of 0.15 to 0.19 percent by all treatments. These levels remained stable throughout the period of the study. Surface total nitrogen levels of 0.04 percent and 0.10 percent are recommended for Pinus banksiana and Picea glauca, respectively (Wilde et al. 1964).

The carbon/nitrogen ratios in the amended tailings sand ranged from 21:1 in the peat plus native sand and peat plus 20 cm of mineral fines to 33:1 in the peat plus lean tar sand treatment. All treatment ratios decreased, with ratios for 1979 ranging from 13:1 for the peat plus native sand to 24:1 for the peat plus lean tar sand. In the surface 15 cm of an average soil, C/N ratios of 10:1 to 12:1 can be expected (Wilde et al. 1972). Competition for available nitrogen between the soil micro-organisms and the plants should lessen as the C/N ratio decreases (Fedkenheuer 1980).

Organic matter contents of one percent and four percent for Pinus banksiana and Picea glauca, respectively are required for satisfactory growth (Wilde et al. 1972). A range of 5.5 percent for the peat plus 20 cm of mineral fines to 8.7 percent for the peat plus lean tar sand was recorded in 1977. These same levels have since dropped to 5.0 percent for the mineral fines treatment and 6.5 percent for that of the lean tar sand. These levels should stabilize as the reclaimed areas become more established.

The tailings sand material used had an available phosphorus level of 11 ppm. Following amendment and the initial overall fertilizer application in 1977, this level rose to a high of 47 ppm for the peat plus 10 cm of mineral fines and to a low of 25 ppm for the peat plus lean tar sand. These same levels dropped dramatically in 1978 to 5 ppm for both treatments. Available phosphorus levels recorded in 1979 indicated a slight increase to 13 ppm for the lean tar treatment and 9 ppm for that of the mineral fines. Levels of 5 ppm and 12 ppm are recommended for Pinus banksiana and Picea glauca, respectively (Wilde et al. 1964).

Although quartz ore materials are generally considered to weather very slowly, a release of nutrient cations can be expected from the tailings sand (Monenco 1980). Figures of one to 25 kg/ha/yr are cited for calcium, magnesium and sodium with 0.2 to 0.5 kg/ha/yr possible for potassium. This rate of release could be increased by further pulverization of the material during the extraction process. Although these levels will not support grassland or forest communities, they are expected to balance the annual losses when the developing ecosystem is self-sustaining.

Results to date indicate that in general, a combination of a peat plus mineral fines amendment satisfies many of the nutrient requirements of the reclamation plant species. During the initial stages of establishment, continuous monitoring of soil nutrient status is essential and corrective measures taken to stabilize the level of available nutrients. Extreme care should be taken with fertilizer applications to ensure that the levels obtained do not lead to increased competition for the woody plants from the introduced grass and legume species used in the initial erosion control ground cover.

5.1.2 Physical Characteristics

Over time, moisture holding capacity, bulk density and erodibility are the three physical characteristics most likely to change in amended tailings sand material (Monenco 1980). Table 5.1-1 shows the results of analyses for selected physical characteristics for both the amended tailings sand material and the individual components. The addition of all types of amendments to tailings sand led to a sizeable increase in moisture content at both the field capacity (0.1 bar) and permanent wilting point (15 bars) level. In the case of the peat plus lean tar and peat plus 10 cm of mineral fines, moisture content and moisture availability were highest on the fertilized plots.

In 1981, Syncrude Canada Ltd. initiated a soil moisture monitoring study on a tailings dyke and on an overburden waste disposal dump site. The objectives of this study are to obtain a record of changes in soil moisture (percent) on different soil materials at various depths; using soil moisture data to relate soil moisture patterns to climatic

Table 5.1-1

Results of analyses for selected physical characteristics of the base soil materials and the tailings amended with these base soil materials (collected in 1977)

Soil Material	Moisture Content (% by wt.)		Available Water (% by wt.)	Particle Size Analysis (%)			Bulk Density* (g/cc)		
	0.1 bar	15 bars		Clay	Silt	Sand	2 cm	18 cm	38 cm
Base Soil Materials									
Peat	89.0	52.6	36.4	6	24	70	-	-	-
Mineral Fines (Clay)	29.5	13.6	15.9	49	14	37	-	-	-
Lean Tar Sand	16.0	4.4	11.6	6	23	71	-	-	-
Native Sand	1.5	0.6	0.9	1	2	97	-	-	-
Tailings Sand	4.0	1.3	2.7	4	5	91	-	-	-
Amended Tailings Sand**									
10 cm Native Sand									
Fertilized	18.0	9.0	9.0	2	9	89	1.22	1.23	1.43
Unfertilized	18.2	8.7	9.5	2	9	89	1.20	1.28	1.47
10 cm Lean Tar Sand									
Fertilized	26.3	13.3	13.0	6	19	75	0.84	1.14	1.48
Unfertilized	19.0	8.8	10.2	5	17	78	0.98	1.21	1.49
10 cm Mineral Fines									
Fertilized	36.2	16.2	20.0	16	14	70	1.12	1.12	1.46
Unfertilized	21.3	11.5	11.3	17	11	72	1.06	1.29	1.48
20 cm Mineral Fines									
Fertilized	29.8	13.5	16.3	25	15	60	0.96	0.94	1.48
Unfertilized	30.3	13.8	16.5	18	14	68	1.16	1.28	1.47

* Samples collected 25 months after rotovating.
** All treatments include 15 cm of peat.

(from Fedkenheuer 1980)

conditions, soil physical characteristics and vegetation. The soil moisture results will indicate water availability to plants during the growing season.

The tailings dyke and soil simulation research plots were sampled at each of three depths: 0 - 10 cm, 10 cm to the topsoil/tailings sand junction, and from the top 10 cm of tailings sand. The waste disposal area plots were sampled at approximately 0 - 15 cm and 15 - 30 cm. Soil samples were collected approximately every two weeks, from mid-May to mid-October, 1982. The gravimetric water content of the samples was determined.

The monthly precipitation was lower than the 30-year average in June and September, 1982. Soil moisture in all areas sampled decreased from mid-June to mid-July, 1982. Recharging of soil moisture, at all depths, did not occur during September and October. Those areas that were seeded during spring, 1982 had soil moisture values greater than the previously seeded areas. This could be attributed to lower evapotranspirational losses from the newly seeded areas.

Moisture tension curves are being prepared for the waste disposal area and one area on the tailings dyke. The moisture tension curves for the remaining areas were completed as part of the 1981 project. This study will be continued in 1983.

The addition of lean tar sand and mineral fines appears to have an appreciable effect on the levels of silt and clay in the growth medium. As a result, soil texture changes from the characteristic sand of tailings sand material to a loamy sand for the peat plus lean tar sand treatment, to a sandy loam for that of the peat plus 10 cm of mineral fines. The texture for the peat plus 20 cm of mineral fines (fertilizer) treatment is a sandy clay loam (Canada Department of Agriculture 1978).

Bulk density measurements were taken in 1979 with no initial levels reported for 1977 or 1978. Of particular interest are the levels recorded for the 18 cm depth where a marked difference occurs between the bulk density of the fertilized and unfertilized plots for all amendment treatments. This difference has been attributed to the increased amount of roots in the fertilized plots which will make the soils less dense (Fedkenheuer 1980).

Bulk density of tailings sands, at approximately 1.6 g/cm^3, is considered high (Monenco 1980). At the 18 cm depth, the levels ranged from 0.94 g/cm^3 for the peat plus 20 cm of mineral fines (fertilized) to a high of 1.29 g/cm^3 for the peat plus 10 cm of mineral fines (unfertilized). Indications are that as vegetation establishes itself on amended tailings sand sites, the natural increase in the amount of organic material will lead to further reduction in the bulk density level, thereby enhancing further root penetration through the soil. A bulk density greater than 1.75 g/cm^3 for sand is considered detrimental to root penetration (Wilde 1958).

Following two years of growth on amended tailings sand, root depths of grasses and legumes were assessed, and in all treatments, 15 percent of the root mass had penetrated into the tailings sand below the amended layer. Depths of root penetration were consistent over all of the treatments with the highest average rooting depth (48 cm) occurring on the peat plus 10 cm of mineral fines (fertilized) and the lowest (38 cm) on the peat plus lean tar sand treatment. This comparatively vigorous root development is a strong indicator of the competitive nature of the initial erosion control ground cover, often considered responsible for the poor survival and establishment of many of the woody plants used to date.

Some settling can be expected on amended tailings sand sites, irrespective of the treatment. The same study indicated that the incorporation layer had settled an average of 3.5 cm over a period of 26 months; this represented a settling of approximately 15 percent.

Tailings sand erodibility should decrease both during soil reconstruction and during revegetation and plant community development (Monenco 1980). An increase in organic matter coupled with the improved structural characteristics will improve and control infiltration rates and soil permeability to a greater degree. An established plant cover will serve to lessen the erosional effects of rainfall and deeper root penetration will improve soil stability and lessen the chances of widespread surficial slumping.

5.1.3 Potential Productivity of Amended Tailings Sand

In an attempt to identify possible productivity levels for engineered soils, Fedkenheuer (1980) has made a comparison between selected forest cover types growing under conditions similar to those found in the Athabasca oil sands area. Table 5.1-2 shows the level of soil chemical and physical factors associated with the forest cover types in these areas and an amended tailings sand site. The pH levels of the forest cover types range from 4.9 to 5.5 which are substantially below that recorded for the amended tailings sand site (7.1 to 7.5).

The range of the organic matter content for the amended tailings sand (3.8 to 6.5 percent) is markedly higher than that for the naturally occurring organic matter on the forest cover types (0.9 to 3.7 percent).

The range of available phosphates (21-34 ppm) and potassium (103-140 ppm) is approximately midway between the lower and upper limits of the ranges occurring on the forest cover types (P_2O_5 - 11 to 66 ppm; K_2O - 27 to 234 ppm).

The range of exchangeable calcium (8.77 to 13.99 mEq/100g) and magnesium (2.39 to 3.51 mEq/100g) on the amended material are generally much higher than those occurring on the forest cover types (Ca - 0.64 to 6.30 mEq/100g; Mg - 0.17 to 2.70 mEq/100g).

Table 5.1-2

Levels of soil chemical and physical factors in the surface 15 cm of selected forest cover types from Wisconsin (U.S.), Minnesota (U.S.) and the Athabasca oil sands and for the amended tailings sand

Forest Cover Type	Geographical Location	pH	Org. Matter (%)	Avail. P_2O_5 (ppm)	Avail. K_2O (ppm)	Exch. Ca	Exch. Mg	Bulk Density (g/cc)	Silt Plus Clay (%)	Avail. Moisture (% by wt.)
						me/100 g				
Pinus banksiana (a)	Wisc.	4.9	0.9	11	27	0.64	0.17	- (b)	7	-
Pinus banksiana (c)	Wisc.	5.1	1.8	31	40	1.33	0.26	-	9	-
Pinus banksiana (d)	Wisc.	5.2	1.5	35	46	1.44	0.33	-	10	-
Pinus banksiana (e)	Minn.	5.3	3.1	66	90	2.15	0.75	1.26	22	4.1
Pinus banksiana - *Populus tremuloides* (f)*	Atha.O.S.	5.5	1.5	-	154	2.37	0.80	-	13	-
Populus tremuloides	Minn.	5.0	3.7	55	102	1.90	0.68	1.13	34	7.5
Picea glauca - *Populus tremuloides* (f)*	Atha.O.S.	5.5	1.5	-	234	6.30	2.70	-	67	-
Amended tailings sand	Atha.O.S.	7.1-7.5	3.8-6.5	21-34	103-140	8.77-13.99	2.39-3.51	1.05-1.23	11-36	9.3-16.4

(from Fedkenheuer 1980)

(a) Wisconsin - Wilde *et al*. 1964, Site 45.
(b) No data.
(c) Wisconsin - Wilde *et al*. 1964, Site 53.
(d) Wisconsin - Wilde *et al*. 1968.
(e) Minnesota - Fedkenheuer 1975.
(f) Athabasca Oil Sands - Twardy 1978.

* Forest cover types designated by Fedkenheuer (1980)

The level of silt plus clay on the amended tailings sand (11 to 36 percent) compares favourably with the range occurring on the forest cover types (7 - 67 percent).

The range of available moisture for the amended tailings sand (9.3 to 16.4 percent by weight) is somewhat higher than the range recorded for the forest cover types (4.7 to 7.5 percent by weight).

The levels of soil chemical and physical properties used as an indicator of potential soil productivity (Table 5.1-2) show clearly that within a relatively short time period, irrespective of the treatment, the amended tailings sand material is as good as, if not better than, the native soils used in the comparison.

5.2 Plant Establishment

5.2.1 Plant Survival

Of the woody plant species highlighted in this report, a number have been planted on amended tailings sand sites at the Suncor Inc. and Syncrude Canada Ltd. operations at Fort McMurray, Alberta as part of their reclamation and research programs. Table 5.2-1 lists the percent survival rate of these plants for 1978 through 1981 plantings at Suncor Inc. and Table 5.2-2 lists the percent survival rate of these plants for assessments carried out in the falls of 1978 and 1979 at Syncrude Canada Ltd.

The results are extremely variable and it is difficult to identify those species which are most suited for planting on amended tailings sand sites. However, a number of species specific points can be made:

- Alnus crispa has shown consistently poor survival rates on both sites;

Table 5.2-1

Percent survival* of shrubs and trees planted on amended tailings sand in 1978, 1979, 1980, 1981 at the Suncor Inc., Fort McMurray operations**

Species / Year and extent of ground cover when planted	1978		1979		1980		1981	
	Dense	Sparse	Dense	Sparse	Dense	Sparse	Dense	Sparse
<u>Alnus</u> <u>crispa</u>	-	-	-	27 ± 6.00	3 ± 1.83	-	9 ± 6.72	13 ± 5.87
<u>Amelanchier</u> <u>alnifolia</u>	-	-	-	-	7 ± 3.00	71 ± 13.74	19 ± 5.33	27 ± 5.53
<u>Caragana</u> <u>arborescens</u>	-	-	63 ± 8.21	-	-	-	-	-
<u>Elaeagnus</u> <u>commutata</u>***	-	-	-	-	-	-	-	-
<u>Prunus</u> <u>pensylvanica</u>	-	-	-	-	13 ± 7.50	-	-	-
<u>Rosa</u> <u>acicularis/woodsii</u>	-	-	0	-	16 ± 6.30	-	19 ± 5.09	37 ± 8.16
<u>Salix</u> <u>bebbiana</u>***	-	-	-	-	-	-	-	-
<u>Shepherdia</u> <u>canadensis</u>	-	-	-	-	31 ± 7.41	-	16 ± 9.95	35 ± 8.22
<u>Picea</u> <u>glauca</u>	9 ± 4.05	-	14 ± 4.52	-	62 ± 6.47	24 ± 2.96	-	-
<u>Pinus</u> <u>banksiana</u>	-	-	-	-	80 ± 2.74	-	-	-
<u>Populus</u> <u>tremuloides</u>	-	-	-	4	-	-	22 ± 7.74	18 ± 1.34
Northwest Poplar	-	-	58 ± 7.74	2	17 ± 12.01	59 ± 7.22	26 ± 8.93	29 ± 7.51
Walker Poplar	-	-	70 ± 7.74	-	39 ± 15.26	59 ± 12.42	-	-

* assessments made in August, 1981; results are given as mean survival ± standard error of mean

(from Suncor 1981)

** tailings sand amended by mixing approximately 15 cm of muskeg soil (40% overburden clay/silt) into the surface 15 cm of sand

*** no data available

Table 5.2-2

Percent survival of native shrubs and trees planted on amended tailings sand when assessed in fall 1978 and 1979 at the Syncrude Canda Ltd., Fort McMurray operations

Species / Soil Amendment*	10 cm Native Sand**				10 cm Lean Tar Sand				10 cm Mineral Fines				20 cm Mineral Fines			
	Fert.		Unfert.		Fert.		Unfert.		Fert.		Unfert.		Fert.		Unfert.	
	78	79	78	79	78	79	78	79	78	79	78	79	78	79	78	79
Alnus crispa	44	11	0	11	22	0	44	44	11	22	22	44	0	0	22	0
Amelanchier alnifolia	78	78	89	78	89	67	100	89	100	89	100	78	100	78	89	56
Rosa acicularis	100	89	78	78	100	89	100	89	100	67	100	100	78	67	100	78
Shepherdia canadensis	89	0	42	11	100	11	100	33	78	0	89	33	89	11	100	33
Picea glauca	42	17	17	33	75	75	83	83	25	33	50	50	42	42	17	25
Pinus banksiana	83	58	92	58	83	83	75	92	58	17	50	67	8	8	33	33
Populus tremuloides	33	8	17	8	42	17	83	83	8	0	0	25	25	8	17	17

(from Fedkenheuer 1980)

* 15 cm of peat was placed over all plots prior to rotovating
** Fert. = Fertilized in 1978 and 1979. Unfert. = Not fertilized in 1978 or 1979

Note: Following assessment in the springs of 1978 and 1979, all dead plants were replaced with live plants. The spring planted material is included in the fall assessment

- at the Syncrude Canada Ltd. site, *Amelanchier alnifolia* and *Rosa acicularis* have shown the greatest ability to survive on all treatments. At the Suncor Inc. site, results for *A. alnifolia* are variable and for *R. acicularis* are poor;

- in terms of survival, *Shepherdia canadensis* has been extremely variable on the Syncrude Canada Ltd. site and has performed moderately to poorly at the Suncor Inc. site;

- of the tree species, survival rates of *Pinus banksiana* and the two poplar hybrids were consistently the highest;

- at Syncrude Canada Ltd., the highest survival rate of both shrubs and trees appears to be on the peat plus lean tar sand (unfertilized); and

- *Caragana arborescens*, although not considered a native species, is readily adaptable to a variety of conditions.

To assume that plants are established, if still alive, after the first or second growing season is incorrect. As some of the data in the literature indicate, a downward trend in plant survival for four or five seasons before a general levelling occurs is not uncommon (McKell and Van Epps 1980). Vegetation cannot be considered established and permanent until seedlings growing from seeds of transplanted woody plants or natural coppicing are observed. Even then, some reduction in plant populations can be expected if long periods of drought are experienced (Klym 1982 - personal communication).

Low moisture availability, as a result of the highly competitive grasses and legumes used in the initial erosion control ground cover and/or extended periods of drought, appears to be the major limiting factor to woody plant survival and establishment (Klym 1982 and Fung 1982 - personal communications). At Syncrude Canada Ltd. the high survival rate of both shrubs and trees on the peat plus lean tar sand (unfertilized) treatment (Table 5.2-2) has been attributed to the relatively low level of grass-legume herbage production of 410 kg/ha in 1978 and only 191 kg/ha in 1979 (Fedkenheuer 1980). Reduced ground cover means less competition for available moisture and nutrients as well as reduced rodent habitat. Similar results have been noted at the Suncor Inc. operations where survival is notably better on sites where reduced application rates of the initial erosion control groundcover have been made or where none was applied and the extent of ground cover is a result of the seed reservoir in the amendment material or natural invasion (Klym 1982 - personal communication).

Data reported by Syncrude Canada Ltd. indicate that in terms of survival, shrubs can generally be split into two groups (Fedkenheuer 1980). Those shrubs normally found on drier sites display the highest survival rates whereas those normally found on more mesic sites tend to perform poorly. Alnus crispa, normally found on dry sites with Pinus banksiana is the only exception. As indicated earlier, it has consistently performed poorly on a variety of sites. Information of this nature is extremely important when considering species selection for particular sites.

5.2.2 Plant Productivity

Little information, in the form of numerical data, is available on the productivity of the few woody plant species established on amended tailings sand sites. Fedkenheuer (1980), in comparing sites with conditions similar to those found in the Athabasca oil sands area has indicated growth rates and tree productivity which can be expected on amended tailings sand sites (Table 5.2-3) if the forest species used are matched to the site conditions. The height growth per year for stands of Populus tremuloides and Picea glauca in the Athabasca oil sands area was 35 cm and 24 cm, respectively. Basal area for the same species was 26 and 34 m^2/ha, respectively. The productivity per year, as measured by the average increase in basal area per hectare per year, for stands of P. tremuloides and P. glauca was 0.72 m^2/ha/yr and 0.37 m^2/ha/yr, respectively.

Table 5.2-3

Growth characteristics of selected forest cover types from Wisconsin (U.S.), Minnesota (U.S.) and the Athabasca oil sands

Forest Cover Type	Geographical Location	Trees (no./ha)	Ave. age (yrs)	Ave. Height (m)	Ht/Age (cm/yrs.)	Ave. Diam. (cm)	Basal Area (m^2/ha/yr)
Pinus banksiana (a)	Wisc.	3066	22	6.7	30	8.6	1.80
Pinus banksiana (b)	Wisc.	2908	24	9.2	38	10.4	2.53
Pinus banksiana (c)	Wisc.	2066	33	12.0	36	12.8	1.92
Pinus banksiana (d)	Minn.	2000	26	12.4	48	11.7	1.58
Populus tremuloides (d)	Minn.	1368	39	17.6	45	13.4	1.15
Populus tremuloides (e)	Atha.O.S.	- (f)	36	12.8	35	-	0.72
Picea glauca (e)	Atha.O.S.	-	92	22	24	-	0.37

(a) Wisconsin - Wilde _et al_. 1964, Site 45.
(b) Wisconsin - Wilde _et al_. 1964, Site 53.
(c) Wisconsin - Wilde _et al_. 1968.
(d) Minnesota - Fedkenheuer 1975.
(e) Athabasca Oil Sands - Peterson and Levinsohn 1977.
(f) No data.

(from Fedkenheuer 1980)

5.2.3 Plant Communities

Plant nutrient levels and physical factors of the amended tailings sand sites are considered more than adequate for the re-establishment of forest and other plant communities found on those areas to be disturbed (Fedkenheuer 1980).

As indicated in Section 2.0, Site Preparation, the potential exists for the disturbed areas to be reclaimed to grassland, jack pine and mixedwood communities. The following sub-sections identify the plant species that may inhabit these communities. Common native associates of many of the species highlighted in this report can be found in the Manual of Species Suitability for Reclamation in Alberta by Watson, Parker and Polster (1980).

5.2.3.1 Grasslands

These are invariably associated with the dike slopes. The continued existence of these areas over time is dependent upon artificially seeding the ground cover, the application of fertilizers and the removal of tree species invading the slopes from adjacent undisturbed areas (Monenco 1980). An alternative approach suggested by Monenco (1980) is to establish a temporary erosion control grass cover and then allow jack pine to invade and establish its own community.

5.2.3.2 Jack Pine

Stands of *Pinus banksiana* can be expected to develop in areas low in both moisture and nutrients. In sandy soils, it develops a deep, penetrating root system that imparts a certain measure of drought resistance to the plants (Monenco 1980). Thompson *et al.* (1978) indicated that jack pine understory communities are determined by drainage and other soil conditions. At either drainage extreme, growth is extremely slow (Cayford *et al.* 1976). Optimal growth conditions are found on loams, clay loams, aeolian deposits and well drained loamy sands (Monenco 1980; Sheldon and Bradshaw 1977). Glacial tills and silty sands will also support good growth (Stringer 1976).

The poorest jack pine sites tend to be open and devoid of tall shrubs and herbs (Monenco 1980) with an understory of lichens (Cladina spp.) and bearberry (Arctostaphylos uva-ursi) (Cayford et al. 1976). As conditions improve, species diversity increases within the communities. Bog cranberry (Vaccinium vitis-idaea) and blueberry (Vaccinium myrtilloides) may be present on intermediate jack pine sites. Other tree species may invade the area. Birch (Betula papyrifera) is often found in association with jack pine but if conditions are too dry, trembling aspen (Populus tremuloides) may replace the birch (Thompson et al. 1978). Areas where jack pine are flourishing can support a wide variety of woody plants. Besides those already mentioned, raspberry (Rubus idaeus), green alder (Alnus crispa), dogwood (Cornus stolonifera), roses (Rosa spp.), honeysuckle (Lonicera dioica) and currant (Ribes spp.) are often found in a jack pine community (Monenco 1980).

In undisturbed areas, the promotion and maintenance of jack pine stands is dependent upon the occurrence of fire. The proximity of the reclaimed areas to the oil extraction facilities will necessitate strict fire control regulations such that in time, the seral jack pine communities will pass through a series of successional stages culminating in the climax vegetation type for the area.

5.2.3.3 **Mixedwood Forests**

The principal coniferous and deciduous species in the Athabasca oil sands area are white spruce (Picea glauca) and aspen. A number of other trees are found on localized sites where suitable conditions exist. These include jack pine (Pinus banksiana), black spruce (Picea mariana), larch (Larix laricina), birch (Betula spp.), balsam poplar (Populus balsamifera) and balsam fir (Abies balsamea) (Thompson et al. 1978).

The diverse nature of the mixedwood forests is such that a wide variety of soil conditions are capable of supporting reasonable growth. Drainage is believed to be the determining factor as to the dominant tree species. On drier, well drained sites, white spruce is usually more evident while the wetter areas tend to support more aspen or birch (Thompson et al. 1978).

In mixedwood forests, species diversity is greatest in the coniferous dominated stands (Thompson et al. 1978). Understory diversity is determined by such factors as moisture availability, soils, nutrient availability, light, litter and root competition (Monenco, 1980). The dry areas may well encourage the growth of jack-pine and cranberry. As moisture levels increase, woody plant species such as alder and rose may invade the area. Willow (Salix spp.) tend to inhabit the moist, poorly drained areas (Rowe 1956).

The planting of a variety of woody plants on amended tailings sand sites represents a transitional stage in the development of mixedwood forest stands. Once established, it is expected that these plants will take an active role in the modification of soils, water balance and light penetration necessary to encourage the invasion of other species of the mixedwood forest type (Monenco 1980). The rate and extent of development of the mixedwood community is dependant, to a large degree, upon the level of competition existing between the woody transplants and the grass-legume ground cover.

SUMMARY

A number of studies designed to monitor the development of amended tailings sand as a soil and consequently its ability to support plant growth are being carried out by the two major operators in the oil sands area. Amendment materials include native sand, lean tarsand, mineral fines (from overburden material) and peat. Indications are that improvements obtained have been maintained for more than two growing seasons.

The pH levels of amended tailings sand on dike slopes have dropped from pH 8.5 to pH 6.5 over a five year period, indicating a low buffering capacity due in part to the low cation exchange capacity (CEC) and the rapid leaching of cations present. Incorporation of mineral fines and organic matter into the surface layer (15 cm) appears to stabilize pH levels.

Electrical conductivity is substantially below the 4.00 mS/cm level normally considered as an indicator of potential salt damage.

The sodium adsorption ratio (SAR) value for all treatments are below 2.0. An SAR value of 6.0 indicates the point at which the physical properties of the soil may be seriously affected.

The CEC of tailings sand is approximately 2.35 mEq/100 g. All treatments have resulted in CEC levels in excess of the 7.0 to 10.0 mEq/100 g level considered suitable for tree nurseries.

The exchangeable sodium level on all amended sites are significantly below the 2.0 to 3.0 mEq/100 g level considered detrimental to plant growth.

Exchangeable potassium, calcium and magnesium levels are all in excess of the recommended levels for plantations of *Pinus banksiana* and *Picea glauca*.

The addition of all amendments to the tailings sand has significantly increased the percent of total nitrogen from 0.01 percent to a range of 0.15 to 0.19 percent.

In the surface, 15 cm of an average soil, C/N ratios of 10:1 to 12:1 can be expected. Initially, on amended tailings sites, ratios of 21:1 to 33:1 were recorded. Within two growing seasons these same levels had decreased to 13:1 and 24:1, respectively.

Reductions have also been recorded in organic matter content levels. In 1977, a range of 5.5 percent to 8.7 percent existed; these same levels have since dropped to 5.0 percent to 6.5 percent, respectively. It is expected that these levels will stabilize as the reclaimed areas become more established.

Following amendments, and the initial fertilizer application, the available phosphorous level rose from 11 ppm to a high of 47 ppm in one of the treatments. These levels dropped dramatically to fall within the range recommended for stands of Pinus banksiana and Picea glauca.

Over time, moisture holding capacity, bulk density and erodibility are the physical characteristics most likely to change in amended material. The addition of all types of amendments increases the moisture content at both the field capacity (0.1 bar) and permanent wilting point (15 bars) level. Soil textures change from the characteristic sand of tailings sand to loamy sands or sandy loams depending upon the treatment.

The bulk density of tailings sand is approximately 1.6 g/cm^3. Following the addition of amendments, the level drops to approximately 1.0 g/cm^3. Indications are that as vegetation establishes itself, the natural build-up of organic matter in the developing soil will lead to further reductions in the bulk density level. A bulk density greater than 1.75 g/cm^3 for sand is considered detrimental to root penetration.

An increase in organic matter coupled with the improved structural characteristics will improve and control infiltration rates and soil permeability. An established plant cover will reduce the erosional effects of rainfall and deeper root penetration will lessen the chances of widespread surficial slumping, particularly on slopes.

A comparison between selected forest cover types growing under conditions similar to those found in the Athabasca oil sands area show that when soil chemical and physical properties are used as an indicator of potential soil productivity, the amended tailings sand is as good as, if not better than, the native soils. Plant nutrient levels and physical factors of the amended tailings sand sites are considered more than adequate for the re-establishment of forest and other plant communities found on those areas to be disturbed. Of the species highlighted in this report, a number are currently being grown on amended tailings sand sites in the Fort McMurray area. The results to date are extremely variable and it is most difficult to identify those species most suited for use in reclamation.

Low moisture availability, as a result of the competitive nature of the grasses and legumes used in the initial erosion control ground cover and/or extended periods of drought, appears to be the major limiting factor to woody plant survival and establishment.

The planting of a variety of woody plants on amended tailings sand sites represents a transitional stage in the development of mixedwood forests. Once established it is expected that these plants will take an active role in the modification of soils, water balance and light penetration necessary to encourage the invasion of other species of the mixedwood forest type. The rate of development of the mixedwood community is dependent upon the level of competition between the woody transplants and the grass-legume ground cover.

6.0 RECOMMENDATIONS FOR FURTHER STUDIES

The review of available literature on woody plant establishment on amended tailings sand site, as well as observations made in the field at two operational oil sands facilities, have indicated certain areas where new or additional information is required that would greatly enhance the possibility of successful establishment of woody plants. The purpose of this section is to identify and briefly outline those areas where further studies are necessary.

6.1 Species Selection

Continued evaluation of shrub and tree species for their suitability in reclamation is recommended. The variability, in terms of survival and establishment, of those species currently in use is an indication that before a plant's adaptability and suitability to 'engineered' soils can be confirmed, field trials over a five to 10 year period are necessary. Although a number of the woody plant species being used have demonstrated an ability to survive (and in some cases to establish themselves), other plant alternatives should be considered, in particular those species which demonstrate an ability to compete with grasses and legumes or are drought tolerant. Species selection should also address the suitability of the plant material for the desired end land use, in particular its potential as wildlife habitat.

Re-assessment of some species selected, particularly Populus spp. and Salix spp., should be made. These particular plants have been classed as water-wasting plants in arid regions (USDA 1972). When grown in close proximity to other woody plants, their phreatophytic nature may compound the problem of moisture availability to these plants.

Recent studies by Malloch and Malloch (1982) on the mycorrhizal status of boreal plants has indicated that there are a number of species of several plant genera that display an association with either ecto- and/or endo-mycorrhizal fungi. Further work is recommended to determine the potential for mycorrhizal association with the woody plants used in the reclamation of amended tailings sands sites.

6.2 Availability and Production of Suitable Planting Stock

During species selection, consideration should always be given to the availability of planting stock. Some species, although considered site suitable, may be difficult to propagate in quantity because of poor seed supply or variable propagation performance (Techman Engineering Ltd. 1982; Novlesky 1982 - personal communication). Identification of suitable seed and vegetative material sources should be documented.

The survival of transplants in the field is dependent in part on the size and quality of the material used. Greenhouse and field trials should be continued to determine what constitutes desirable planting stock and what production methods are necessary to achieve this end. In order to accurately evaluate planting stock quality, the desirable morphological and physiological characteristics of the individual species should be determined.

Although considerable work has been done on the genetic improvement of agricultural crops, little has been accomplished with native woody plants. Among natural populations, variation occurs from location to location in characteristics such as germination and growth habits, growth rate and productivity, palatability and nutritional values, disease resistance, insect susceptibility, and drought, cold and fire tolerance (USDA 1972). Further work is necessary to determine the range of these characteristics before site-matched stock can be developed through selection within species or by species hybridization.

6.3 Site Preparation

6.3.1 Amendment Materials

Further research is recommended in the use of peat as an organic matter substitute in soil reconstruction. Although the use of peat as a tailings sand amendment is an integral part of the soil reconstruction process, little is known about its functional role in terms of its use as an interim substitute for soil organic matter. Further work is required in delineating the physical, chemical and biological characteristics of peat, and how these equate with those of naturally occurring organic matter in forest soils.

6.3.2 Amendment Materials Handling

The amendment materials, prior to incorporation, are usually stockpiled near to the area to be reclaimed. Little information is available as to the physical, chemical and biological changes that these materials may undergo while in storage. Studies have shown that the muskeg material can be a valuable seed reservoir such that when incorporated into the tailings sand, a ground cover quickly establishes, particularly when an initial grass-legume erosion control ground cover is not used. Continued assessment of stockpiling techniques is recommended in order to identify the handling procedures necessary to mitigate the impacts on the physical, chemical and biological integrity of the materials prior to their use as an amendment.

6.3.3 Materials Mixing

The quantity of amendment material used and the depth and uniformity of incorporation into the tailings sand are critical in terms of woody plant survival. The penetration of roots into the tailings sand material appears to be affected by the extent of mixing at the amendment/tailings sand interface. The more distinct the boundary the less penetration occurs. Further work is required to identify both the amount of amendment to be spread over the tailings sand and how and to what depth it should be incorporated for the desired vegetation cover.

6.4 Planting Alternatives

The reclamation procedures of establishing an erosion control ground cover and planting woody plants on the same site do not appear to be compatible as the vigorous growth of the ground cover material is known to have a detrimental effect on the level of growth and establishment of woody plants. In areas where productive forests have been identified as the end land use, more extensive field work is necessary to identify a reclamation management approach which will ensure an acceptable level of erosion control but at the same time minimize the effects of moisture and nutrient competition created by the highly competitive nature of grasses and legumes.

In areas where erosion control ground covers are artificially established, either prior to or at the same time as shrub and tree planting, further work is required in the areas of:

- seed mixture composition and rate of sowing;
- formulation and rate of initial fertilizer applications; and
- feasibility of scarification and strip-seeding as a means of creating open planting sites;

Indications are that an efficient but non-competitve form of ground cover can establish itself from the amendment materials incorporated into the tailings sand. This option should be investigated with comparison studies between artificial and naturally established ground covers on amended tailings sand sites.

6.5 Planting Techniques

6.5.1 Direct-Seeding

Although only limited success with regard to shrub establishment has been achieved with direct-seeding on amended tailings sand sites, the potential for establishment still exists. Rather than seeding a composite mixture of grasses, herbs, shrubs and trees at one time, as is normally done, the direct seeding of woody plants in strips or patches may be more successful. Field trials should be initiated to test this approach.

6.5.2 Transplanting

There are differing schools of thought on the use of container-grown and bareroot stock in a reclamation setting. The advantages of one over the other tend to focus on the economics of the operation in terms of handling and the potential for mechanical planting, with little attention being given to a plant's 'establishment growth pattern'. More growth chamber and field trials are necessary to monitor and compare the performance, particularly that of root system development, between container-grown and bareroot stock planted in amended tailings sand.

Planting into established ground cover material is sometimes necessary, particularly on sloped areas where it is essential that an erosion control ground cover be established quickly. The amount of scarification carried out is usually sufficient to facilitate planting but may be inadequate to reduce subsequent competition from grasses and legumes. Further field work is required to identify the minimum ground cover-free area around individual woody plants which will enhance plant establishment and to identify the most efficient and economic way this can be achieved.

Time of transplanting is a critical area where further work is necessary. More emphasis should be placed on determining the extremes of soil conditions, in terms of moisture availability and temperature, that transplants can be subjected to before survival is threatened. Collection of on-site meteorological and soil analysis data over time would indicate the optimum planting time(s) available, and these could be tested with a number of field trials.

The planting pattern, or mosaic, is an area about which there is little information. Studies should be designed and implemented which would demonstrate the intermixing and spacing of tree and shrubs species necessary to promote a balanced tree and shrub canopy that would lead to the establishment of a maintenance-free forest community.

6.6 Post-Planting Management Techniques

6.6.1 Control of Competition

Subsequent to planting, control of competitive grasses and legumes is extremely difficult, except perhaps on a small site-specific level. A series of field trials involving possible herbicidal control, scarification, reduced fertilizer applications or various forms of mulching are necessary to identify control measures that can be applied effectively over large areas.

6.6.2 Maintenance of Soil Fertility

Current use of fertilizers has tended to benefit the erosion control ground cover at the expense of woody species planted in the same area. More work is necessary to determine the specific nutrient requirements for these plants, particularly the shrubs, in order that the nutrient status of the soil can be adjusted and maintained at a level that is more beneficial to woody plant growth. Suitable placement techniques of fertilizers warrants further study.

Studies on soil fertility should be designed to identify the minimum nutrient levels required for optimal plant growth in order that the plants do not become reliant upon continual fertilizer applications, as the intent is to establish a forest community that is completely self-sustaining. Studies to observe the effects of nitrogenous fertilizer applications on the level of mycorrhizal development on woody plants are also recommended.

6.6.3 Maintenance of Soil Moisture

The three to four years following planting is the period during which competition for moisture availability appears to be the most intense. The use of mulches, in particular various designs of condensation traps, should be examined in the field during this critical period as their design not only maintains and supplements available moisture levels, but also helps to control herbaceous growth adjacent to the individual plants.

Although conventional irrigation systems are not considered feasible, they may represent the only means available that will ensure survival and enhance establishment during the initial stages of reclamation. A small, pilot scheme incorporating a drip irrigation system might well demonstrate the long term economic advantage of irrigation on amended tailings sand sites.

6.6.4 Erosion Control

In order to establish a system of erosion control management that can identify areas that are susceptible to erosion, a series of field and laboratory studies are recommended that would determine the rate of sediment loss for a given rainfall intensity on specific sites with varying amounts of ground cover.

In addition, methods of dealing quickly and efficiently with erosion problems on amended tailings sand sites should be reviewed and recommendations made for specific site conditions.

6.6.5 Control of Small Mammal Damage

Continued research is necessary to develop effective small rodent control measures, particularly in reclaimed areas with a dense grass-legume ground cover. A variety of control measures designed to reduce the density of the ground cover might include selective ploughing and burning of ground cover, herbicidal control or a reduction in fertilizer applications.

It has been suggested that girdling of woody plants by small rodents, particularly during the winter months, can be attributed to the nutritional stress the animals are under. Further work is necessary to determine the feeding habits and dietary demands of small rodents at different times of the year so that effective control measures can be developed.

6.7 Plant-Soil Water Relationships

In order to accurately predict vegetation productivity or performance, extensive field and growth chamber studies are necessary to provide an understanding of the plant-soil moisture relations in amended tailings sands. Little is known about moisture retention and the movement of water in tailings sand, particularly at moisture levels between field capacity and the permanent wilting point.

6.8 Reclamation Performance Monitoring

Continued monitoring of all reclaimed sites is recommended as this is the only way that an effective reclamation management program for tailings sand sites can be developed. This program should be all encompassing and monitor:

- soil development; and
- woody plant establishment.

6.8.1 Soil Development

Field and laboratory soil analyses should be designed to monitor the development of the soil complex in terms of its physical, chemical and biological characteristics. Particular attention should be paid to the development of a stable organic matter content as it is this component above all others which will decide the time at which the reclaimed areas can be considered self-sustaining.

Chemical analyses will indicate whether fertilizer applications are necessary, and if so, the formulations and rates required to enhance the growth of the desired plant species. In this way, the competitive effects of the grasses and legumes can be reduced.

A series of soil profile pits would indicate the extent of root development and the level of peat degradation occurring in the reclaimed areas. Of particular concern is the amount of root penetration into the tailings sand material directly below the amended layer.

6.8.2 Woody Plant Survival and Establishment

Regular monitoring of new transplants, particularly over the three to four year period following planting, would allow for the early identification of factors affecting the survival rate of woody plants. Of particular concern is the availability of moisture to these plants which is affected primarily by the presence of competitive grass and legume species. Monitoring of the changes in floristic composition of the ground cover material would be a means of determining the presence and rate of spread of those species considered unsuitable and would allow remedial measures to be developed to reduce the level of competition.

Not only does the established ground cover affect the availability of moisture to the woody plants but it also serves as a habitat for small rodents. In areas where a dense grass-legume ground cover has been established, losses of many plants have been attributed to rodent damage (girdling). A monitoring program designed to identify the behavioural patterns of small rodents and rodent population cycling would be extremely useful. Planting trees and shrubs during periods when small rodent populations are at the low point of their cycle, in combination with some form of ground cover modification, might prove to be an effective but relatively inexpensive form of control.

Monitoring of rodent damage would also allow for early identification of other mammal damage to trees and shrubs. Of particular concern is the expected increase in snowshoe hare and ungulate browsing as the tree and shrub canopy develops.

Little documented information is available on the effects of insects and diseases on transplants on amended tailings sand sites. A continuous monitoring program designed to identify the infesting species, the damage they cause and their rate of spread is needed before any control measures can be developed.

A long term monitoring program is necessary to quantify the level and rate of plant productivity and establishment as a result of specific management practices, particularly those involving the maintenance of soil moisture and fertility. Measurements of plant height, increase in stem diameter, shoot development, leaf size and seed production would be useful in determining acceptable levels of plant productivity. Studies designed to monitor the changes in floristic composition should be able to determine the level of establishment occurring on various sites.

An understanding of the reproductive ecology of woody plant species is essential to the understanding of ecosystem recovery following disturbance. A field study designed to provide species specific information on the nature and extent of developing shrub and tree clones on amended tailings sand sites is recommended. This study should determine the ability of underground parts to produce new shoots and roots and the conditions under which this occurs, and the seed dormancy pattern and germination requirements where applicable.

SUMMARY

The review of available literature on woody plant establishment on amended tailings sand sites, as well as observation made in the field, have indicated areas where new or additional information is required. These areas include:

- continued evaluation of woody plant species for their suitability in reclamation;
- availability and production of suitable planting stock;
- site preparation, including amendment materials and their handling;
- planting alternatives;
- planting techniques;
- post-planting management techniques; and
- reclamation performance monitoring.

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GLOSSARY

Agriform tablets: Fertilizer tablets used for root-zone feeding of new or established plants. They have an N-P-K formulation of 20-10-5 and last for up to two years.

amendments: A variety of materials incorporated into the tailings sand as a means of creating a suitable growth medium. These materials include overburden and peat.

bareroot stock: Plant material grown outdoors in nursery beds; when lifted, prior to storage and/or transplanting, soil is removed and roots are exposed. Usually stored and/or transported to the field in plastic bags.

Bracke cultivator scarifier/seeder: Machine designed to create a patch type of scarification over rough ground which provides microsites suitable for planting or seeding.

brushland plow: A heavy duty disc plough designed for use where large rocks would damage a standard disc plough. Used for breaking up overburden and on-site mixing of materials.

chlorosis: A condition in plants marked by yellowing or blanching.

container-grown stock: Planting material grown in containers under greenhouse conditions and then hardened prior to planting.

cyclone seeder: A seeder which scatters seed directly on to soil surface without any soil coverage. Handheld, tractor mounted or helicopter slung models are available. Ideal for small areas (hand-held) or areas with limited access (helicopter-slung). Tends to distribute seed unevenly, and where seed mixtures are used, segregation of seed by weight occurs in those models without agitators.

dibble: Sharpened wooden peg used to create a planting hole. More suited to planting containerized stock.

dryland sodder: Modified front-end loader bucket designed to recover and preserve topsoil structure and vegetation cover, when transporting to a new planting site.

engineered soils: Growth medium created by incorporating amend-ment materials into the tailings sand.

established plant: A plant showing both visible signs of growth and the ability to reproduce its own kind, indicated by the presence of seedlings or natural coppicing.

hardening: Process of acclimatizing container-grown plant material to unfavourable environmental conditions.

hydrophobic: Lacking affinity for water.

hydroseeders: Truck or trailer mounted seeder used for the application of seed, fertilizer and soil amendments in a hydraulic spray or slurry. Provides a method of seeding steep, inaccessible slopes. Germination of some seeds is reduced due to the damage caused by the mixing systems incorporated into the machine. Slurries containing both fertilizer and seed can reduce the effectiveness of inoculating bacteria for legumes.

girdling: Removal of a ring of bark and cambium around a woody plant stem that interrupts the flow of water and nutrients, usually resulting in death of the affected plant.

introduced species: Plant material introduced and not indigenous to the area.

Klodbuster: Used to prepare steep slopes for seeding; the prime mover operates from the terrace above the slope. Can also be used to round tops of slopes, erase erosion scars, fill ruts and gullies and remove growth from embankments. The prepared surface is especially suited for broadcast and hydraulic seeding. Not effective on slopes less than 20 percent or at speeds less than 8 km/h. Slopes must be terraced if over 15 m high.

klx: Unit used for measuring light intensity; the basic unit is the lux (lx).

Land Imprinter: A long, steel cylinder with strips of angle iron welded to it. Used during seedbed preparation to compact the soil, as a means of creating microsites prior to seeding and planting, and as an erosion control measure.

Mara Planter: Machine capable of planting tree seedlings in open swamps and wet fields.

mattock: A digging and grubbing implement with features of an adz, axe and pick.

mineral fines: The clay, silt or sand found in the overburden material.

mulches: Any protective covering spread or placed over the soil to reduce evaporation, maintain even soil temperatures, prevent erosion, maintain or supplement soil moisture levels, or control weed growth.

native species: Plant material indigenous to the area.

natural coppicing: The development of a tree or shrub stand originating mainly from stolonic or rhizomatous growth.

outplanting: The act of planting bareroot and container grown stock in the field.

overburden: The coarse textured glacial-fluvial and glacio-lacustrine materials overlying an economically mineable resource.

phreatophyte: A plant with a deep, widespreading root system that successfully competes with other species for water.

Pottiputki: Manually operated planting tube designed to plant containerized tree seedlings. Plants seedlings upright rather than slanted, as can happen when a mattock or shovel are used. Does not function effectively on bare soil where stones or boulders are present. Difficult to use in wet heavy soils.

precocious germination: Germination of seeds in conditions where germination would not normally be expected.

rangeland drill: Heavy duty seed drill, especially suited for rocky, rough terrain. Mechanically plants a variety of seed types with or without previous seedbed preparation; able to break up compaction. Limited to use on moderate slopes.

rejuvenation: Increasing tree and shrub stand density through natural coppicing or seed dispersal and germination.

root egress: Root material growing out of the slits or holes of containers used in container-grown stock production.

root plug: Term used to describe the root mass of a container-grown plant. Is usually a dense inter-wined mass of roots and growth medium.

scarification: The physical disturbance of established ground-cover material as a means of creating microsites suitable for seeding or planting.

seed dribbler: Broadcasts seed and provides soil coverage in one operation. Designed to be mounted on the deck of a tracked tractor, one dribbler over each track. Seed is metered onto pad at a point over the front idler; as the tractor moves forward, the seed drops onto the soil surface and is imbedded by the tracks. Can cause compaction of seedbed; possibility of seed damage and incomplete coverage.

seeder/scalper: Dual purpose machine designed to remove existing vegetation and seed the cleared area in one operation.

steep slope tree/ shrub planter: Planter designed to plant containerized stock up to 210 cm long on steep slopes up to 1:1. Machine digs hole with auger, then uses a short, high velocity blast of water to propel the seedlings down the drop tube into the hole. A hydraulic cylinder then compacts soil around the seedling. May not be commercially available.

surviving plant: A plant showing any visible signs of growth, such as bud swelling, leaf expansion, stem extension.

tailings sand: The material coming from an oil sands extraction plant following the separation of oil from the lean tar sand. Not to be confused with native sands which are naturally occurring sand deposits.

Thiram: An organic compound used as a fungicide and animal repellant.

Warfarin: An anti-coagulant rodenticide.

APPENDIX A

Growth Conditions for the Production of Selected Species

This appendix contains, in part, details of the growth conditions and procedures used for the container and bareroot production of some of the species highlighted in this report. The information was provided by Syncrude Canada Ltd., Edmonton and the PFRA Tree Nursery at Indian Head, Saskatchewan.

GREENHOUSE/SHADEHOUSE CULTURAL PRACTICES

SEASON	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GROWTH STAGE		GERM; JUVENILE GROWTH	EXPO. GROWTH	BUD SET H'DNG.	COLD H'DNG; MAINTAIN DORMANCY			
DAY TEMP. °C		25; 23	23	18	AMBIENT ⟷ 2			
NIGHT TEMP. °C		25; 18	18	13	AMBIENT ⟷ 2			
RELATIVE HUMIDITY %		>90; 50	50	50	NORMAL ATMOSPHERE			
DAYLIGHT		SHADECLOTH 47%						
SUPPLEMENTARY LIGHT		NONE						
CO2 LEVEL		NORMAL ATMOSPHERE						
WATER		AS REQD; 10 MIN.PRIOR TO FERTILIZATION		DRY; AS REQUIRED		GOOD SOAKING PRIOR TO FREEZE UP		
FERTILIZER		10.52.10 @ 80 PPM N MWF	20.20.20 @ 60ppm N MWF	NONE; 10.52.10 @ 80ppm N TF	44-104-105 5% Fe ONCE PER WEEK	DISCONTINUE		
OPERATIONS	STRAT.SEED, ASSEMBLE CONTAIN., MIX SOIL	SOW SEED, COVER WITH PLASTIC, REMOVE PLASTIC.; THIN, TRANSPLANT, RESEED, PRUNE	MOVE TO SHADEHOUSE, PLACE ON PALLETS, MAINTAIN DRY SPOTS		DRAIN IRRIGATION LINES DAILY. REMOVE SHADE SCREEN			
			WEED INSECT CONTROL		INSULATE CONTAINERS WITH STYROFOAM			

SYNCRUDE CANADA LTD. (1983)

GREENHOUSE/SHADEHOUSE CULTURAL PRACTICES

SEASON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GROWTH STAGE		GERM.	JUV. GROWTH	EXPONEN GROWTH	BUD SET HARDENING / COLD H'DNG.	MULTIPLE FLUSHING		NATURAL HARDENING				
DAY TEMP. °C		25	23	23	18 / AMB ←+2							
NIGHT TEMP. °C		25	18	18	13 / AMB ←+2							
RELATIVE HUMIDITY %		90	50	50	50 / 50	NORMAL ATMOSPHERE						
DAYLIGHT			NATURAL		SHADE-CLOTH 47%							
SUPPLEMENTARY LIGHT		22 hrs/d - 18 hrs/d			NONE							
CO2 LEVEL		NORMAL ATMOSPHERE										
WATER		AS REQ'D	10 MIN. PRIOR TO FERTILIZATION		DRY	AS REQUIRED			GOOD SOAKING PRIOR TO FREEZE UP			
FERTILIZER			10-52-10 @ 80 ppm N MWF	20-20-20 @ 100ppm N MWF	NONE / 10-52-10 @ 80 PPM N MWF	20-20-20 @ 60 PPM N F		10-52-10 @ 80 PPM N T F	44-104-150 5% Fe Once per week	Discontinue		
OPERATIONS	ASSEMBLE CONTAIN, MIX SOIL, STRAT. SEED	SOW SEED, COVER WITH PLASTIC	THIN, TRANSPL, RESEED	ADJ. TIME CLOCKS	ERECT SHADE COVERING	MOVE TO S'HOUSE, PLACE ON PALLETS	PRUNE, WEED	DRAIN IRRIG. LINES DAILY. REMOVE SHADE COVERING				
			FUNGICIDE APPLICATIONS (to APR)		MAINTAIN DRY SPOTS (to JUL)			INSULATE CONTAINERS WITH STYROFOAM (to DEC)				

SYNCRUDE CANADA LTD. (1983)

Production Characteristics / Species	Alnus crispa	Amelanchier alnifolia	Caragana arborescens	Elaeagnus commutata	Prunus pensylvanica	Rosa woodsii/acicularis	Salix bebbiana	Shepherdia canadensis	Picea glauca	Pinus banksiana	Populus tremuloides	Populus X 'Walker Hybrid'	Populus X 'North West Hybrid'
SEED HANDLING Date collected; storage conditions		Collected late July or early August. Stored in sealed poly bags at -18° C. Seed should have less than 10% moisture content	Collected late July or early August as soon as fruit ripens. Stored in sealed poly bags at -18° C. Seed should have less than 10% moisture content	Collected from mid September to mid October. Seed cleaned by maceration and floating off pulp. Stored at -18° C in sealed poly bags	Collected in August. Seed cleaned by maceration and floating off pulp. Stored at -0° C in sealed containers	Collect seed in August. Seed cleaned by maceration and floating off pulp. Can be stored for 5 years dry at 0° C in sealed containers	Collect seed from May to June. Can be stored for 30 days at 0° C. Viability decreases rapidly with age	Collect seed in late August to early September, when moisture content is less than 13%. Seed cleaned by maceration and floating off pulp	Cones ripen from August 15 to September 15. Cones should be harvested promptly when ripe		Seed should be collected from early to mid June	Collect seed in late June. Separate seed from fluff using a vacuum cleaner. Storage life is minimal	
Stratification and/or other pretreatments		120 days at 5°C in sand with 10% moisture	Minimal stratification requirements, however, 30 days at 5° C will enhance germination	45 days at 5° C in sand media with 10% moisture.	Stratify 60 days at 20° C followed by 120 days at 5° C in sand media with 10% moisture	Stratify for 30 days at 5° C in sand with 10% moisture content	None necessary	Dip seed in concentrated H_2SO_4 for 15 minutes then stratify for 30 days at 5° C in sand with 10% moisture content	Stratify for 90 days at 5° C		No stratification required	No stratification required	No stratification required
CULTURAL PRACTICES Seed sown in field - date, density, technique		Sown early October in seed beds. 25 seeds/foot and 1/4" deep. Seed with fabricated shrub seeder	Sown mid June in fields. 45 seeds/foot, 1/2" deep. Sown with fabricated nursery seeder	Sow non-stratified seed in October in seed beds Depth 1 - 5 cm	Sow non-stratified seed in the fall	Sow non-stratified seed in the fall. Sow stratified seed in the spring. Depth: 0.5 - 2 cm	Sow as soon as seed is collected	Sow non-stratified seed in late October. Depth: 0.5 - 1 cm	Sow non-stratified seed in October. Depth: 0.5 cm Seven row beds		Broadcase seed as soon as extracted from fluff. Rate: 100 seeds/sq. foot. Cover seedbed with snowfence and place burlap on snowfence. Keep burlap moist until germination is complete	Broadcast seed as soon as extracted from fluff. Rate: 100 seeds/sq. foot. Cover seedbed with snowfence and place burlap on snowfence. Keep burlap moist until germination is complete	Broadcast seed as soon as extracted from fluff. Rate: 100 seeds/sq. foot. Cover seedbed with snowfence and place burlap on snowfence. Keep burlap moist until germination is complete
Seed bed preparation		Seedbed is rotovated. Mylone applied 1 month prior to seeding. Beds are formed at time of Mylone application	Fields are worked prior to seeding	Field is rotovated. Beds are formed one month prior to seeding				Field is rotovated. Beds are formed 30 days prior to seeding at time of Mylone application	Beds are formed 30 days prior to seeding at time of Mylone application. Boards are placed along side of beds. Beds seeded, covered with a shallow layer of silica sand and covered with snow fence				
Seed sown in greenhouse - date, medium, technique, etc.		Sown by hand in Spencer-Lemaire (Tinus) containers. Media: 5:1 peat moss/vermiculite; sown in November. Nutrient solution of N,P,K, Ca and Mg											
Transplanting - date, technique, etc.									Seedlings are transplanted in the spring after two growing seasons. Transplanting done with a mechanical transplanter				
Irrigation/fertilizer application		No fertilizer. Irrigated when needed ie. when soil moisture is less than 50% field capacity	No fertilizer. Irrigate immediately following seeding and subsequently as required	No fertilizer. Irrigation as required ie. when soil moisture is less than 50% field capacity				No fertilizer. Irrigation as required ie. when soil moisture is less than 50% field capacity	Nitrogen fertilizer is applied to seedbeds throughout the growing season. Irrigation as required		No fertilization. Light irrigation until germinated then irrigate as required	No fertilization. Light irrigation until germinated then irrigate as required	No fertilization. Light irrigation until germinated then irrigate as required
Root and/or top pruning		None											
Pest control - weeds, insects, diseases		Greenhouse mites	Chloroxuron applied at 5.6 kg/ha immediately following seeding	Mylone applied (278 kg/ha) one month prior to seeding for disease and weed control				Mylone (Dazomet) at 278 kg/ha is applied 30 days prior to seeding for disease and weed control	Mylone (278 kg/ha) is applied 30 days prior to seeding. Immediately following transplanting Linuron (2.2 kg/ha) is applied followed by irrigation (2.5 cm).		Mylone (Dazomet) is applied to beds 30 days prior to sowing for disease and weed control	Mylone (Dazomet) is applied to beds 30 days prior to sowing for disease and weed control	Mylone (Dazomet) is applied to beds 30 days prior to sowing for disease and weed control
HARVESTING Time of year		Harvest in October after two growing seasons	Harvest in October after two growing seasons. Harvest when leaves have dropped	Harvested in fall after leaf drop				October after leaves have dropped	Harvested in fall or spring depending on weather conditions. Fall harvest begins in October		Harvest in fall following leaf drop	Harvest in fall following leaf drop	Harvest in fall following leaf drop
Technique		Seedlings are top pruned to a height of 30 cm prior to harvesting	Seedlings are top pruned to a height of 30 cm prior to harvesting	Seedlings are top pruned to a height of 30 cm prior to harvesting				Seedlings are top pruned to 30 cm prior to harvest			Seedings are pruned to 30 cm prior to harvest	Seedlings are top pruned to 30 cm prior to harvest	Seedlings are top pruned to 30 cm prior to harvest
Handling and storage		Seedlings are culled and bundled, then placed in storage (-2° C) or heeled-in outdoors	Seedlings are culled and bundled, then placed in storage (-2° C) or heeled-in outdoors	Seedlings are culled and bundled, then placed in storage (-2° C) or heeled-in outdoors				Seedlings are culled bundled, then placed in storage (-2° C) or heeled-in outdoors			Seedlings are culled and bundled, then placed in storage (-2° C) or heeled in outdoors	Seedlings are culled and bundled, then placed in storage (-2° C) or heeled-in outdoors	Seedlings are culled and bundled, then placed in storage (-2° C) or heeled-in outdoors
Shipment		Shipped in spring. Packed in peat moss and bundled	Shipped in spring. Packed in peat moss and bundled	Shipped in spring. Packed in peat moss and bundled				Shipped in spring. Packed in peat moss and bundled	Shipped in spring. Packed in peat moss and bundled				
PLANT CHARACTERISTICS Age when harvested		Harvested after two growing seasons	Harvested after two growing seasons	Harvested after one or two growing seasons depending on growth					Harvested after two growing seasons in the seedbed and two growing seasons in the transplant fields		Harvested after two growing seasons	Harvested after two growing seasons	Harvested after two growing seasons

(Information provided by PFRA Tree Nursery, Indian Head, Saskatchewan 1983)

Bareroot Plant Production - From Cuttings

Species / Production Characteristics	*Alnus crispa*	*Amelanchier alnifolia*	*Caragana arborescens*	*Elaeagnus commutata*	*Prunus pensylvanica*	*Rosa woodsii/acicularis*	*Salix bebbiana*	*Shepherdia canadensis*	*Picea glauca*	*Pinus banksiana*	*Populus tremuloides*	Populus X 'Walker Hybrid'	Populus X 'North West Hybrid'
CUTTING COLLECTION Source and date taken							Cutting culture of Willows is same as outlined for Poplar hybrids					Popular whips are obtained from nursery stooling beds in December. The whips are divided into 15 cm cuttings (1 and 2 cm diameter) then dipped in a Captan solution prior to being placed in storage	
Age of wood and storage (if any)												Cuttings are stored in poly-lined bins at -1° C	
CULTURAL PRACTICES Date of insertion												Planting of cuttings done in late May	
Cutting preparation (including any treatment)												Cutting beds are rotovated prior to planting	
Cutting bed preparation and planting												Cuttings are planted using a mechanical planter. They are planted so that the top of the cutting is flush with the soil surface; spacing is approximately 1.5 cm	
Irrigation and fertilizer application												Cutting fields are irrigated immediately after planting and regularly during the growing season. Moisture requirements are especially high when leaves first emerge	
Root and/or top pruning												Seedlings are top pruned to 25 cm prior to harvesting to facilitate mechanical harvesting	
Pest and disease control												Fields are sprayed with Linuron (2.2 kg/ha) immediately after planting for weed control. Cottonwood leaf beetle can be a problem causing leaf defoliation; control is with Dimethoate 10.5 ml/L active ingredient	
HARVESTING Time of year												Harvesting is done in October after leaf drop	
Technique												Seedlings are top pruned to 25 cm then harvested mechanically	
Handling and storage												Seedlings are culled and bundled in groups of ten, then placed in storage (-2° C) or heeled-in outdoors	
Shipment												Shipped in spring packed in peat moss and bundled	
PLANT CHARACTERISTICS Age when harvested												Harvested after one growing season	

(Information provided by PFRA Tree Nursery, Indian Head, Saskatchewan 1983)

APPENDIX B

Nutrient Deficiency Symptoms

Although specific nutrient deficiency symptoms vary from one species to another, the following descriptions will be useful in helping to identify such deficiencies. They are taken from Tinus and McDonald (1979)

Nitrogen deficiency. - Seedlings are stunted. Older leaves fade and die; younger leaves are pale green to bright yellow. The transition from green to yellow portions of the leaf is abrupt, and there is no extension of chlorosis down the mid-vein into green areas. Chlorosis extends from the leaf tip toward the base. There may be purple or red spotting of the leaves, especially near the tips. Roots are black and necrotic.

Phosphorus deficiency. - Seedlings are stunted, but leaf size may or may not be reduced. Leaves are dark green turning to purple at needle tips or interveinal areas. Purple areas become brown and die. Appearance of broadleafed species is often variegated. Youngest needle tips of spruce and pine may be gold in color. Roots are sparse and purple to black.

Potassium deficiency. - Stems are short and stout. Youngest leaf tips and interveinal areas turn pale green to light yellow and fade to tan or grey. Transition in color from one part of the leaf to another is diffuse, not abrupt. In the field, uppermost exposed foliage on the largest seedlings is likely to be damaged the worst. Leaves at the tips of lower branches will be most damaged in the greenhouse. Roots are long and threadlike.

Calcium deficiency. - Youngest leaves are stunted, and their tips and interveinal areas may be yellow and faded. Leaf margins are pale yellow and buckled. Terminal and subterminal buds die or fail to elongate. Shoots are deformed and twisted; branching intensifies, resembling insect damage. Roots are black, and tips are dying.

Magnesium deficiency. - Leaf tips are bright yellow to orange, with the color progressing from tip to base along the entire length. Midvein chlorosis extends well into green interveinal tissue at leaf base; transition is diffuse. Cotyledons and lower primary needles of pine remain green.

Sulphur deficiency. - Stems are short and slender, with pale yellowish-green foliage. Leaves are abundant but small. Yellowing is even across veins and interveinal areas. Youngest leaves are most affected; older ones are less so.

Iron deficiency. - Symptoms appear first on the terminal leaves; older foliage is unaffected. New leaves turn pale yellow to almost white in interveinal areas or at needle fascicle bases. Roots are few but long.

Boron deficiency. - Terminal is stunted and forms a rosette. All else appears normal, although some foliage may exhibit interveinal chlorosis.

Deficiencies of Mn, Cu, Zn, Mo, or Cl also cause recognizable symptoms, but they are hard to characterize in a general way.

Although specific deficiency symptoms attributable to certain elemental deficiencies have been indicated, it must be kept in mind that deficiency symptoms may be linked to pH levels, which are known to have strong effects on ion availability to plants. Also, high salt concentrations will cause symptoms that are similar to some nutrient deficiencies.

The nutrition of stock must be balanced to insure proper elemental nutrition, at appropriate pH and electrical conductivity levels to enhance optimum growth and development.