Report No. RRTAC 88-7

BASELINE GROWTH PERFORMANCE LEVELS AND ASSESSMENT PROCEDURES FOR COMMERCIAL TREE SPECIES IN ALBERTA'S MOUNTAINS AND FOOTHILLS

by

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Prepared for

THE MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM
ALBERTA LAND CONSERVATION AND RECLAMATION COUNCIL
(Reclamation Research Technical Advisory Committee)

and

The Coal Association of Canada

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DISCLAIMER

The opinions, findings, conclusions and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Alberta Government or The Coal Association of Canada. Specifically, any implications that the document serves as a procedure leading to certification are not supported by the Alberta Government or by The Coal Association at this time.

This report is intended only to provide government and industry staff baseline growth performance data, and technical information on how to measure field performance. There are still too many unknown variables regarding tree growth for this information to be developed into mined - land reclamation standards. The report is also available to the public so that interested individuals similarly have access to the most current information on land reclamation topics.

ALBERTA'S RECLAMATION RESEARCH PROGRAM

The regulation of surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a Chairman from the Department of Forestry, Lands and Wildlife. Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The Reclamation Research Program was established to provide answers to the many practical questions which arise in reclamation. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund.

To assist in technical matters related to the development and administration of the Research Program, the Council appointed the Reclamation Research Advisory Committee (RRTAC). The Committee first met in March 1978 and consists of eight members representing the Alberta Departments of Agriculture, Energy, Forestry, Lands and Wildlife, Environment and the Alberta Research Council. The Committee meets regularly to update research priorities, review solicited and unsolicited research proposals, arrange workshops and otherwise act as a referral and coordinating body for Reclamation Research.

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RECLAMATION RESEARCH REPORTS

** 1. RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites. N.S.C. Cameron et al. 46 pp.

DESCRIPTION: This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

** 2. RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. P.F. Ziemkiewicz, S.K. Takyi, and H.F. Regier. 160 pp.

DESCRIPTION: Experts in the field of forestry and forest soils report on research relevant to forest soil reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

N/A 3. RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta. L.E. Watson, R.W. Parker, and P.F. Polster. 2 vols, 541 pp.

DESCRIPTION: Forty-three grass, fourteen forb, and thirty-four shrub and tree species are assessed in terms of their fitness for use in Reclamation. Range maps, growth habit, propagation, tolerance, and availability information are provided.

N/A 4. RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta. D.G. Walker and R.L. Rothwell. 76 pp.

DESCRIPTION: This survey is an update of a report prepared in 1976 on reclamation activities in Alberta, and includes research and operational reclamation, locations, personnel, etc.

N/A 5. RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation. P.F. Ziemkiewicz, R. Stien, R. Leitch, and G. Lutwick. 253 pp.

DESCRIPTION: Presents nine technical papers on the chemical, physical and engineering properties of Alberta fly and bottom ashes, revegetation of ash disposal sites and use of ash as a soil amendment. Workshop discussions and summaries are also included.

N/A 6. RRTAC 82-1: Land Surface Reclamation: An International Bibliography. H.P. Sims and C.B. Powter. 2 vols, 292 pp.

DESCRIPTION: Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system. Vol. 2 comprises the keyword index and computer access manual.

N/A 7. RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. C.B. Powter and H.P. Sims. 97 pp.

DESCRIPTION: This bibliography provides baseline information for persons involved in reclamation research or in the preparation of environmental impact assessments. Materials, up to date as of December 1981, are available from the Alberta Environment Library.

N/A 8. RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings. Monenco Consultants Ltd. 185 pp.

DESCRIPTION: Volumes of peat and clay required to amend oil sand tailings were estimated based on existing literature. Separate soil prescriptions were made for spruce, jack pine, and herbaceous cover types. The estimates form the basis of field trials.

N/A 9. RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta. Hardy Associates (1978) Ltd. 205 pp.

DESCRIPTION: Available information on pipeline reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type, construction method, etc. on resulting crop production.

N/A 10. RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology. P.F. Ziemkiewicz. 123 pp.

DESCRIPTION: Technical papers are presented dealing with the impacts of mining on mountain watersheds, their flow characteristics and resulting water quality. Mitigative measures and priorities were also discussed.

N/A 11. RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation. Techman Engineering Ltd. 124 pp.

DESCRIPTION: This is a review and analysis of information on planting stock quality, rearing site preparation, planting and procedures necessary to ensure survival of trees and shrubs in oil sand reclamation.

*** 12. RRTAC 84-1: Land Surface Reclamation: A Review of International Literature. H.P. Sims, C.B. Powter, and J.A. Campbell. 2 vols, 1549 pp.

DESCRIPTION: Nearly all topics of interest to reclamation including mining methods, soil amendments, revegetation, propagation and toxic materials are reviewed in light of the international literature.

** 13. RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation. Techman Engineering Ltd. 58 pp.

DESCRIPTION: This report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in oil sand reclamation.

* 14. RRTAC 84-3: Reclamation Research Annual Report - 1983. P.F. Ziemkiewicz. 42 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results and expenditures.

** 15. RRTAC 84-4: Soil Microbiology in Land Reclamation. D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser, and J.C. Zak. 2 vols, 676 pp.

DESCRIPTION: This is a collection of five reports dealing with re-establishment of fungal decomposers and mycorrhizal symboints in various amended spoil types.

** 16. RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills. P.F. Ziemkiewicz. 416 pp.

DESCRIPTION: Results of long-term experiments and field experience on species selection, fertilization, reforestation, topsoiling, shrub propagation and establishment are presented.

* 17. RRTAC 85-2: Reclamation Research Annual Report - 1984. P.F. Ziemkiewicz. 29 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results and expenditures.

** 18. RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies. A. Somani. 372 pp.

DESCRIPTION: The report examines the critical issue of settling pond design and sizing and alternative technologies.

** 19. RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta. T.M. Macyk. 146 pp.

DESCRIPTION: Reconstructed soils representing different materials handling and replacement techniques were characterized and variability in chemical and physical properties was assessed. The data obtained indicate that reconstructed soil properties are determined largely by parent material characteristics and further tempered by materials handling procedures. Mining tends to create a relatively homogeneous soil landscape in contrast to the mixture of diverse soils found before mining.

* 20. RRTAC 86-3: Generalized Procedures for Assessing Post-Mining Groundwater Supply Potential in the Plains of Alberta - Plains Hydrology and Reclamation Project. M.R. Trudell and S.R. Moran. 30 pp.

DESCRIPTION: In the Plains region of Alberta, the surface mining of coal generally occurs in rural, agricultural areas in which domestic water supply requirements are met almost entirely by groundwater. Consequently, an important aspect of the capability of reclaimed lands to satisfy the needs of a residential component is the post-mining availability of groundwater. This report proposes a sequence of steps or procedures to identify and characterize potential post-mining aquifers.

** 21. RRTAC 86-4: Geology of the Battle River Site: Plains Hydrology and Reclamation Project. A Maslowski-Schutze, R. Li, M. Fenton and S.R. Moran. 86 pp.

DESCRIPTION: This report summarzies the geological setting of the Battle River study site. It is designed to provide a general understanding of geological conditions adequate to establish a framework for hydrogeological and general reclamation studies. The report is not intended to be a detailed synthesis such as would be required for mine planning purposes.

** 22. RRTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Program. A. Maslowski-Schutze. 71 pp.

DESCRIPTION: This report describes the physical and mineralogical properties of overburden materials in an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential.

* 23. RRTAC 86-6: Post-Mining Groundwater Supply at the Battle River Site: Plains Hydrology and Reclamation Project. M.R. Trudell, G.J. Sterenberg and S.R. Moran. 49 pp.

DESCRIPTION: The report deals with the availability of water supply in or beneath cast overburden at the Battle River Mining area in east-central Alberta to support post-mining land use. Both groundwater quantity and quality are evaluated.

* 24. RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project. M.R. Trudell. 25 pp.

DESCRIPTION: This report evaluates the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is the Highvale mining area in west-central Alberta.

* 25. RRTAC 86-8: Reclamation Research Annual Report - 1985. P.F. Ziemkiewicz. 54 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results and expenditures.

** 26. RRTAC 86-9: Wildlife Habitat Requirements and Reclamation Techniques for the Mountains and Foothills of Alberta. J.E. Green, R.E. Salter and D.G. Walker. 285 pp.

DESCRIPTION: This report presents a review of relevant North American literature on wildlife habitats in mountain and foothills biomes, reclamation techniques, potential problems in wildlife habitat reclamation, and potential habitat assessment methodologies. Four biomes (Alpine, Subalpine, Montane, and Boreal Uplands) and 10 key wildlife species (snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse, and white-tailed ptarmigan) are discussed.

** 27. RRTAC 87-1: Disposal of Drilling Wastes. L.A. Leskiw, E. Reinl-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp.

DESCRIPTION: Current drilling waste disposal practices are reviewed and criteria in Alberta guidelines are assessed. The report also identifies research needs and indicates mitigation measures. A manual included provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

** 28. RRTAC 87-2: Minesoil and Landscape Reclamation of the Coal Mines in Alberta's Mountains and Foothills. A.W. Fedkenheuer, L.J. Knapik, and D.G. Walker. 174 pp.

DESCRIPTION: This report reviews current reclamation practices with regard to site and soil reconstruction and re-establishment of biological productivity. It also identifies research needs in the Mountain-Foothills area.

** 29. RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings. D.A. Lloyd (compiler). 218 pp.

DESCRIPTION: Technical papers were presented which describe: the mud systems used and their purpose; industrial constraints; government regulations, procedures and concerns; environmental considerations in waste disposal; and toxic constituents of drilling wastes. Answers to a questionnaire distributed to participants are included in an appendix.

* 30. RRTAC 87-4: Reclamation Research Annual Report - 1986. 50 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results and expenditures.

* 31. RRTAC 87-5: Review of the Scientific Basis of Water Quality Criteria for the East Slope Foothills of Alberta. Beak Associates Consulting Ltd. 46 pp.

DESCRIPTION: The report reviews existing Alberta guidelines to assess the quality of water drained from coal mine sites in the East Slope Foothills of Alberta. World literature was reviewed within the context of the east slopes environment and current mining operations. The ability of coal mine operators to meet the various guidelines is discussed.

** 32. RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes. Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp.

DESCRIPTION: The report provides an evaluation of current methodologies used to determine sediment yields due to rainfall events in well-defined areas. Models are available in Alberta to evaluate water and sediment discharge in a post-mining situation. SEDIMOT II (Sedimentology Disturbed Modelling Techniques) is a single storm model that was developed specifically for the design of sediment control structures in watersheds disturbed by surface mining and is well suited to Alberta conditions.

* 33. RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil. S. Fullerton. 83 pp.

DESCRIPTION: The report details the use of bottom ash as an amendment to sodic coal mine spoil. Several rates and methods of application of bottom ash to sodic spoil were tested to determine which was the best at reducing the effects of excess sodium and promoting crop growth. Field trials were set up near the Vesta mine in East Central Alberta using ash readily available from nearby coal-fired thermal generating station. The research indicated that bottom ash incorporated to a depth of 30 cm using a subsoiler provided the best results.

* 34. RRTAC 87-8: Waste Dump Design for Erosion Control. R.G. Chopiuk and S.E. Thornton. 45 pp.

DESCRIPTION: This report describes a study to evaluate the influence of erosion from reclaimed waste dumps on downslope environments such as streams and rivers. Sites were selected from coal mines in Alberta's mountains and foothills, and included resloped dumps of different configurations and ages, and having different vegetation covers. The study concluded that the average annual amount of surface erosion is minimal. As expected, erosion was greatest on slopes which were newly regraded. Slopes with dense grass cover showed no signs of erosion. Generally, the amount of erosion decreased with time, as a result of initial loss of fine particles, the formation of a weathered surface, and increased vegetative cover.

** 35. RRTAC 87-9: Hydrogeology and Groundwater Chemistry of the Battle River Mining Area. M.R. Trudell, R.L. Faught and S.R. Moran. 97 pp.

DESCRIPTION: This report describes the premining geologic conditions in the Battle River coal mining area including the geology as well as the groundwater flow patterns, and the groundwater quality of a sequence of several water-bearing formations extending from the surface to a depth of about 100 metres.

** 36. RRTAC 87-10: Soil Survey of the Plains Hydrology and Reclamation Project - Battle River Project Area. T.M. Macyk and A.H. MacLean. 62 pp. plus maps.

DESCRIPTION: The report evaluates the capability of post-mining landscapes and assesses the changes in capability as a result of mining, in the Battle River mining area. Detailed soils information is provided in the report for lands adjacent to areas already mined as well as for lands that are destined to be mined. Characterization of the reconstructed soils in the reclaimed areas is also provided. Data were collected from 1979 to 1985. A series of maps supplement the report.

** 37. RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 78 pp.

DESCRIPTION: The report is one of a series that describes the geology, soils and groundwater conditions at the Highvale Coal Mine study site. The purpose of the study was to establish a summary of site geology to a level of detail necessary to provide a framework for studies of hydrogeology and reclamation.

** 38. RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site. M.R. Trudell and R. Faught. 83 pp.

DESCRIPTION: This report presents a detailed discussion of the premining flow patterns, hydraulic properties, and isotopic and hydrochemical characteristics of five layers within the Paskapoo Geological Formation, the underlying sandstone beds of the Upper Horseshoe Canyon Formation, and the surficial glacial drift.

* 39. RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils. T.M. Macyk. 27 pp.

DESCRIPTION: This report provides the rationale and a system for assessing the agricultural capability of reconstructed soils. Data on the properties of the soils used in this report are provided in RRTAC 86-2.

** 40. RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook. Eccles, T.R., R.E. Salter and J.E. Green 101 pp. plus appendix.

DESCRIPTION: The report focuses on the development of guidelines and procedures for the assessment of reclaimed wildlife habitat in the Mountains and Foothills regions of Alberta. The technical section provides background documentation including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques and a glossary of basic terminology. The assessment handbook section contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for certification. This handbook is intended as a field manual that could potentially be used by site operators and reclamation officers.

** 41. RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and its Impacts on Surface Water. M.R. Trudell (Compiler). Alberta Land Conservation and Reclamation Council Report #RRTAC 88-2. 135 pp.

DESCRIPTION: Two reports comprise this volume. The first "Chemistry of Groundwater in Mine Spoil, Central Alberta," describes the chemical make-up of spoil groundwater at four mines in the Plains of Alberta. It explains the nature and magnitude of changes in groundwater chemistry following mining and reclamation.
The second report, "Impacts of Surface Mining on Chemical Quality of Streams in the Battle River Mining Area," describes the chemical quality of water in streams in the Battle River mining area, and the potential impact of groundwater discharge from surface mines on these streams.

** 42. RRTAC 88-3: Revegetation of Oil Sands Tailings: Growth Improvement of Silver-berry and Buffalo-berry by Inoculation with Mycorrhizal Fungi and N_2-Fixing Bacteria. S. Visser and R.M. Danielson. 98 pp.

DESCRIPTION: The report provides results of a study: (1) To determine the mycorrhizal affinities of various actinorrhizal shrubs in the Fort McMurray, Alberta region; (2) To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry; (3) To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry; and, (4) To conduct a field trial on reconstructed soil on the Syncrude oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their uninoculated counterparts.

** 43. RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill. D.R. Pauls (compiler). 135 pp.

DESCRIPTION: This three part volume covers the laboratory assessment of the potential for subsidence in reclaimed landscapes. The first report in this volume, "Simulation of Mine Spoil Subsidence by Consolidation Tests," covers laboratory simulations of the subsidence process particularly as it is influenced by resaturation of mine spoil. The second report, "Water Sensitivity of Smectitic Overburden: Plains Region of Alberta" describes a series of laboratory tests that have been used to determine the behaviour of overburden materials when brought into contact with water. The report entitled "Classification System for Transitional Materials: Plains Region of Alberta" describes a lithological classification system developed to address the characteristics of the smectite rich, clayey transition materials that make up the overburden in the Plains of Alberta.

** 44. RRTAC 88-5: Ectomycorrhizae of Jack Pine and Green Alder: Assessment of the Need for Inoculation, Development of Inoculation Techniques and Outplanting Trials on Oil Sand Tailings. R.H. Danielson and S. Visser. 177 pp.

DESCRIPTION: The overall objective of this research was to characterize the mycorrhizal status of Jack Pine and Green Alder which are prime candidates as reclamation species for oil sand tailings and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting.

* 45. RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee. 67 pp.

DESCRIPTION: This annual report describes the expenditure of $500,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program. The report also lists the 44 research reports published under the program.

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N/A Not available for purchase but available for review at the Alberta Environment Library, 14th Floor, 9820-106 Street, Edmonton, Alberta T5K 2J6.

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ABSTRACT

Field work was undertaken on cut-over or burned sites during the summer of 1986 to acquire data on juvenile height development of commercial tree species growing in coal-bearing areas of the Eastern Slopes of Alberta. These data were used to define reasonable expectations of early growth performance under prevailing environmental conditions, as a basis for evaluating the success of reforestation following coal mining.

Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures are described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth standards, and for testing actual growth performance against these expectations.

ACKNOWLEDGEMENTS

This study was conducted under the Mountain and Foothills Reclamation Research Program. It was funded by The Coal Association of Canada and the Alberta Land Conservation and Reclamation Council. Funds in the latter case were provided through the Alberta Heritage Savings Trust Fund.

Help in locating field samples was given by companies participating in the Mountain Foothills Program. In addition, considerable assistance in locating suitable samples and in determining stand histories was provided by Champion Forest Products, Blue Ridge Lumber, and the Alberta Forest Service.

1. INTRODUCTION

Field work was undertaken during the summer of 1986 to determine tree-seedling growth rates in coal-bearing areas of the Eastern Slopes. The purpose was to define reasonable expectations of juvenile growth performance under prevailing environmental conditions, as a baseline for evaluating the success of reforestation following coal mining. This also required the development of assessment criteria and procedures suitable for inclusion into guidelines that could be used by government and industry.

The specific objectives were:

1. The provision of growth performance expectations in the form of tables and graphs for commercial tree species being used in reclamation following coal mining in the Eastern Slopes;
2. Establishment of procedures that could be used for measuring seedlings and site factors to determine whether reforestation has been successful.

The project terms of reference specified the development of:

1. Tables and curves relating height and height growth to age;
2. Procedures and timing for the measurement of total height and leader growth;
3. Adjustment procedures accommodating variation in local site conditions and cultural practices.

Other requirements included the provision of procedures for assessing stocking standards, and the integration of evaluation procedures with those used by the Alberta Forest Service (AFS) for assessing reforestation after logging.

A general approach to validating restoration of forest productivity through assessment of early height growth was outlined by Dempster and Higginbotham (1985). This involved a pre-disturbance evaluation of site index, the development of seedling growth curves relating height growth to age and site index, and a post-reclamation regeneration survey using conventional AFS procedures for evaluating stocking, augmented by sampling of total seedling height and annual height increment. This approach has been modified slightly in view of the subsequent findings of Udell and Dempster (1986), which suggested that the early height growth of regenerated lodgepole pine could be correlated with elevation, and was a better measure of timber production potential than was the site index of old fire origin stands. Earlier work by Johnstone (1976) was also drawn upon.

The species studied were lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), white spruce (*Picea glauca* (Moench) Voss), and engelmann spruce (*Picea engelmannii* Parry). The latter two species were treated as one, since differences in growth appeared more related to site than taxonomy.

Whilst the study was being undertaken, regeneration assessments by the AFS Reforestation and Reclamation Branch were also being analyzed. These assessments were concentrated in the main logging areas of the Province, and no basis was found for differentiating growth performance expectations other than by species. Because little sampling was undertaken at high elevations, there was some concern that coal mine reclamation sites in the Eastern Slopes may have lower baseline growth levels, not represented by a single provincial standard. The emphasis in the current study was therefore to quantify any adjustment merited on high elevation or other marginal sites. However, it should be made clear that results of this study are intended to apply only to lands classified as productive in the Alberta Forest Inventory. It is assumed that any pre-disturbance planning will include differentiation of productive versus non-productive forest lands, and that this will be taken into account when reclamation objectives are set.

2. STUDY AREAS

Figure 1 shows the location of study areas . Highest priority was given to areas in which surface mining is currently taking place, and to areas which may be disturbed in the next decade. Sampling was therefore concentrated in lands defined as Category 4 under the Land Classification for Coal Exploration and Development in the Eastern Slopes of Alberta (Alberta Environment 1976). The main area of study included such lands in the Hinton-Coal Valley vicinity, but outlying areas near Grande Cache, Coleman, and Judy Creek were also included.

The study area is located in the Boreal and Subalpine Southern Cordilleran Regions, as defined by the Canada Committee on Ecological Land Classification. Thus all sites sampled occur in a transition zone through boreal and cordilleran ecological conditions (Environment Canada 1987).

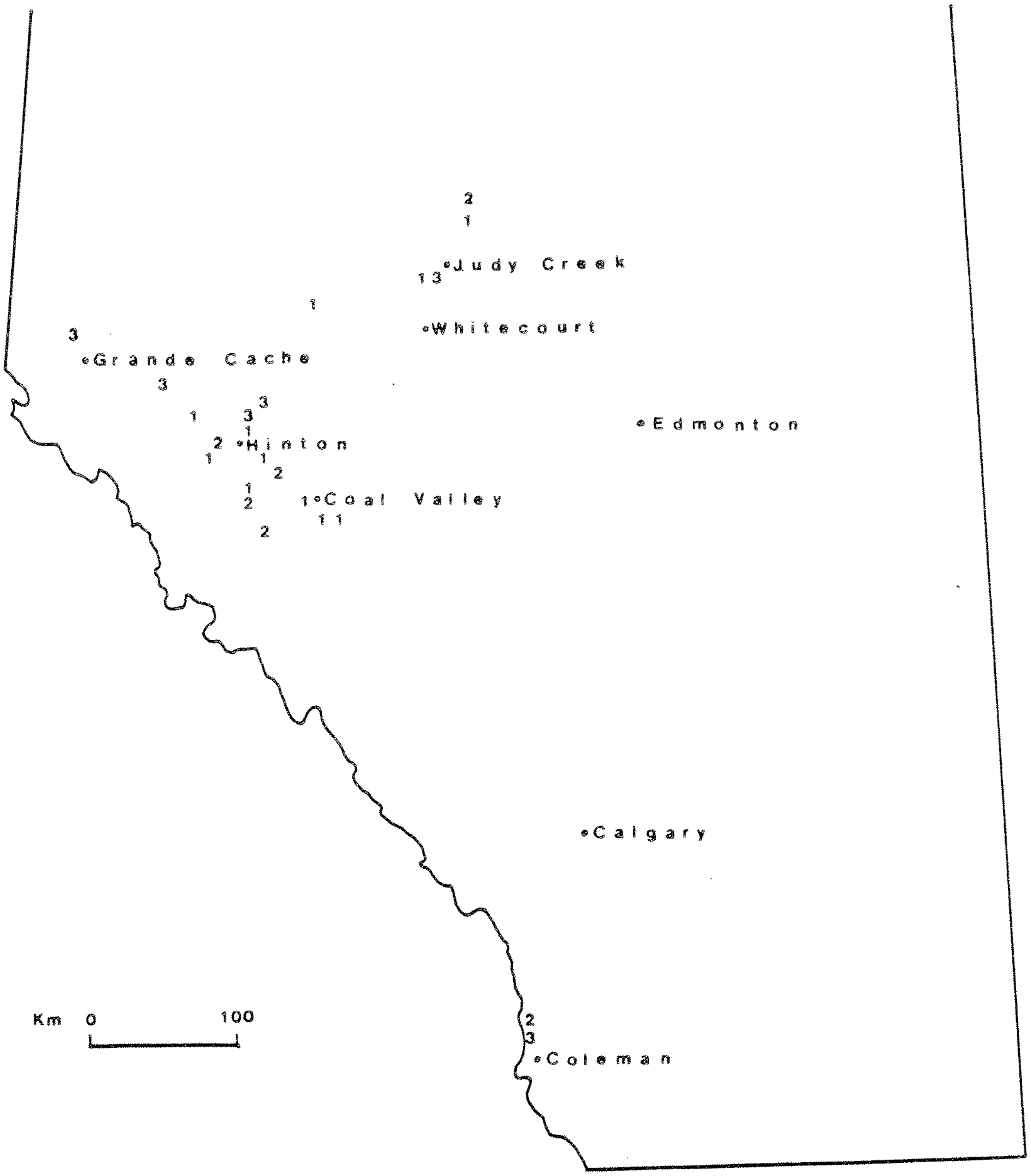

Figure 1. Location of field samples (each single digit indicates number of sites within one township).

3. SAMPLE DESIGN AND FIELD METHODS

The following section refers to the methods used in this study for acquiring data upon which to base growth performance expectations. See Section 5 for procedures recommended for operational reforestation assessment.

The basic sampling unit adopted was a circular sample plot, 0.001 ha in area and 1.8 m in radius. This unit is consistent with that used throughout the Province by the Alberta Forest Service and forest industry for juvenile stand surveys and mandatory regeneration surveys (Alberta Energy and Natural Resources 1979).

Criteria used in selecting sample locations were as follows:

1. Logged sites, where available, were selected as providing the best basis for evaluating early growth performance.
2. Stands subjected to site improvement or other intensive management practices were avoided.
3. Regeneration of the selected stand or block was over five, and preferably at least ten, years old.
4. Stand history was known, or could be deduced.
5. Locations were distributed over a wide range of site conditions, with emphasis on sampling the full elevation range over which post-mining reforestation may be required in the boreal-cordilleran transition (approximately 1100 to 1900 m above sea level).
6. An attempt was made to obtain an approximately even number of samples for both spruce and pine.

These conditions severely limited the choice of locations. Inventory and silviculture records, provided by the Alberta Forest Service, Champion Forest Products, and Blue Ridge Lumber, provided the basis for initial selection. In order to obtain samples across the full range of site conditions, it was necessary to supplement samples from logged stands with those originating after fires. Fewer suitable samples of spruce were found than of pine.

In designing the sampling scheme, an attempt was made to balance the need for sample plots being as widely distributed throughout the study area as possible, whilst obtaining meaningful estimates in each stand or block visited. This, combined with the limited choice of suitable stands and logistical considerations, resulted in a design involving systematic sampling of 40 blocks (i.e. regenerated stands meeting the above criteria) each with a minimum of 12 plots. (In fact, a total of 522 plots were sampled on 41 blocks. However, one block was rejected from analyses for lack of reliable information on stand history.)

Within each block, bias in plot placement was avoided by the following random-systematic layout procedure. A baseline was established using Alberta Forest Service standards (Alberta Energy and Natural Resources 1979). Along this baseline, tie points were spaced equidistantly at 60 m intervals. A random number from 1 to the number of tie points was chosen. From the randomly selected tie point, a bearing perpendicular to the baseline was taken. Plots were spaced along this bearing at 60 m intervals until the block boundary was reached. If more plots were required, a second random tie-point was selected without replacement, and the process repeated. This was continued until at least 12 stocked plots were established in the block.

For each block, the location, year of cut or disturbance, year and type of reforestation treatment[1], and map soil series (Dumanski et al. 1972), was recorded.

At each plot, the following information was recorded: location, elevation, slope steepness and aspect, topographic class (Alberta Energy and Natural Resources 1985), drainage class (Alberta Energy and Natural Resources 1983), exposure class (after Fralish and Loucks 1975), percentage vegetative cover (distinguishing trees, shrubs, forbs, grasses, and mosses), rooting depth limitations (if present) and tree count. Because the final crop is likely to be formed from the tallest juvenile trees, on every plot the tallest

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1. Treatments included: planted, scarified, burned, ploughed, drag scarified, none and unknown.

tree, if present, of each of the two species (spruce and pine) was destructively sampled to obtain a complete and accurate record of the tree's height growth since germination. This involved the following procedure, after first recording total height, whether the current year's terminal extension was yet complete, and whether the tree was planted or seeded (if discernible):

1. Locate the root collar.
2. Record the ring count at the root collar; this is the total tree age.
3. Identify probable annual nodes.
4. If the number of nodes equals the total age minus one, record age against the corresponding section (internode), and measure the section length.
5. If the number of nodes does not equal the total age minus one, then continue sectioning immediately above and below each node, and counting rings, to determine the true positions of the annual nodes.

A total of 457 trees remained after trees less than five years old were excluded. Of these, 190 were spruce and 267 were pine.

4. ANALYTICAL METHODS AND RESULTS

4.1 HEIGHT GROWTH IN RELATION TO SITE VARIABLES

Data were entered for computer analysis, screened, and edited. Computer-graphic techniques were used for checking the height-age data obtained by stem analysis. Heights at five, seven, and ten years were used as indices of height growth, and a series of exploratory analyses (involving statistical breakdowns, analyses of variance, and correlation analyses) were conducted to determine whether any useful relationships between height growth and readily-measured site or locational factors could be established. The data were summarized and important statistical analyses are given in Appendix 1.

Table 1 gives the correlations between the continuous variables and height at seven years. Although many variables are statistically significant, the amount of variation explained (the square of "r") is relatively small for all variables. For both pine and spruce, elevation accounts for most of the variation in height and even then the proportions are only 35.3% for pine and 17.9% for spruce. For pine, height is also related to slope steepness and aspect. However, the variations accounted for are much smaller than for elevation: 3.6% for steepness and 5.5% for aspect.

The relationships between height and the other variables of Table 1 were not considered further. This was because they were either insignificant, inconsistent or difficult to interpret, or difficult to include into a simple and useful predictive model.

Table 2 summarizes analysis of variance and analysis of covariance (Steel and Torrie 1980) results for discrete variables. From Table 2 (a) it is clear that stratifying the blocks into ecoregions (following the classification of Strong and Leggat (1981)) results in the largest proportion of total variation being accounted for in pine and the second largest amount for spruce.

Most of the other variables also resulted in significant differences in heights at seven years. In fact the only variables not significant in at least one species were seedling source (planted

Table 1. Correlations between juvenile height (at 7 years) and continuous variables.

Variable	Pine r	Pine significance	Spruce r	Spruce significance
Steepness	-.191	.003*	-.106	.156
Elevation	-.594	.000*	-.423	.000*
Aspect	-.234	.001*	.082	.347
Percent Cover:				
-trees	.148	.021*	-.104	.167
-shrubs	.080	.216	-.004	.956
-forbs	.169	.009*	.163	.029*
-grasses	.028	.661	.091	.225
-mosses	-.251	.001*	-.329	.000*
-bare ground	-.037	.570	.061	.420
Tree Density:				
-pine	.324	.000*	.012	.869
-white/engelmann spruce	-.035	.589	-.198	.008*
-fir	-.168	.295	-.236	.001*
-black spruce	.120	.064	-	-
-larch	-.066	.304	-.056	.455
-trembling aspen	.273	.000*	.176	.018*
-balsam poplar	.052	.425	-.078	.301
-birch	.129	.045*	.098	.191
-all softwoods	.066	.307	-.258	.000*
-all hardwoods	.281	.000*	.117	.118

*Significant at 0.05

Note: Based on a maximum of 241 cases for pine and 179 cases for spruce.

Table 2. Relationships between juvenile height (at 7 years) and discrete variables.

	Pine		Spruce	
	Variance Accounted for (%)	Signif. of F-stat.	Variance Accounted for (%)	Signif. of F-stat.
a) No covariate				
Variable:				
Ecoregion	30.7	.000*	11.6	.000*
Exposure Class	8.0	.001*	5.4	.046*
Drainage Class	8.6	.000*	4.7	.014*
Topographic Class	11.6	.000*	7.3	.004*
Rooting Limitation	4.8	.001*	2.1	.052
Treatment	1.7	.295	22.8	.000*
Seedling Source	0.3	.424	0.7	.297
b) Elevation covariate				
Variable:				
Ecoregion	3.6	.001*	3.3	.027*
Exposure Class	3.7	.009*	0.8	.782
Drainage class	2.2	.017*	3.4	.025*
Topographic Class	2.0	.125	3.6	.050*
Rooting Limitation	1.3	.030*	1.7	.052
Treatment	-	-	-	.108

* Significant at 0.05

or seeded), site treatment (for pine) and limited rooting depth (for spruce). Certain variables were dropped because of inconsistencies or because of application difficulties. For example, exposure was dropped for pine because the mean heights for intermediate exposures were lower than either protected or very exposed sites and rooting depth restrictions were dropped because of the difficulty in using this variable in reclamation applications relative to the very small amount of variation explained.

Because elevation was the major source of variation in Table 1, it was included as a covariate in the analysis of discrete variables. The results, given in part b) of Table 2, show some changes in significance levels. More importantly, the major impacts of including elevation were relatively large decreases in the variation accounted for by most of the discrete variables.

In summary, the most significant and consistent relationships with height growth were demonstrated by elevation, ecoregion, drainage class and (for pine but not spruce) aspect. Slope steepness although also significant for pine is not considered further. As a covariate it contributes less than elevation and it is not significant when included as a joint covariate with elevation.

4.1.1 Drainage Class

Table 3 summarizes mean seedling height by drainage class, species and age.

Table 3. Mean juvenile heights (m) by species, age, and drainage class.

Drainage	Pine			Spruce		
Class	5 yrs	7 yrs	10 yrs	5 yrs	7 yrs	10 yrs
Rapidly drained	0.73	1.16	1.60	0.38	0.59	0.85
Moderately well-drained	0.91	1.48	2.21	0.45	0.72	1.17
Poorly drained	0.67	1.12	1.97	0.35	0.55	1.05
All classes	0.78	1.26	1.88	0.40	0.63	0.98
cases (n) =	255	239	143	189	179	129

Note that in all combinations of species and age tested, growth performance was greater on moderately well-drained sites than on either rapidly or poorly drained sites. These effects were tested by one-way analyses of variance and multiple-range tests using the Student-Newman-Keuls procedure (Steel and Torrie 1980), and were found to be significant at the 95 percent probability level.

4.1.2 Aspect

Slope aspect, with an azimuth correction applied (after Myers and Van Deusen 1960), showed a weak but significant correlation with height growth in lodgepole pine, but not in spruce. In pine, results indicated a tendency best shown in the Hinton-Coal Valley area, towards highest productivity on northeast aspects, consistent with the observations of Corns and Pluth (1984). The relationship between total seedling height at seven years (Y) and transformed slope aspect (X)[2] was as follows:

Hinton-Coal Valley: $Y = 1.578 - 0.26455X$ $n = 108$

R-squared = 0.05 Standard error of estimate = 0.496 m

Note that only a small proportion of the variation in height can be explained by aspect. However, the results imply that height growth can be as much as 20 percent higher than average on favourable northeast aspects, and 20 percent lower on unfavourable southwest aspects (based on differences between overall mean and regression equation predictions).

4.1.3 Elevation

Table 4 gives (in somewhat more detail than does Table 2) the results of introducing elevation as a covariate in an analysis of variance investigating the effect of ecoregion on cumulative height growth by 7 years. It was found that elevation had a highly significant effect on height growth, but that ecoregion differences were also significant, even after elevation had been taken into

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2. Transformed aspect (X) is defined as: $X = 1 + \mathrm{SIN}(\text{aspect} - 135)$.

account. Both the amount of variation attributed to elevation, and the total explained variation, were higher relative to residual variation in pine than in spruce.

Table 4. Analyses of covariance examining relationship between juvenile height (at 7 years), elevation, and ecoregion.

Source of variation	Sum of squares	DF	Mean Square	F	Signif. of F
(a) Pine (n = 241)					
Covariate (elevation)	22.98	1	22.98	137.23	.000
Main effect (ecoregion)	2.37	2	1.18	7.07	.001
Explained	23.35	3	8.45	50.46	.000
Residual	39.69	237	.167		
Total	65.04	240	.271		
(b) Spruce (n = 179)					
Covariate (elevation)	2.50	1	2.50	39.67	.000
Main effect (ecoregion)	.46	2	.23	3.69	.027
Explained	2.96	3	.99	15.68	.000
Residual	11.02	175	.06		
Total	13.98	178	.08		

Table 5 gives the mean heights at 7 years by ecoregion. For both pine and spruce, the differences in height between the subalpine ecoregion and the two boreal ecoregions are significant (based on the Student-Newman-Keuls procedure (Steel and Torrie 1980)). In addition, the means for the Boreal Foothills ecoregion and Boreal Uplands ecoregion are significantly different for pine but not for spruce.

Table 6 summarizes simple linear regression analyses relating height growth (as the dependent variable) to elevation in west-central Alberta. In pine, 50 percent or more of the variation in height growth was explained by elevation, the amount increasing

Table 5. Mean heights (m) at 7 years by species and ecoregion.

	Pine		Spruce	
Ecoregion	Mean	n	Mean	n
Subalpine	0.94	65	.49	53
Boreal Uplands	1.19	109	.71	61
Boreal Foothills	1.69	67	.68	65
All Classes	1.26	241	.63	179

with age. In spruce, although the relationship was still highly significant, the amount of explained variation was much lower (12 to 17 percent). However, it was observed that the poorer relationship in spruce appeared to result from a relatively small number of outlier plots, possibly indicating that vegetative competition, microclimate, and other factors were confounding the effect of elevation to a greater extent in this species than in pine.

Table 6. Relationship between elevation and unadjusted cumulative height growth in west-central Alberta.

Species	Age (yrs)	N	R-Squared	Intercept (m)	Slope*	S.E. of estimate (m)	S.E. of estimate (% of mean)	Sig.
Pine	5	212	0.50	2.386	-0.00036	0.255	32.1	0.0000
	7	205	0.54	3.870	-0.00057	0.368	28.8	0.0000
	10	134	0.63	6.816	-0.00103	0.495	26.3	0.0000
Spruce	5	162	0.14	0.775	-0.00009	0.167	40.5	0.0000
	7	155	0.17	1.273	-0.00015	0.263	40.2	0.0000
	10	117	0.12	1.835	-0.00019	0.413	41.2	0.0002

* change in tree height (m) per metre change in elevation

4.2 ELEVATION-BASED HEIGHT-GROWTH MODELS

In young lodgepole pine growing in west-central Alberta, elevation was judged to be the most useful variable for differentiating growth expectations with respect to location. Not only was elevation highly correlated with height growth and better correlated than any other site variable measured, but it is easily determined and, as a measure of prevailing macro-climate conditions, is presumably applicable to both pre-disturbance and post-disturbance conditions. It was therefore concluded that the most useful approach towards developing quantitative growth performance standards in this area was to develop predictive equations from the stem-analysis data, forecasting height as a function of age and elevation.

Although the relationship between height growth and elevation was much weaker in spruce, it was decided to retain the same approach as for pine, because elevation was still highly significant, explaining more variation than any other variable measured.

In the Coleman area, height-growth data did not conform to the trend observed in west-central Alberta, and insufficient data were acquired to develop a separate elevation-based model.

Johnstone (1976) predicted height of spruce and pine seedlings in west-central Alberta as a function of age and years taken to reach a certain height. In the present study, it was initially intended to relate elevation to an index such as years to breast-height, and then to link this to height at a given age using Johnstone's model. However, this approach was rejected because extreme inequalities in residual variances were observed when Johnstone's model was formulated. Various other approaches were tried. The following model was finally selected:

$$\ln (\text{Height}) = a + b (\text{Age}) + c (\text{Elevation})$$

The equation demonstrates the best combination of linearity and equality of variance, as indicated by normal probability plots, standardized scatterplots of residuals, and plots of untransformed predicted versus observed values. It can be transformed to forecast total seedling height in metres from age in years and elevation in metres above sea-level:

$$\text{Height} = \exp (a + b (\text{Age}) + c (\text{Elevation}))$$

Current annual height increment (CAI) can be derived from the above equation directly and easily:

CAI = b (Height)

Table 7 contains the coefficients obtained by stepwise multiple linear regression to fit the above equations. Note that the equations for the Coleman area do not include elevations, and represent average local height-age curves.

Table 7. Coefficients for height-growth models

Model	Coefficients a	b	c	N*	Adjusted R-Square
West-central pine	1.84199	0.16813	-0.0021052	1393	0.769
West-central spruce	-0.06249	0.16476	-0.0012628	854	0.736
Coleman pine	-1.25334	0.19024	-	173	0.391
Coleman spruce	-1.75341	0.12980	-	154	0.463

* number of tree sections

Some outlying data were excluded from the above analyses. Rejected data were from:

1. Blocks in which data were suspect (e.g. blocks with possibly erroneous or misleading stand histories).
2. Blocks where seedling development was suspected of being excessively influenced by vegetative factors. (Positive growth effects appear to have resulted when, for example, spruce developed in association with protective advance growth of other conifers. Negative effects were suspected to have resulted, especially in spruce on some lower elevation sites, where seedlings had been subjected to grass or other inter-specific competition.)
3. Individual seedlings which showed unexplained large deviation from general elevation/growth trends.

This procedure resulted in approximately 5 and 27 percent, of the pine and spruce stem-analyses respectively, being rejected from the data used in formulating the final elevation-based models.

Tables 8 and 9 contain forecast values of height and height increment for pine and spruce in west-central Alberta. The same data are represented graphically in Figures 2 to 5. Data for the Coleman area were limited and variable, but indicated generally higher growth at a given elevation when compared with the west-central models.

Table 8. Height development of juvenile lodgepole pine in west-central Alberta.

(a) Total Height (m)

Age	Elevation (m)							
(yrs)	1200	1300	1400	1500	1600	1700	1800	1900
5	1.17	.95	.77	.62	.50	.41	.33	.27
6	1.38	1.12	.91	.74	.60	.48	.39	.32
7	1.64	1.33	1.07	.87	.71	.57	.46	.37
8	1.94	1.57	1.27	1.03	.83	.68	.55	.44
9	-	1.86	1.50	1.22	.99	.80	.65	.52
10	-	-	1.78	1.44	1.17	.95	.77	.62

(b) Current Annual Increment (cm)

Age	Elevation (m)							
(yrs)	1200	1300	1400	1500	1600	1700	1800	1900
5	19.7	15.9	12.9	10.5	8.5	6.9	5.6	4.5
6	23.3	18.8	15.3	12.4	10.0	8.1	6.6	5.3
7	27.5	22.3	18.1	14.6	11.9	9.6	7.8	6.3
8	32.6	26.4	21.4	17.3	14.0	11.4	9.2	7.5
9	-	31.2	25.3	20.5	16.6	13.4	10.9	8.8
10	-	-	29.9	24.2	19.6	15.9	12.9	10.4

Table 9. Height development of juvenile white and engelmann spruce in west-central Alberta.

(a) Total Height (m)

Age	Elevation (m)								
(yrs)	1100	1200	1300	1400	1500	1600	1700	1800	1900
5	.53	.47	.41	.37	.32	.28	.25	.22	.19
6	.63	.55	.49	.43	.38	.33	.30	.26	.23
7	.74	.65	.58	.51	.45	.39	.35	.31	.27
8	.88	.77	.68	.60	.53	.47	.41	.36	.32
9	1.03	.91	.80	.71	.62	.55	.48	.43	.38
10	1.22	1.07	.95	.83	.73	.65	.57	.50	.44

(b) Current Annual Increment (cm)

Age	Elevation (m)								
(yrs)	1100	1200	1300	1400	1500	1600	1700	1800	1900
5	8.8	7.8	6.8	6.0	5.3	4.7	4.1	3.6	3.2
6	10.4	9.1	8.1	7.1	6.3	5.5	4.9	4.3	3.8
7	12.2	10.8	9.5	8.4	7.4	6.5	5.7	5.1	4.5
8	14.4	12.7	11.2	9.9	8.7	7.7	6.8	6.0	5.2
9	17.0	15.0	13.2	11.6	10.3	9.0	8.0	7.0	6.2
10	20.0	17.7	15.6	13.7	12.1	10.7	9.4	8.3	7.3

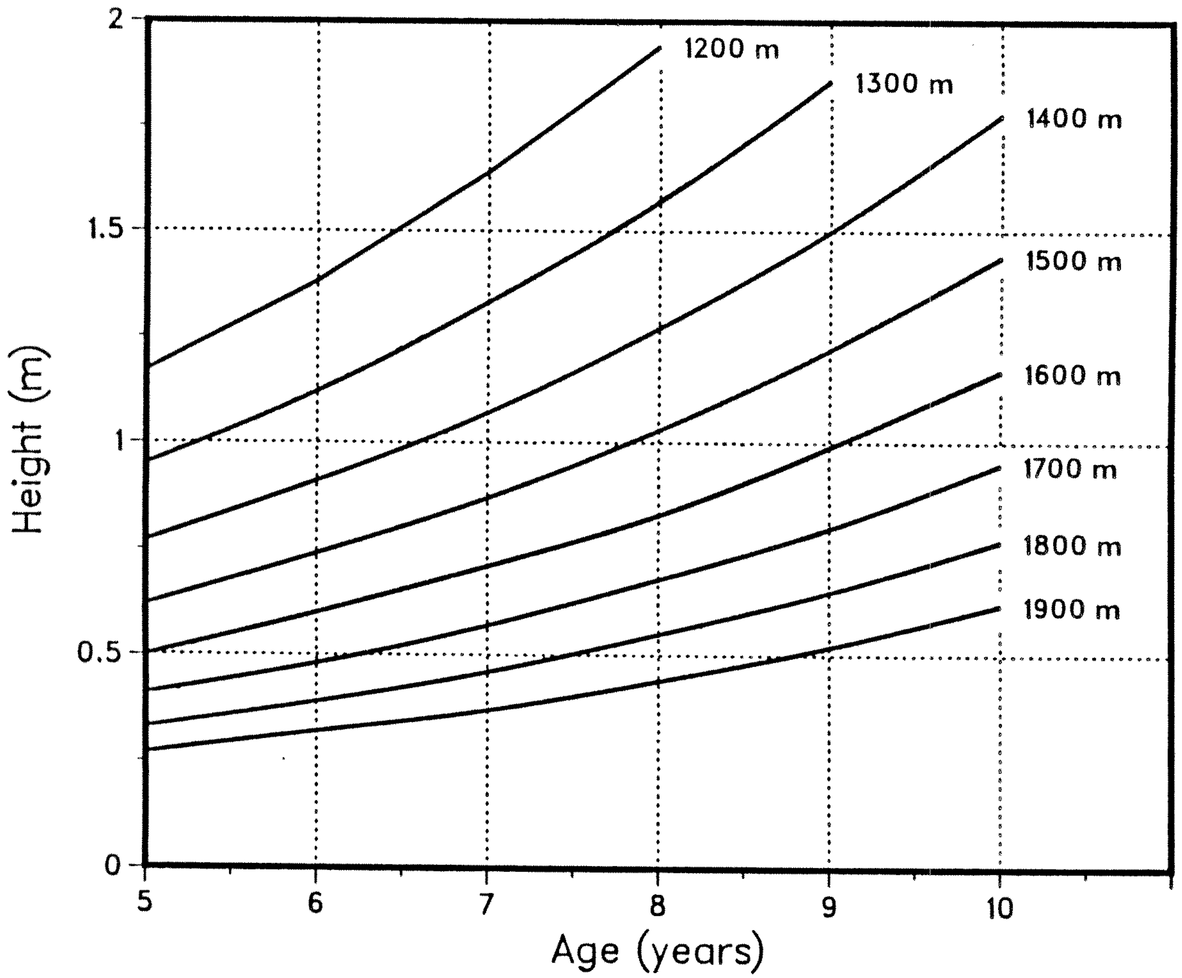


Figure 2. Height development of juvenile pine in west-central Alberta by age and elevation.

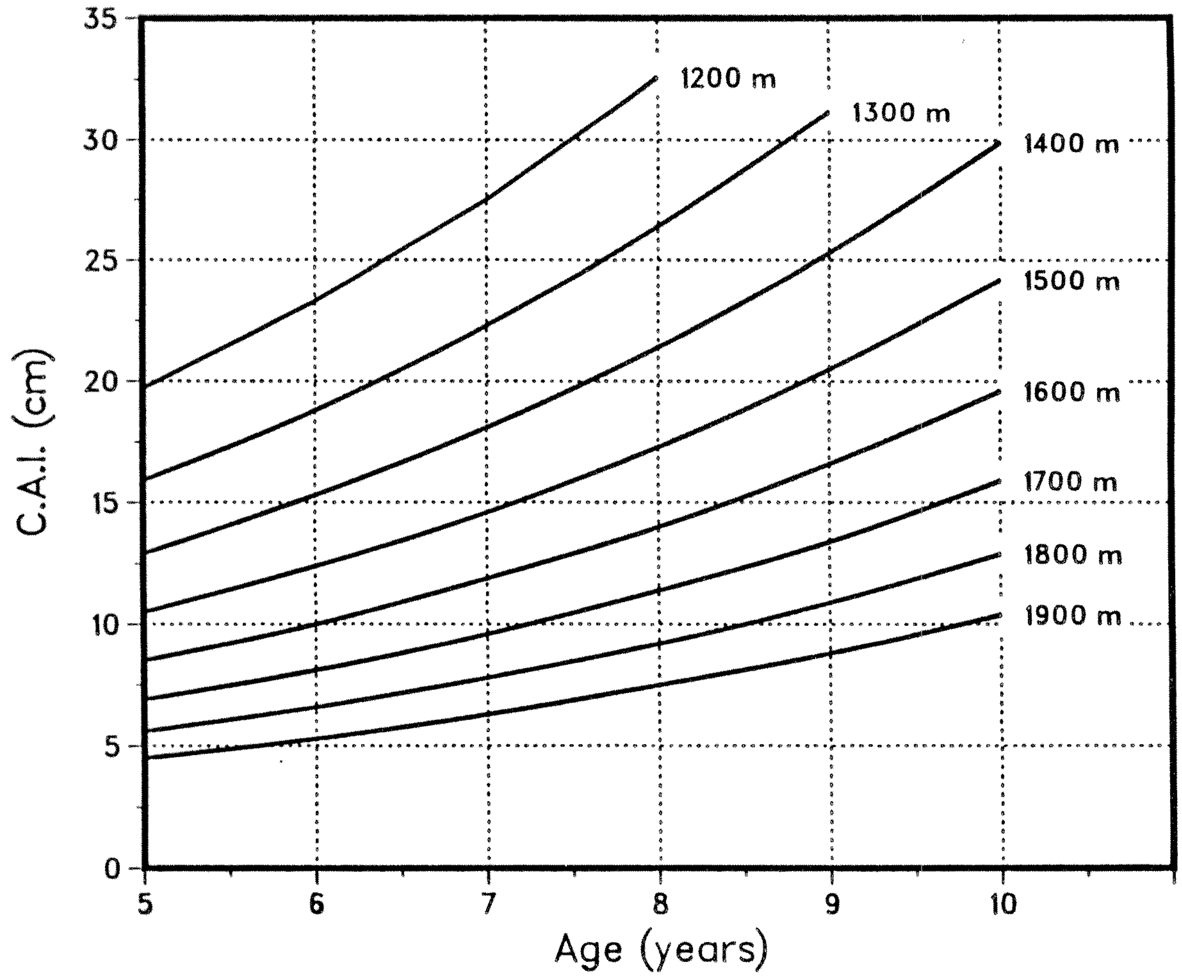


Figure 3. Current annual height increment (C.A.I.) of juvenile pine in west-central Alberta by age and elevation.

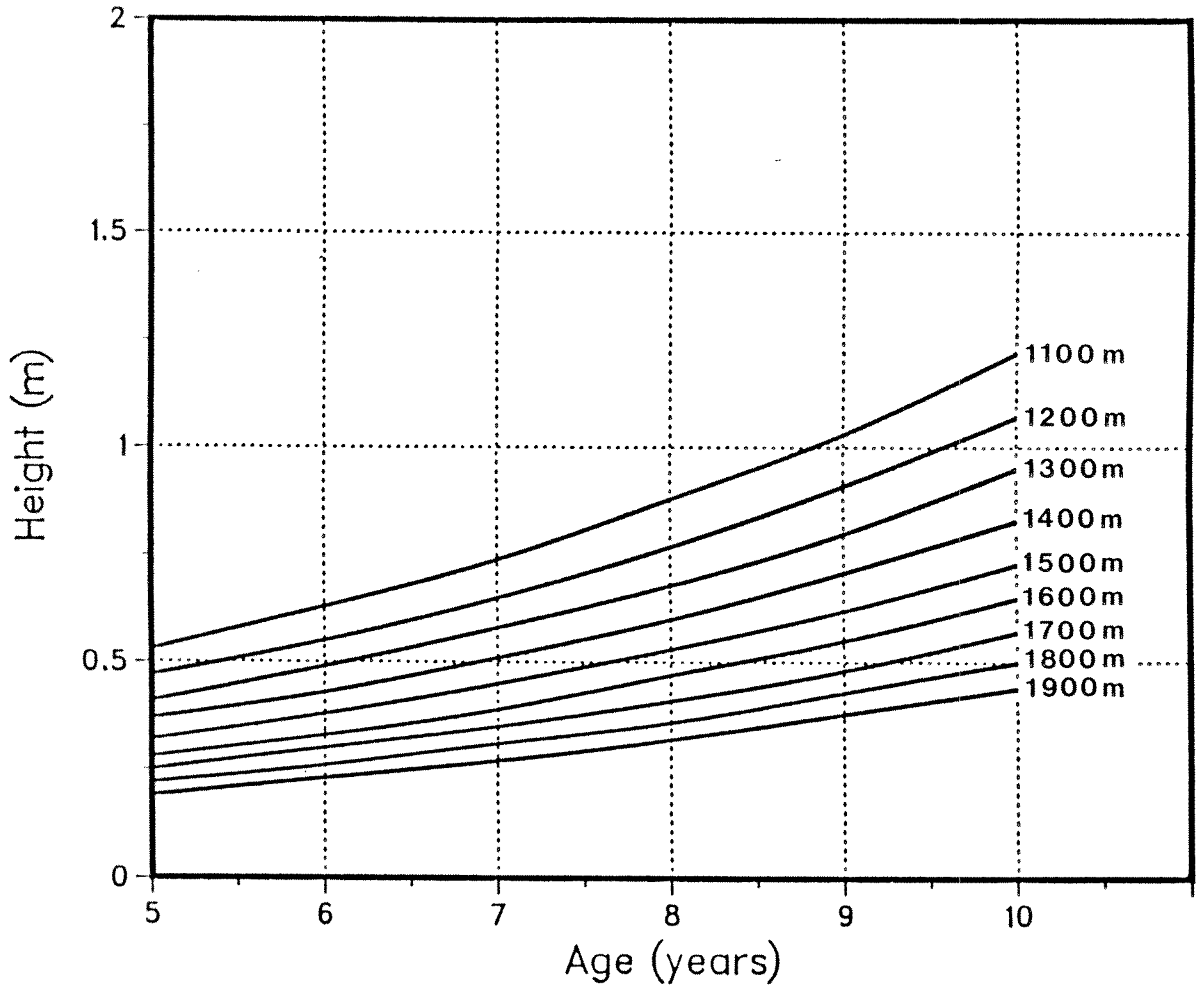


Figure 4. Height development of juvenile spruce in west-central Alberta by age and elevation.

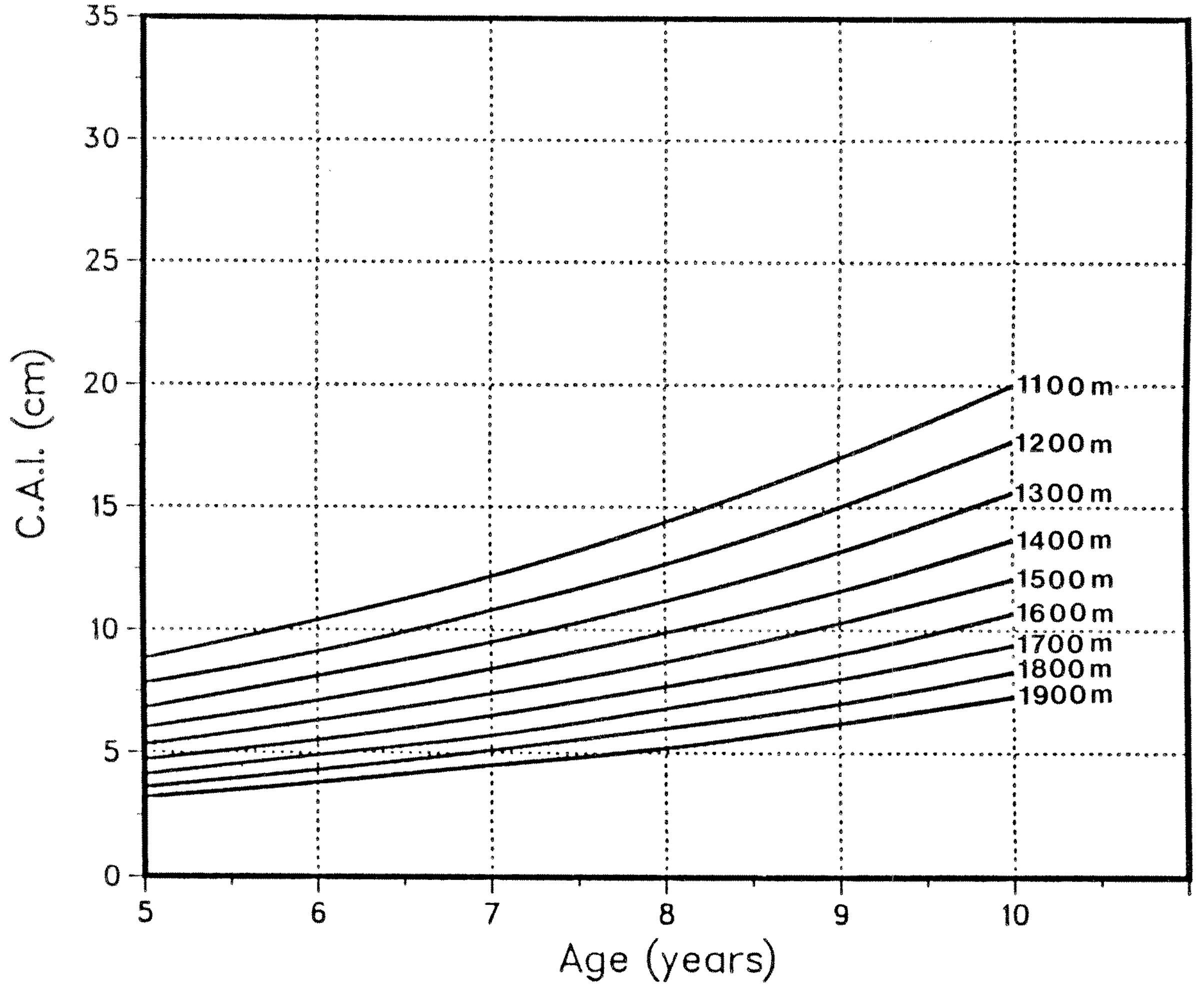


Figure 5. Current annual height increment (C.A.I.) of juvenile spruce in west-central Alberta by age and elevation.

Figures 6 to 11 summarize the data on actual heights by age for each ecoregion and species. Heights are predicted for each plot using the equations and coefficients presented earlier in this section. Appendix 1 contains these data in tabular form. Note that the predictions are generally conservative relative to the actual values, but are always within one standard deviation.

4.3 REGENERATION LAG

It was observed that, in most of the blocks studied, the average age of seedlings selected by the sampling procedure indicated a significant regeneration lag between date of disturbance and germination of the crop trees. In six of the 41 blocks sampled, reliable data on date of disturbance were not available. On a further three, average ages of seedlings were greater than the recorded time since disturbance, suggesting that these seedlings were advance growth already present when the original stands were harvested. In the remaining 32 blocks, the average age of trees sampled was 11.7 years, compared to an average of 16.6 years since disturbance. Thus an average regeneration lag of five years was indicated. It should be noted that delayed ingress in pine regeneration has been noted previously in the literature (Crossley 1976). This has important implications to growth performance expectations on reclaimed sites. Under prevailing conditions following logging or fire, ingress or planting of crop trees has generally occurred over a period of time long enough for seedling development to be influenced by physical protection, nutrient cycling, and competition created by other vegetation. Clearly further study is needed to determine the impact of regeneration lags.

Figure 6. Actual and predicted heights for pine in the boreal foothills ecoregion.

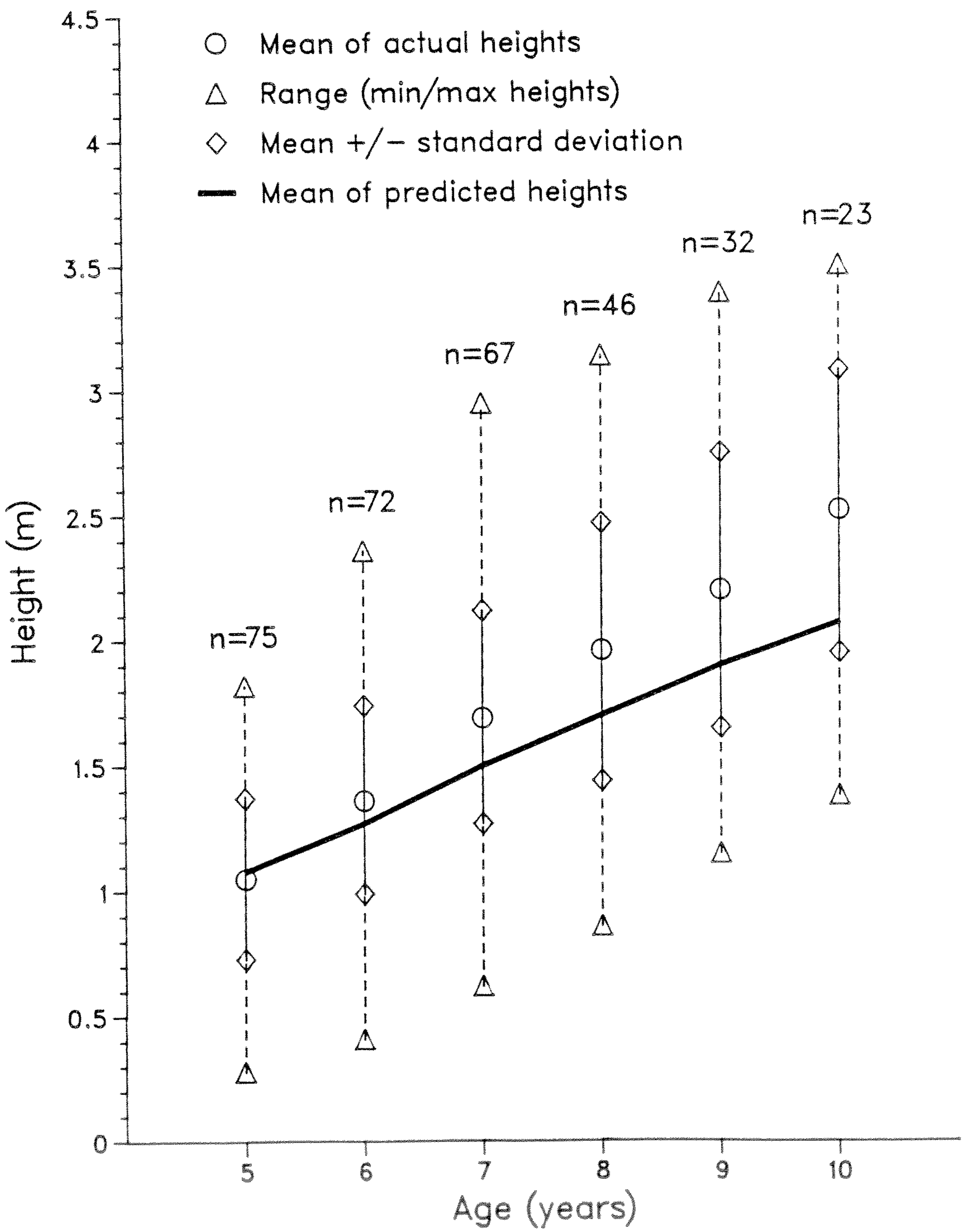


Figure 7. Actual and predicted heights for spruce in the boreal foothills ecoregion.

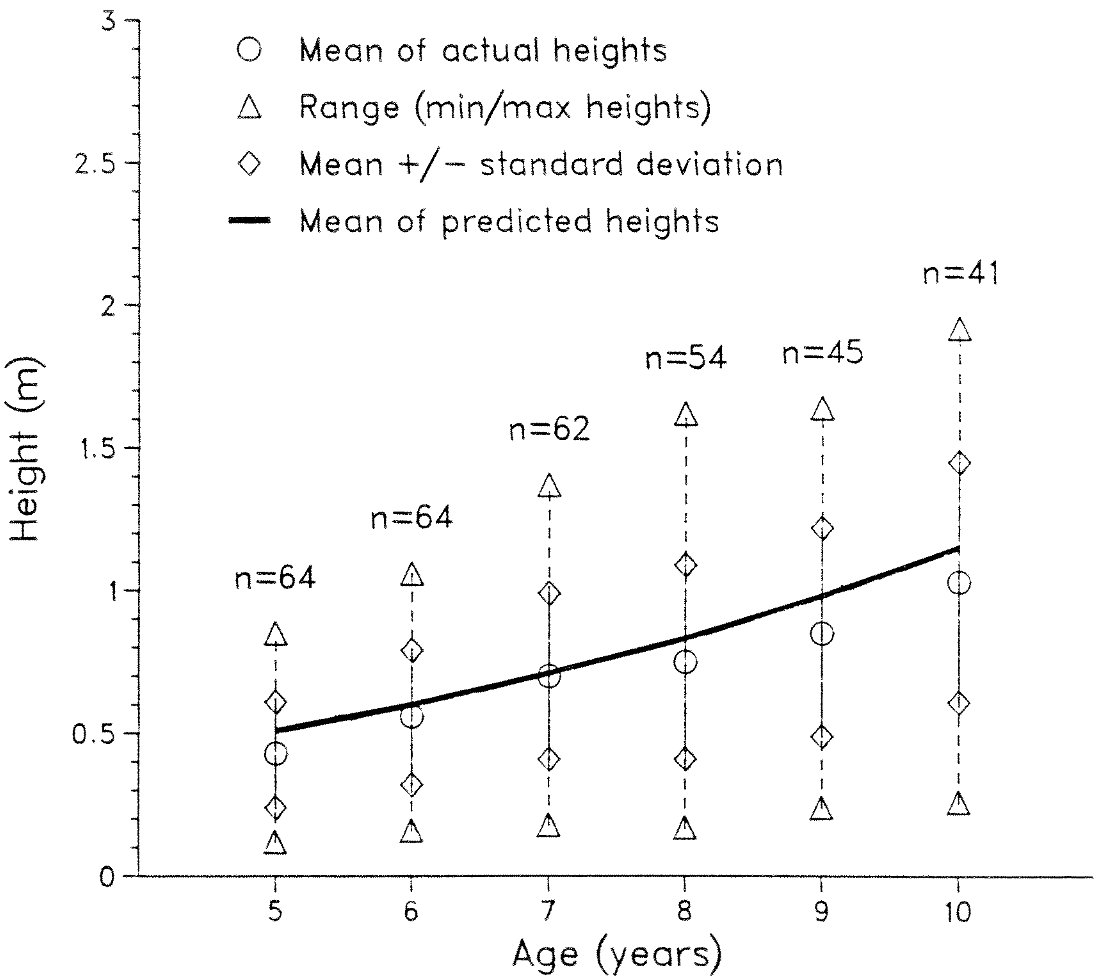


Figure 8. Actual and predicted heights for pine in the boreal uplands ecoregion.

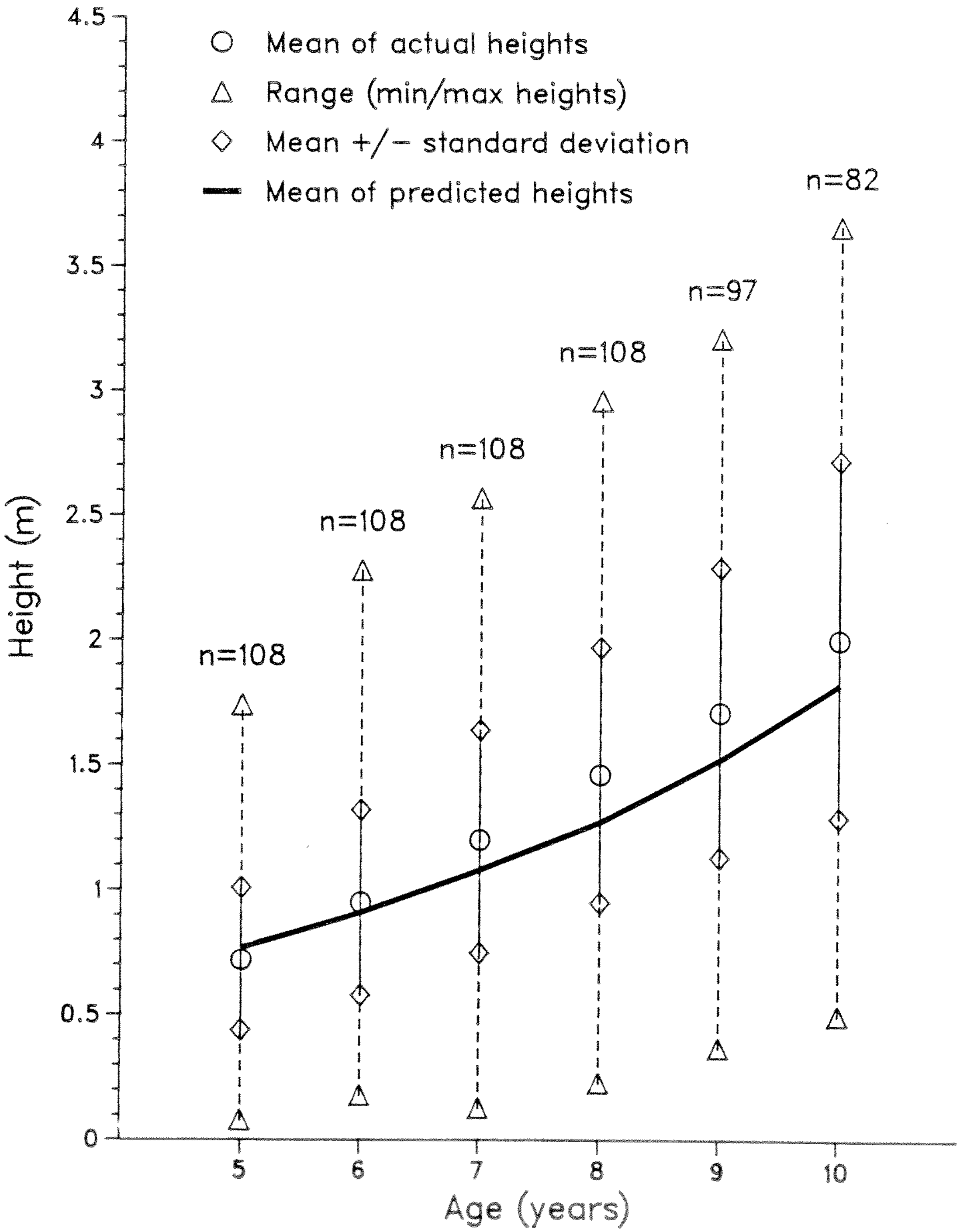


Figure 9. Actual and predicted heights for spruce in the boreal uplands ecoregion.

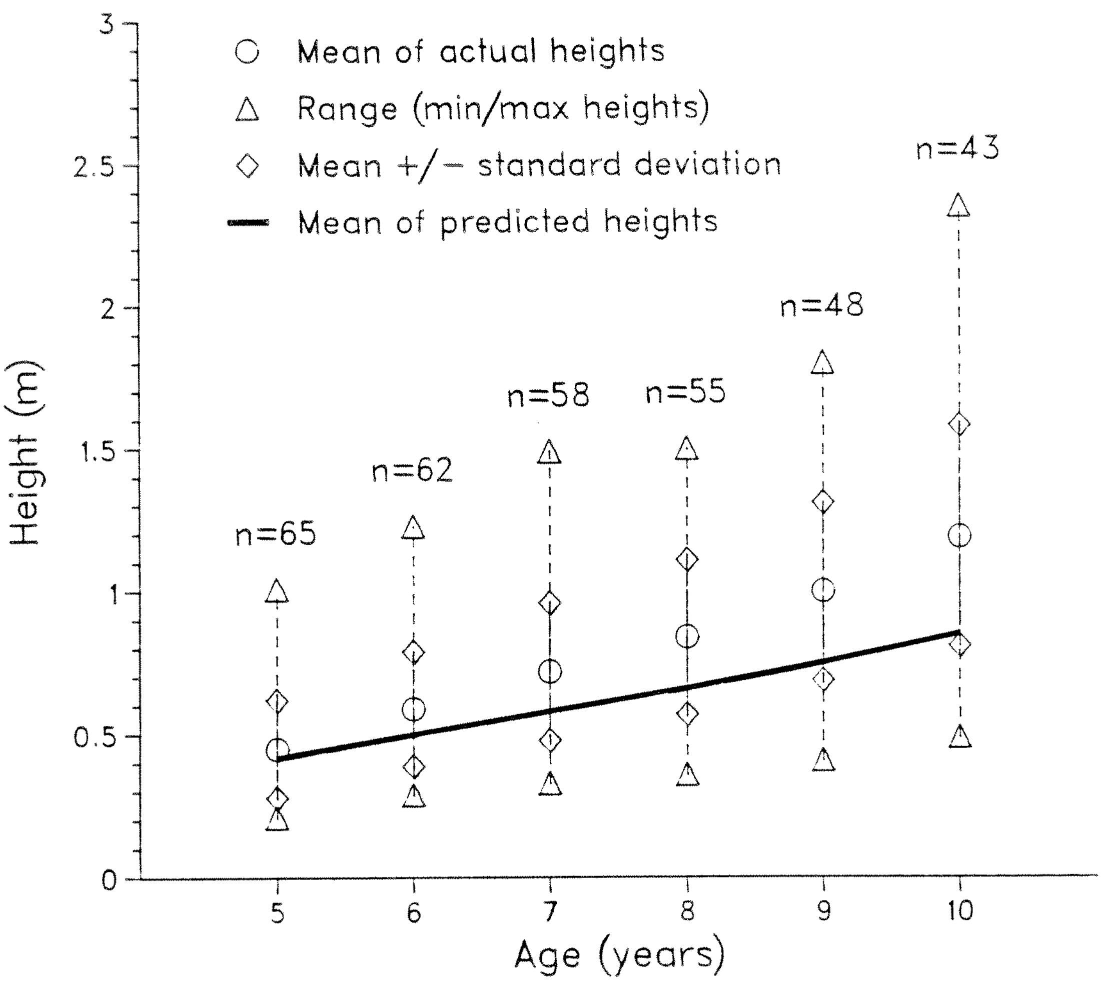


Figure 10. Actual and predicted heights for pine in the subalpine ecoregion.

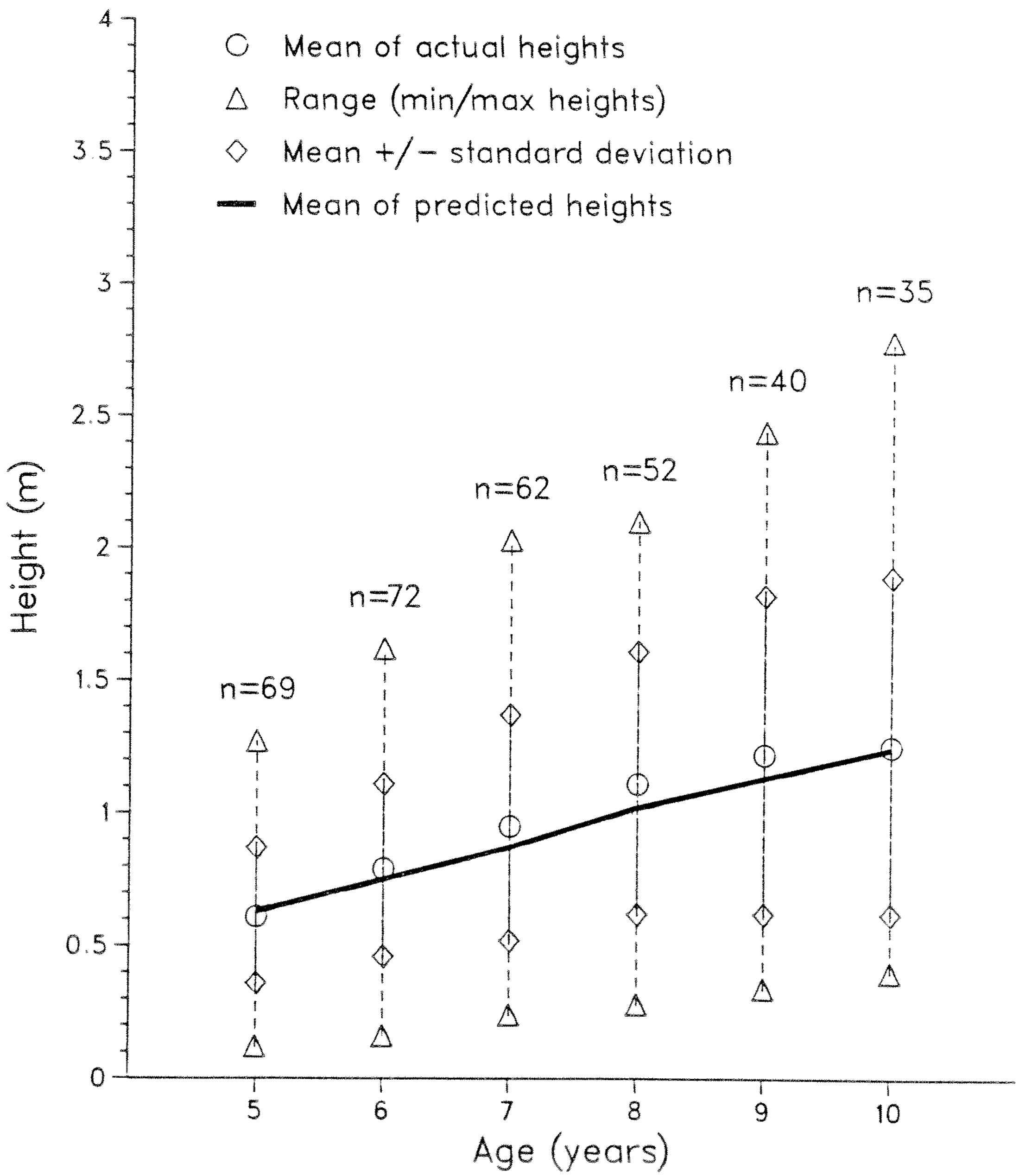
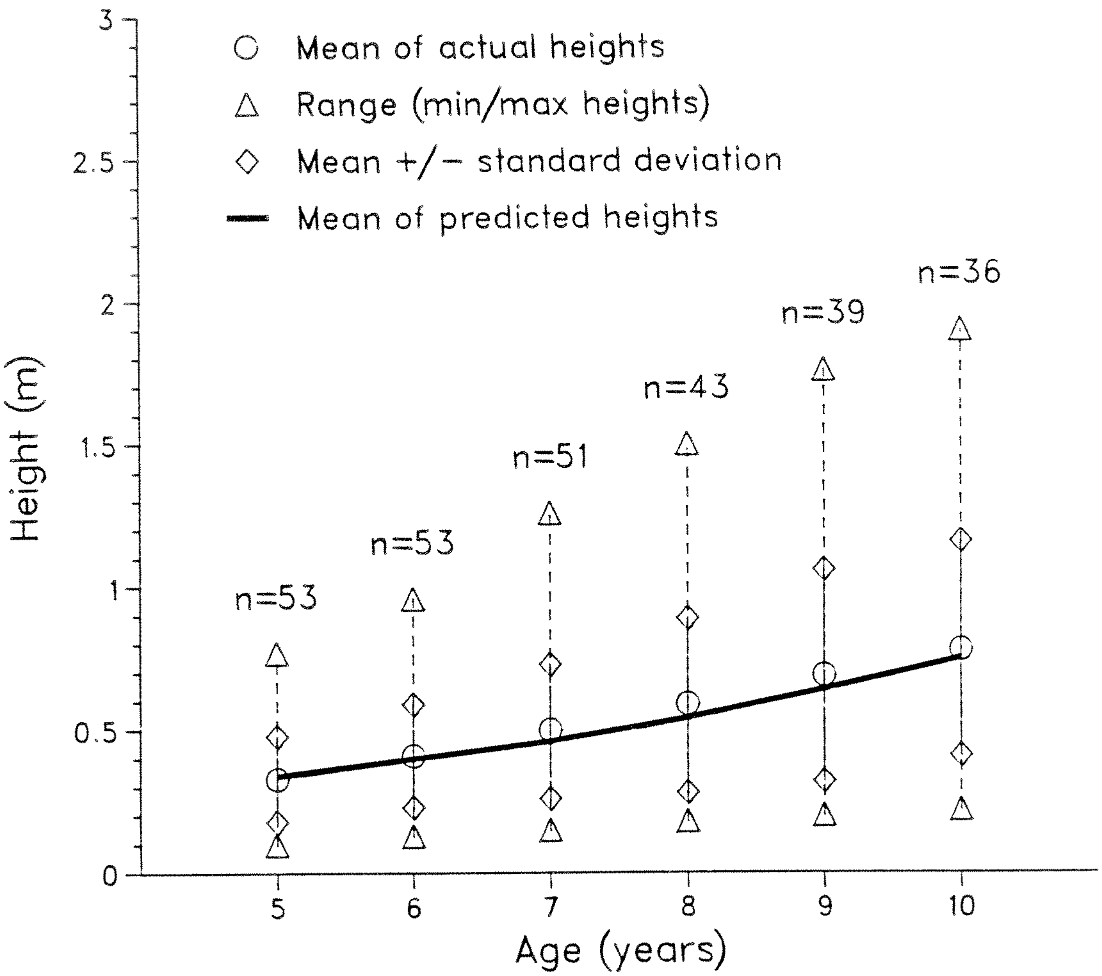


Figure 11. Actual and predicted heights for spruce in the subalpine ecoregion.



5. RECOMMENDED APPLICATION PROCEDURES

5.1 STOCKING SURVEY

Procedures and standards developed by the Alberta Forest Service, with input from the Canadian Forestry Service and the Alberta forest industry, should be used for assessing stocking levels where the end land-use is solely commercial forestry. Timing of the survey will need to be modified to incorporate both stocking and growth assessment simultaneously (see 5.2 below).

The AFS regeneration survey procedure for assessing stocking levels has been developed over a long period of time. Its implementation is supported by legislation, documentation, training programs, and general acceptance by the forest industry. No evidence was found in this study that the levels of stocking required were unachievable on any of the sites evaluated.

The provincial standard essentially requires that 80 percent of sample plots, each 0.001 ha in area, distributed systematically throughout the reforested block, must be stocked with at least one well-established tree seedling of an acceptable species. Sufficient plots are installed to achieve a sampling precision of 10 percent (12.5 percent on blocks 4 ha or less), with a minimum sampling intensity of 2.77 plots per ha.

The basic procedure is applicable where the distribution of seedlings can be considered random. An alternative procedure can be used for systematic plantations where spacing is absolutely uniform, and if the operator is willing to establish the plots immediately after planting.

The system is simply and well documented (Alberta Energy and Natural Resources 1979), and will not be further elaborated upon here.

5.2 HEIGHT GROWTH

The following procedures are recommended for incorporation into the conventional provincial regeneration survey system, as a means of determining whether achieved levels of seedling growth performance are consistent with reclamation goals based on locally-adjusted pre-disturbance growth standards.

5.2.1 Establishment of a Local Baseline

Establishment of baseline levels of growth performance for pine and spruce will require knowledge of pre-disturbance elevation, drainage class, and aspect.

Elevation above sea level can be rounded to the nearest 100 m class, and associated growth rates obtained from Tables 5 and 6.

If the prevailing drainage characteristics of the site prior to disturbance were unfavourable (i.e. either rapidly drained or poorly drained) and/or aspect was unfavourable (e.g. a south-western exposure to chinook winds) the growth rates assumed should be for one elevation class higher than indicated by the actual elevation. If a combination of unfavourable site conditions (whatever they might be) suggests further adjustment may be merited, an attempt should be made to obtain local baseline data using similar methods to those described in Section 3 of this report. In any event, if industry is prepared to develop such data locally, they should be given the opportunity of so doing.

Performance expectations for locations below the lowest elevations given in Tables 8 and 9 should be read from the 1200 m table for pine, and the 1100 m table for spruce. If the elevation class after adjustment for drainage and aspect conditions exceeds 1900 m, the application of commercial reforestation standards, at least in west-central Alberta, should be reconsidered.

5.2.2 Timing of Regeneration Survey

For reasons discussed previously (Dempster and Higginbotham 1985), height-growth assessment should not be attempted on reclaimed sites until at least five growing-seasons after outplanting. Assuming nursery stock are overwintered once before planting, the minimum seedling age evaluated will be six years.

5.2.3 Measurement and Computational Procedures

It is assumed that the planting date and seedling age will be known for the area surveyed. Measure and record to the nearest millimetre, after terminal-bud set, total height and the last two seasons' leader extension of the tallest pine or spruce seedling on each 0.001 ha plot established according to conventional survey procedures (see 5.1). Note any damage to the last two years' leader growth. Compute average total height and average annual leader extension by species. Compare average total height to the value given in Table 8 or 9 for the appropriate age and elevation class. Compare average leader extension to the current annual increment given in the table for the previous year.

5.2.4 Tolerances

If both average height and increment equal or exceed the baseline values, it may be assumed with some confidence that pre-disturbance growth rates have been achieved. If observed increments equal or exceed the table values, but total heights do not, results should be considered satisfactory providing seedlings appear generally vigorous and healthy. If observed increments are less than the baseline values, successful reforestation may be questioned even though the total cumulative height growth meets the baseline level. In this latter situation the operator should be given the benefit of the doubt providing the poor leader growth is attributable to uncontrollable climatic damage, and the satisfactory cumulative height growth has been achieved on site without temporary site improvement (i.e. fertilization).

The growth standards in this report are intended to provide quantitative goals for operational reclamation. They do not represent levels of achievement which can be reasonably expected in all situations. The setting of mandatory achievement levels is a necessarily arbitrary process in which some tolerances must be recognized for the following reasons:

1. The defined standards represent average estimates subject to statistical error based on populations

subject to variation. At least one sixth of a normally-distributed sample can be expected to fall below regression estimates by amounts exceeding the standard error of estimate (see Table 6).

2. If it is attempted to re-introduce trees at faster rates than occur after fire or logging, reduced initial growth rates may be expected (see Section 4.3).

3. Climatic events or other influences, which are beyond the control of the operator, may occur at levels of detriment not reflected by the sample data used in this study.

At the time of writing, no decision has been made by the Alberta Forest Service regarding what percentage tolerance on average provincial growth rates will be allowed in the application of provincial growth standards. It would seem equitable to adopt whatever tolerance is agreed to between the Government and the provincial forest industry, providing this can be applied to whichever baseline level is the least: the average provincial growth rate (forming the basis for the industry standard) or the local growth expectation adjusted for elevation.

6. COMPARISON OF DATA FROM RECLAIMED SITES WITH BASELINE GROWTH CURVES

Data on the actual growth performance of seedlings on reclaimed sites were provided by three participating companies. The data were compared with the baseline models following as closely as possible the proposed procedures. Results are presented and discussed in Appendix 2.

Generally, growth performance as measured by current or periodic annual increment was reasonably consistent with predicted values, especially when observed variability in the baseline data was taken into account. Total seedling height generally lagged well behind the predicted values. This observation appears related to early climatic and browsing damage, and initial planting shock. The fact that current increment is generally closer, and sometimes clearly exceeds, baseline predictions suggests that many seedlings have recovered from initial establishment problems. There seems to be little question that climatic factors exert an overriding effect on early stand growth especially at higher elevations.

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APPENDIX 1

DATA SUMMARIES AND RESULTS

There were two basic files used in this study. The first contains 457 tree records for the 440 plots containing trees over 5 years old. Information on this file consists of 59 variables including site variables, location variables and vegetation variables. It was used primarily for correlation analysis and analysis of variance.

The second file, containing tree section data, consisted of 5651 cases. It was used primarily in regression analyses.

Because of the size of these files, it was felt not worthwhile to list all cases and variables; instead, some of the more significant data are presented. However, the original data are available on request.

Table 1 describes the variables referred to in the main text. Table 2 lists the 457 cases of the tree/plot file but for only 17 of the 59 variables found in the file. Table 3 summarizes height at seven years by species and other discrete classification variables.

Tables 4 and 6 contain some of the results found in the study. Table 4 summarizes the data used to create Figures 6 to 11 of the main report. Finally, Tables 5 and 6 give the analysis of variance results for pine and spruce respectively. Pairs of groups with significant differences are also shown.

Table 1. Definition of Variables

Variable:	Labels:			
BLK	BLOCK			
PLOT				
SP	SPECIES: PL - LODGEPOLE PINE, SW - SPRUCE			
HT5YR	HEIGHT AT 5 YEARS			
HT7YR	" " 7 "			
HT10YR	" " 10 "			
SOURCE	P = PLANTED, S (OR ' ') = SEEDED, U = UNCERTAIN			
STEEP	SLOPE DEGREES			
ASPECT				
TOPO	TOPOGRAPHIC CLASS			
	1	FLAT	2	GENTLE
	3	MEDIUM	4	STEEP
	5	V. STEEP		
DRAIN	DRAINAGE CLASS			
	1	EXCESSIVE	2	RAPID
	3	MODERATE	4	POOR
	5	V. POOR		
EXP	EXPOSURE CLASS			
	1	V. EXPOSED	2	MOD. EXPOSED
	3	INTERMEDIATE	4	MOD. PROTECTTED
	5	PROTECTED		
ROOT	ROOTING DEPTH LIMITING			
	Y	YES	N	NO
ECOREG	ECOREGION			
	6	SUBALPINE	9	BOREAL FOOTHILLS
	10	BOREAL UPLANDS		
TRT	TREATMENT			
	P	PLANTED	B	BURNED
	S	SCARIFIED	R	RIPPED
	D	DRAGGED	N	NONE
ELEV	ELEVATION (M)			
AREA	1	WEST CENTRAL ALBERTA	3	SW ALBERTA (COLEMAN)

Variables not shown:

Percent Vegetative Cover (for trees, shrubs, forbs, grasses and mosses)
Tree densities by species
Legal location (TWP, RGE, M, LSECT)
Aspect (transformed)
Mapped soil series and productivity

Table 2. Summary of Major Variables by Plot and Species

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXP	ROOT	SOURCE	TRT	ECOREG	AREA
1	1	PL	.77	1.39	2.60	1356.38	30	103	4	2	3	N	S	P	9	1
1	2	PL	.71	1.49	2.42	1356.38	30	147	4	2	3	N	U	P	9	1
1	3	PL	.88	1.75	2.84	1356.38	25	145	4	2	3	N	U	P	9	1
1	5	PL	.48	.79	1.49	1356.38	30	115	4	2	2	N	U	P	9	1
1	6	PL	.28	.62	1.39	1356.38	30	121	4	2	2	N	U	P	9	1
1	7	PL	.46	.85	1.45	1356.38	20	103	4	2	2	N	U	P	9	1
1	8	PL	1.46	2.28	3.50	1356.38	5	39	2	3	4	N	U	P	9	1
1	9	PL	1.14	1.51	2.34	1356.38	15	90	3	3	4	N	U	P	9	1
1	9	SW	.46	.69	1.20	1356.38	15	90	3	3	4	N	S	P	9	1
1	10	PL	.75	1.29	2.12	1356.38	10	105	3	3	4	N	U	P	9	1
1	10	SW	.21	.34	.54	1356.38	10	105	3	3	4	N	S	P	9	1
1	11	PL	1.32	1.74	2.72	1356.38	0	323	1	2	5	N	P	P	9	1
1	12	PL	.83	1.70	2.41	1356.38	5	21	2	2	4	N	P	P	9	1
1	13	PL	.64	1.16	2.21	1356.38	5	335	2	2	4	N	P	P	9	1
1	13	SW	.23	.48	.73	1356.38	5	335	2	2	4	N	U	P	9	1
2	1	PL	1.10	1.85	2.76	1341.14	2	93	1	3	2	N	U	P	9	1
2	2	PL	1.32	2.08	2.78	1341.14	0	999	1	3	2	N	P	P	9	1
2	3	PL	.84	1.41	1.85	1341.14	10	253	2	3	3	N	P	P	9	1
2	4	PL	1.14	1.79	2.67	1341.14	0	999	1	3	2	N	P	P	9	1
2	5	PL	1.68	2.16	3.03	1341.14	10	91	2	3	2	N	P	P	9	1
2	6	PL	1.49	2.24	3.09	1341.14	10	91	2	3	2	N	P	P	9	1
2	7	PL	.57	.96	.	1341.14	5	75	2	2	2	N	U	P	9	1
2	8	PL	.91	1.87	3.22	1341.14	5	91	2	3	2	N	U	P	9	1
2	9	PL	.83	1.52	2.72	1341.14	10	45	2	3	2	N	U	P	9	1
3	1	SW	1.01	1.49	1.56	1584.98	3	97	1	3	1	N	U	S	10	1
3	2	SW	.53	.72	1.32	1584.98	0	999	1	3	1	N	U	S	10	1
3	3	SW	.51	.88	1.68	1584.98	0	999	1	3	1	N	U	S	10	1
3	4	SW	.70	.86	1.04	1584.98	10	105	2	3	1	N	U	S	10	1
3	5	SW	.23	.36	.68	1584.98	5	145	2	3	1	N	U	S	10	1
3	6	SW	.40	.72	1.14	1584.98	0	999	1	3	1	N	U	S	10	1
3	7	SW	.63	.99	1.77	1584.98	5	165	2	3	1	N	U	S	10	1
3	8	SW	.42	.58	1.02	1584.98	3	25	1	3	1	N	U	S	10	1
3	9	SW	.41	.64	.90	1584.98	0	999	1	3	1	N	U	S	10	1
3	10	SW	.38	.64	.96	1584.98	0	999	1	3	1	N	U	S	10	1
3	11	SW	.44	.70	1.36	1584.98	0	999	1	3	1	N	U	S	10	1
3	12	SW	.34	.44	.92	1584.98	0	999	1	3	1	N	U	S	10	1
4	2	PL	.47	.78	1.36	1584.98	0	999	1	3	1	N	U	P	10	1
4	3	PL	.57	.88	1.50	1584.98	0	999	1	3	1	N	U	P	10	1
4	4	PL	.60	.84	1.32	1584.98	0	999	1	3	1	N	P	P	10	1
4	5	PL	.54	.85	1.40	1584.98	0	999	1	3	1	N	P	P	10	1
4	6	PL	.69	1.02	1.78	1584.98	0	999	1	3	1	N	U	P	10	1
4	7	PL	.37	.56	1.06	1584.98	0	999	1	3	1	N	U	P	10	1
4	9	PL	.62	.97	1.45	1584.98	0	999	1	3	1	N	P	P	10	1
4	10	PL	.62	1.04	1.84	1584.98	0	999	1	3	1	N	P	P	10	1
4	11	PL	.39	.66	1.69	1584.98	0	999	1	3	1	N	P	P	10	1
4	12	PL	.75	1.14	1.67	1584.98	0	999	1	3	1	N	P	P	10	1
4	13	PL	.36	.58	1.23	1584.98	0	999	1	3	1	N	P	P	10	1
4	14	PL	.40	.71	1.60	1584.98	0	999	1	3	1	N	P	P	10	1
5	1	SW	.25	.38	.71	1524.02	0	999	1	3	1	N	P	S	10	1
5	4	SW	.33	.35	.49	1524.02	1	165	2	4	1	N	U	S	10	1
5	5	SW	.24	.45	.85	1524.02	10	137	2	4	2	N	S	S	10	1
5	6	SW	.33	.61	1.22	1524.02	5	135	2	4	1	N	U	S	10	1
5	7	SW	.23	.36	.60	1524.02	5	135	2	4	1	N	U	S	10	1
5	8	SW	.27	.40	.87	1524.02	5	135	2	4	1	N	U	S	10	1
6	1	PL	.67	1.14	1.76	1524.02	15	113	2	3	1	N	U	S	10	1
6	2	PL	.72	.99	1.40	1524.02	10	135	2	3	1	N	P	S	10	1
6	3	PL	.40	.62	1.10	1524.02	0	999	2	3	1	N	P	S	10	1
6	4	PL	.26	.46	.97	1524.02	10	107	2	3	1	N	P	S	10	1
6	5	PL	.54	.78	1.42	1524.02	5	130	2	3	1	N	P	S	10	1

Table 2 (cont).

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXP	ROOT	SOURCE	TRT	ECOREG	AREA
6	6	PL	.30	.76	1.24	1524.02	30	167	4	2	1	N	U	S	10	1
6	7	PL	.51	.77	1.17	1524.02	5	125	2	3	1	N	P	S	10	1
6	8	PL	.67	1.09	1.83	1524.02	10	125	3	2	1	N	U	S	10	1
6	9	PL	.68	1.08	1.99	1524.02	5	135	2	3	1	N	P	S	10	1
6	10	PL	.49	.93	1.76	1524.02	5	155	2	3	1	N	P	S	10	1
6	11	PL	.45	.80	1.61	1524.02	5	125	2	3	1	N	P	S	10	1
6	13	SW	.33	.67	1.22	1524.02	5	145	2	3	1	N	U	S	10	1
7	1	PL	1.18	1.55	2.53	1280.18	15	319	3	2	3	N	P	S	10	1
7	2	PL	.63	1.07	.	1280.18	15	299	3	2	4	N	U	S	10	1
7	3	PL	1.01	1.77	2.62	1280.18	15	305	3	2	4	N	U	S	10	1
7	4	SW	.39	.71	1.31	1280.18	0	999	1	4	4	N	U	S	10	1
7	5	PL	.60	.97	1.65	1280.18	15	329	3	2	4	N	P	S	10	1
7	6	PL	.79	1.44	2.69	1280.18	5	295	2	3	4	N	P	S	10	1
7	7	PL	1.00	1.63	2.76	1280.18	50	330	5	3	4	N	P	S	10	1
7	8	PL	.50	.77	1.30	1280.18	5	0	2	3	4	N	U	S	10	1
7	9	PL	.95	1.31	.	1280.18	15	339	3	3	4	N	P	S	10	1
7	10	SW	.58	.80	1.31	1280.18	15	7	3	3	4	N	S	S	10	1
7	11	SW	.36	.62	1.11	1280.18	3	355	2	3	4	N	S	S	10	1
7	12	PL	.94	1.31	2.21	1280.18	3	25	1	3	4	N	U	S	10	1
8	1	SW	.69	.96	1.49	1310.66	0	999	1	3	1	Y	S	S	10	1
8	2	SW	.35	.61	1.31	1310.66	0	999	1	3	1	Y	S	S	10	1
8	5	PL	.96	1.45	2.38	1310.66	0	999	1	4	1	N	U	S	10	1
8	6	PL	.80	1.25	2.40	1310.66	0	999	1	4	1	N	U	S	10	1
8	7	PL	.66	1.20	1.97	1310.66	0	999	1	3	1	N	U	S	10	1
8	8	PL	.69	1.27	2.00	1310.66	0	999	1	3	1	N	U	S	10	1
8	8	SW	.28	.56	1.19	1310.66	0	999	1	3	1	N	U	S	10	1
8	9	PL	.88	1.55	2.86	1310.66	0	999	1	3	1	N	U	S	10	1
8	10	PL	.61	1.23	2.03	1310.66	0	999	1	3	1	N	U	S	10	1
8	11	PL	.53	1.09	2.12	1310.66	0	999	1	3	1	N	U	S	10	1
8	11	SW	.39	.68	1.42	1310.66	0	999	1	3	1	N	U	S	10	1
9	1	PL	1.21	1.47	2.12	1280.18	1	190	1	3	2	N	U	S	10	1
9	2	PL	.95	1.74	2.89	1280.18	5	215	2	4	2	N	U	S	10	1
9	2	SW	.53	.90	1.92	1280.18	5	215	2	4	2	N	U	S	10	1
9	3	PL	.80	1.11	1.76	1280.18	3	215	1	4	2	N	U	S	10	1
9	3	SW	.39	.54	1.14	1280.18	3	215	1	4	2	N	U	S	10	1
9	4	PL	.80	1.22	2.13	1280.18	10	227	2	4	2	N	U	S	10	1
9	5	PL	.73	1.28	2.45	1280.18	12	193	2	3	2	N	U	S	10	1
9	7	PL	1.42	2.45	3.43	1280.18	10	287	3	2	5	N	U	S	10	1
9	8	PL	.70	1.10	1.81	1280.18	10	290	2	2	5	N	U	S	10	1
9	8	SW	.52	.85	1.41	1280.18	10	290	2	2	5	N	U	S	10	1
9	9	PL	.80	1.43	2.66	1280.18	30	267	4	2	5	N	U	S	10	1
9	9	SW	.43	.68	1.34	1280.18	30	267	4	2	5	N	U	S	10	1
10	1	PL	.53	.84	1.68	1447.82	15	95	3	4	2	Y	U	S	6	1
10	2	PL	.50	.83	1.48	1447.82	15	95	3	4	2	N	U	S	6	1
10	3	PL	.58	1.05	2.06	1447.82	10	99	3	4	2	Y	U	S	6	1
10	4	PL	.60	1.24	2.34	1447.82	5	91	2	4	2	Y	U	S	6	1
10	5	PL	.44	1.02	1.93	1447.82	5	75	3	4	2	Y	U	S	6	1
10	6	PL	.32	.52	1.00	1447.82	5	215	2	4	4	Y	U	S	6	1
10	7	PL	.48	1.03	1.62	1447.82	3	205	2	4	4	N	U	S	6	1
10	7	SW	.19	.35	.57	1447.82	3	205	2	4	4	N	S	S	6	1
11	1	PL	.38	.60	.87	1722.14	40	11	4	2	3	N	S	B	6	1
11	1	SW	.26	.40	.63	1722.14	40	11	4	2	3	N	S	B	6	1
11	2	PL	.40	.53	.91	1722.14	30	5	4	2	3	Y	S	B	6	1
11	3	PL	.50	.63	.78	1722.14	30	21	4	2	3	N	S	B	6	1
11	3	SW	.25	.33	.48	1722.14	30	21	4	2	3	N	S	B	6	1
11	4	PL	.38	.52	.68	1722.14	30	25	4	2	3	N	S	B	6	1
11	4	SW	.25	.38	.66	1722.14	30	25	4	2	3	N	S	B	6	1
11	5	PL	.31	.45	.57	1722.14	3	21	2	2	4	Y	S	B	6	1
11	6	PL	.40	.77	1.07	1722.14	5	7	2	2	4	N	S	B	6	1

Table 2 (cont).

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXPO	ROOT	SOURCE	TRT	ECOREG	AREA
11	6	SW	.28	.38	.66	1722.14	5	7	2	2	4	N	S	B	6	1
11	7	PL	.45	.64	.76	1722.14	55	25	5	2	4	N	S	B	6	1
11	8	PL	.22	.47	.83	1722.14	50	29	5	2	3	N	S	B	6	1
11	9	PL	.28	.42	.92	1722.14	60	21	5	2	4	Y	S	B	6	1
11	10	PL	.42	.61	.92	1722.14	50	17	5	2	4	N	S	B	6	1
12	1	SW	.24	.33	.47	1722.14	10	263	3	3	4	N	S	B	6	1
12	3	SW	.30	.53	.71	1722.14	20	226	3	3	4	N	S	B	6	1
12	5	SW	.29	.43	.70	1722.14	20	283	3	3	4	N	S	B	6	1
12	6	SW	.22	.30	.37	1722.14	30	243	3	3	4	N	S	B	6	1
13	3	SW	.47	.68	1.13	1127.77	5	181	2	3	3	N	S	S	9	1
13	4	SW	.51	.84	1.51	1127.77	15	173	2	3	2	N	S	S	9	1
13	5	SW	.31	.59	.87	1127.77	10	209	2	3	3	N	S	S	9	1
13	6	SW	.46	.90	1.41	1127.77	15	185	2	3	3	N	S	S	9	1
13	7	SW	.21	.40	.78	1127.77	5	180	2	3	4	N	S	S	9	1
13	8	SW	.25	.34	.44	1127.77	10	173	2	2	3	N	S	S	9	1
13	9	SW	.43	.74	1.29	1127.77	5	200	2	2	3	N	S	S	9	1
13	10	SW	.25	.52	.81	1127.77	5	187	1	2	3	N	S	S	9	1
13	11	SW	.20	.32	.89	1127.77	3	190	1	2	3	N	S	S	9	1
13	12	SW	.15	.19	.35	1127.77	2	169	1	2	3	N	S	S	9	1
14	1	PL	.	.	.49	1402.10	0	999	1	3	5	N	S	N	10	1
14	4	PL	.37	.64	.	1402.10	0	999	1	4	5	N	S	N	10	1
14	6	PL	.10	.18	.32	1402.10	0	999	1	3	5	N	S	N	10	1
14	12	PL	.46	.49	.54	1402.10	0	999	1	4	5	N	S	N	10	1
14	16	PL	.22	.31	.42	1402.10	0	999	1	4	5	N	S	N	10	1
14	17	PL	.31	.43	.50	1402.10	0	999	1	3	5	N	S	N	10	1
14	18	PL	.34	.63	1.39	1402.10	0	999	1	3	5	N	S	N	10	1
14	19	PL	.29	.39	.54	1402.10	0	999	1	3	5	N	S	N	10	1
14	20	PL	.36	.47	.74	1402.10	0	999	1	3	5	N	S	N	10	1
15	2	PL	1.22	2.15	3.49	1219.21	1	248	1	3	4	N	S	S	10	1
15	3	PL	.88	1.81	3.62	1219.21	1	250	1	3	4	N	S	S	10	1
15	4	PL	1.74	2.57	3.37	1219.21	5	237	2	3	4	N	S	S	10	1
15	5	PL	1.39	2.13	3.09	1219.21	15	265	3	3	4	N	S	S	10	1
15	6	SW	.45	.68	1.32	1219.21	1	247	1	3	4	N	S	S	10	1
15	7	PL	1.32	2.09	3.31	1219.21	3	261	2	3	4	N	S	S	10	1
15	8	PL	1.19	2.30	3.59	1219.21	5	265	2	3	4	N	S	S	10	1
15	9	PL	1.27	2.18	3.04	1219.21	3	247	2	3	4	N	S	S	10	1
15	9	SW	.48	.91	2.35	1219.21	3	247	2	3	4	N	S	S	10	1
15	10	PL	1.48	2.33	3.66	1219.21	0	226	1	3	4	N	S	S	10	1
15	11	PL	.88	1.66	2.99	1219.21	3	261	1	3	4	N	S	S	10	1
15	12	PL	1.22	1.90	2.97	1219.21	3	241	1	3	4	N	S	S	10	1
16	1	PL	.58	.99	1.66	1828.82	10	248	2	2	3	N	S	B	6	1
16	1	SW	.13	.18	.32	1828.82	10	248	2	2	3	N	S	B	6	1
16	2	SW	.16	.26	.43	1828.82	15	227	3	2	4	N	S	B	6	1
16	3	SW	.16	.36	.57	1828.82	20	231	3	2	4	N	S	B	6	1
16	4	SW	.10	.18	.44	1828.82	15	245	3	2	4	N	S	B	6	1
16	5	SW	.27	.41	.66	1828.82	10	211	3	2	3	N	S	B	6	1
16	6	SW	.32	.44	.70	1828.82	10	197	2	2	3	N	S	B	6	1
17	1	PL	.10	.13	.50	1524.02	15	90	3	2	1	Y	S	S	10	1
17	2	PL	.33	.71	1.25	1524.02	15	90	3	2	2	Y	S	S	10	1
17	2	SW	.30	.54	.87	1524.02	15	90	3	2	2	Y	S	S	10	1
17	3	PL	.37	.57	1.05	1524.02	20	90	3	2	2	Y	S	S	10	1
17	4	PL	.	.46	1.19	1524.02	15	95	3	2	2	Y	S	S	10	1
17	5	PL	.64	1.10	1.99	1524.02	18	85	3	2	3	Y	S	S	10	1
17	5	SW	.29	.47	.93	1524.02	18	85	3	2	3	Y	S	S	10	1
17	6	PL	.61	.84	1.57	1524.02	30	111	3	2	3	Y	S	S	10	1
17	7	PL	.42	.75	1.37	1524.02	20	145	3	2	3	Y	S	S	10	1
18	1	PL	.75	1.43	.	1066.81	5	15	2	2	2	N	S	S	9	1
18	2	PL	1.41	2.24	.	1066.81	0	999	1	3	1	N	S	S	9	1
18	3	PL	1.41	.	.	1066.81	0	226	1	2	1	N	S	S	9	1

Table 2 (cont).

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXP	ROOT	SOURCE	TRT	ECOREG	AREA
18	4	PL	1.16	.	.	1066.81	0	999	1	2	1	N	S	S	9	1
18	5	PL	1.01	1.92	.	1066.81	0	999	1	2	1	N	S	S	9	1
18	6	PL	1.58	2.44	.	1066.81	0	999	0	0	0	0	S	S	9	1
18	7	PL	.94	1.83	.	1066.81	0	999	1	2	5	N	S	S	9	1
18	8	PL	1.38	.	.	1066.81	0	999	1	2	5	N	S	S	9	1
18	9	PL	1.04	1.72	.	1066.81	0	999	1	2	5	Y	S	S	9	1
18	10	PL	.86	1.59	.	1066.81	0	999	1	3	5	N	S	S	9	1
18	11	PL	1.08	2.05	.	1066.81	0	999	2	2	5	Y	S	S	9	1
18	12	PL	.89	1.56	.	1066.81	0	999	1	2	5	N	S	S	9	1
19	1	PL	1.68	.	.	1066.81	0	999	1	2	2	N	S	S	9	1
19	2	PL	1.50	.	.	1066.81	0	999	2	2	2	N	S	S	9	1
19	3	PL	1.31	2.34	.	1066.81	5	85	2	2	2	N	S	S	9	1
19	4	PL	1.29	2.03	.	1066.81	5	105	2	2	2	N	S	S	9	1
19	5	PL	1.31	2.05	.	1066.81	0	226	1	2	1	N	S	S	9	1
19	6	PL	.91	1.55	.	1066.81	5	131	2	2	2	N	S	S	9	1
19	7	PL	1.03	1.78	.	1066.81	3	115	2	3	4	Y	S	S	9	1
19	8	SW	.50	.84	.	1066.81	3	115	2	3	4	N	S	S	9	1
19	9	SW	.39	.76	.	1066.81	5	115	2	3	2	Y	S	S	9	1
19	10	SW	.79	1.04	.	1066.81	5	115	2	3	2	Y	S	S	9	1
19	11	SW	.40	.58	.	1066.81	7	115	2	3	2	Y	S	S	9	1
19	12	SW	.56	.95	.	1066.81	5	115	2	3	2	N	S	S	9	1
19	13	PL	.85	1.56	.	1066.81	0	999	1	3	2	N	S	S	9	1
20	2	SW	.70	1.06	.	1005.85	10	181	2	2	2	N	U	P	9	1
20	3	PL	.77	1.33	.	1005.85	5	175	2	2	2	N	U	P	9	1
20	4	SW	.56	.97	.	1005.85	5	175	2	2	2	N	U	P	9	1
20	5	SW	.65	1.17	.	1005.85	0	999	1	2	1	N	U	P	9	1
20	6	SW	.46	.89	.	1005.85	0	999	1	2	1	N	U	P	9	1
20	7	PL	1.33	.	.	1005.85	0	999	1	2	1	N	S	P	9	1
20	7	SW	.71	1.09	.	1005.85	0	999	1	2	1	N	U	P	9	1
20	8	SW	.85	1.25	.	1005.85	3	191	2	3	2	N	P	P	9	1
20	9	SW	.43	.52	.	1005.85	0	173	2	4	2	N	U	P	9	1
20	10	SW	.40	.66	.	1005.85	1	174	2	3	2	N	P	P	9	1
20	12	PL	.97	.	.	1005.85	0	999	1	2	2	Y	P	P	9	1
20	12	SW	.82	1.37	.	1005.85	0	999	1	2	2	Y	U	P	9	1
20	13	SW	.	.	.	1005.85	0	999	1	3	2	N	S	P	9	1
20	14	SW	.77	1.20	.	1005.85	0	999	1	2	2	Y	U	P	9	1
21	1	SW	.38	.80	.	1097.29	10	253	3	2	2	N	S	S	10	1
21	2	SW	.34	.58	.	1097.29	5	45	2	2	2	N	S	S	10	1
21	3	PL	.66	.97	1.62	1097.29	8	121	2	2	2	N	S	S	10	1
21	5	SW	.52	1.00	.	1097.29	5	225	2	2	2	N	S	S	10	1
21	7	SW	.64	1.03	1.76	1097.29	10	225	2	2	2	N	S	S	10	1
22	1	SW	.43	.70	1.40	1097.29	3	225	2	3	4	N	S	S	9	1
22	2	SW	.64	.98	.	1097.29	3	220	2	3	3	N	S	S	9	1
22	3	SW	.58	.88	1.64	1097.29	8	315	2	3	5	N	S	S	9	1
22	4	SW	.51	.82	1.48	1097.29	5	260	2	3	4	N	S	S	9	1
22	5	SW	.49	.81	1.44	1097.29	3	357	2	3	4	N	S	S	9	1
22	6	SW	.42	.67	1.19	1097.29	5	223	2	4	3	N	S	S	9	1
22	7	PL	1.43	2.32	.	1097.29	5	245	1	3	4	N	S	S	9	1
22	7	SW	.47	1.01	1.92	1097.29	5	245	1	3	4	N	S	S	9	1
23	1	SW	.63	1.05	1.81	1097.29	10	235	2	2	2	N	S	P	9	1
23	2	SW	.61	.76	1.05	1097.29	45	153	4	2	3	N	S	P	9	1
23	4	SW	.69	1.23	.	1097.29	20	191	3	2	4	N	S	P	9	1
23	5	PL	.68	1.09	.	1097.29	0	165	3	2	2	N	S	P	9	1
23	6	SW	.55	.	.	1097.29	0	999	1	3	1	N	S	P	9	1
23	7	SW	.32	.55	.	1097.29	3	65	2	3	3	N	S	P	9	1
23	8	SW	.57	1.01	.	1097.29	15	65	3	3	4	N	S	P	9	1
23	9	SW	.47	.79	1.34	1097.29	15	105	2	3	4	N	S	P	9	1
23	10	SW	.50	.81	1.36	1097.29	50	55	2	4	4	N	S	P	9	1
24	1	PL	1.09	1.83	2.99	944.89	0	999	1	2	1	N	U	P	9	1

Table 2 (cont).

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXP	ROOT	SOURCE	TRT	ECOREG	AREA
24	2	PL	.71	1.31	.	944.89	0	999	1	2	1	N	P	P	9	1
24	3	PL	.92	1.41	.	944.89	0	999	0	0	0	N	P	P	9	1
24	4	PL	1.22	1.61	.	944.89	5	45	2	2	1	N	P	P	9	1
24	8	PL	1.38	1.89	.	944.89	5	55	2	3	4	N	P	P	9	1
24	9	SW	.32	.51	.	944.89	3	55	2	3	2	N	S	P	9	1
24	10	SW	.53	.87	.	944.89	3	115	2	3	3	N	S	P	9	1
24	11	SW	.24	.47	.89	944.89	0	999	1	2	1	N	S	P	9	1
24	15	SW	.32	.69	1.51	944.89	0	999	1	3	1	N	S	P	9	1
25	1	PL	.71	1.33	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	2	PL	.77	1.18	.	1158.25	0	999	1	2	1	N	S	B	9	1
25	3	PL	.95	1.56	2.41	1158.25	0	999	1	3	1	N	S	B	9	1
25	4	PL	.94	1.68	.	1158.25	0	999	1	2	1	N	S	B	9	1
25	5	PL	.99	1.65	.	1158.25	0	999	1	2	1	N	S	B	9	1
25	6	PL	.86	1.43	.	1158.25	0	999	1	2	1	N	S	B	9	1
25	7	PL	1.82	.	.	1158.25	10	315	2	2	1	N	S	B	9	1
25	8	PL	1.14	2.01	.	1158.25	0	999	1	2	1	N	S	B	9	1
25	9	PL	.82	1.41	.	1158.25	0	999	1	2	1	N	S	B	9	1
25	10	PL	1.04	1.82	.	1158.25	10	315	1	2	1	N	S	B	9	1
25	11	PL	.79	1.43	.	1158.25	0	315	3	2	2	N	S	B	9	1
25	12	PL	.97	1.48	.	1158.25	20	283	3	2	3	N	S	B	9	1
25	13	PL	.90	1.65	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	13	SW	.48	.64	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	14	PL	.99	1.30	.	1158.25	0	999	1	5	1	N	S	B	9	1
25	15	PL	1.14	1.71	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	16	PL	.87	1.62	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	17	PL	1.17	2.15	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	18	PL	1.58	2.58	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	19	PL	1.30	2.05	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	20	PL	1.82	2.95	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	20	SW	.44	.	.	1158.25	0	999	1	3	1	N	S	B	9	1
25	21	PL	1.23	2.16	.	1158.25	2	305	2	3	1	N	S	B	9	1
25	22	PL	.95	1.68	.	1158.25	10	150	2	2	3	N	S	B	9	1
25	23	PL	.86	1.72	.	1158.25	15	165	2	2	3	N	S	B	9	1
25	24	PL	1.01	1.69	2.95	1158.25	3	135	2	2	3	N	S	B	9	1
26	1	PL	.71	1.06	1.74	1341.14	5	35	2	2	2	N	P	P	10	1
26	1	SW	.21	.24	.28	1341.14	5	35	2	2	2	N	S	P	10	1
26	2	PL	.64	1.27	2.01	1341.14	10	161	2	2	2	N	P	P	10	1
26	3	PL	.62	1.05	2.03	1341.14	264	235	3	2	2	N	P	P	10	1
26	4	PL	.59	.76	1.16	1341.14	10	205	2	3	3	N	P	P	10	1
26	5	PL	.70	.95	1.89	1341.14	10	179	2	3	3	N	P	P	10	1
26	5	SW	.32	.65	1.04	1341.14	10	179	2	3	3	N	S	P	10	1
26	6	PL	1.04	1.62	.	1341.14	10	95	2	3	3	N	S	P	10	1
26	6	SW	.41	.90	1.80	1341.14	10	95	2	3	3	N	S	P	10	1
26	8	PL	.91	1.30	.	1341.14	3	135	2	3	4	N	S	P	10	1
27	1	SW	.30	.37	.71	1341.14	8	35	3	2	2	N	S		10	1
27	2	SW	.26	.59	.88	1341.14	10	18	3	2	2	N	S		10	1
27	4	SW	.45	.80	1.15	1341.14	5	305	2	2	4	N	S		10	1
27	5	PL	1.12	1.60	2.55	1341.14	15	215	2	3	2	N	U		10	1
27	6	SW	.46	.72	1.24	1341.14	5	225	2	2	2	N	S		10	1
27	7	SW	.59	.90	1.13	1341.14	3	233	2	3	2	N	S		10	1
28	1	SW	.17	.24	.30	1158.25	5	159	2	2	2	N	S		9	1
28	2	SW	.12	.18	.26	1158.25	5	195	2	2	2	N	S		9	1
28	3	SW	.20	.30	.80	1158.25	5	225	2	2	2	N	S		9	1
28	4	SW	.29	.48	.64	1158.25	5	225	2	2	2	N	S		9	1
28	5	SW	.17	.27	.66	1158.25	5	245	1	2	2	N	S		9	1
28	6	SW	.16	.29	.51	1158.25	8	225	2	2	2	N	S		9	1
28	7	SW	.17	.28	.67	1158.25	3	165	2	3	1	N	S		9	1
28	8	SW	.31	.38	.64	1158.25	0	155	2	3	1	N	S		9	1
28	9	SW	.51	.69	1.09	1158.25	5	210	2	2	1	N	S		9	1

Table 2 (cont).

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXPO	ROOT	SOURCE	TRT	ECOREG	AREA
28	10	SW	.24	.36	.72	1158.25	5	205	2	2	1	N	S		9	1
28	11	SW	.18	.32	.64	1158.25	7	210	2	2	1	N	S		9	1
28	12	SW	.13	.15	.28	1158.25	5	185	2	2	1	N	S		9	1
29	1	SW	.34	.86	1.66	1165.87	5	1	2	2	2	N	S	P	9	1
29	2	SW	.44	.64	.98	1165.87	5	45	2	2	.	N	S	P	9	1
29	4	SW	.17	.25	.60	1165.87	3	34	2	2	1	N	S	P	9	1
29	5	SW	.32	.68	1.20	1165.87	1	355	2	2	1	N	S	P	9	1
29	6	SW	.42	.70	1.15	1165.87	7	45	2	2	1	N	S	P	9	1
29	7	SW	.37	.56	1.06	1165.87	0	999	1	2	1	N	S	P	9	1
30	1	SW	.39	.56	1.01	1158.25	0	999	1	2	1	N	S	P	6	1
30	2	SW	.20	.41	.75	1158.25	0	999	1	2	1	N	S	P	6	1
30	3	SW	.30	.40	.72	1158.25	0	999	1	2	1	N	S	P	6	1
30	5	SW	.38	.70	1.12	1158.25	0	999	1	2	1	N	S	P	6	1
30	6	SW	.37	.46	.61	1158.25	0	999	1	2	1	N	S	P	6	1
30	8	SW	.37	.46	.82	1158.25	0	999	1	2	1	N	S	P	6	1
30	9	SW	.60	.85	1.29	1158.25	0	999	1	2	1	N	S	P	6	1
30	10	SW	.64	1.26	.	1158.25	0	999	1	2	1	N	S	P	6	1
30	11	SW	.77	1.21	1.90	1158.25	0	999	1	2	1	N	S	P	6	1
30	12	SW	.52	.68	1.20	1158.25	0	999	1	2	1	N	S	P	6	1
30	13	SW	.67	.96	1.72	1158.25	0	999	1	2	1	N	S	P	6	1
30	14	SW	.29	.44	.84	1158.25	0	999	1	2	1	N	S	P	6	1
31	1	SW	.27	.33	.70	1097.29	0	999	1	2	1	N	S	P	10	1
31	2	SW	.24	.54	1.23	1097.29	0	999	1	2	1	N	S	P	10	1
31	3	SW	.74	.	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	7	SW	.74	.	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	9	SW	.72	1.26	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	10	SW	.57	.94	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	20	SW	.66	1.24	.	1097.29	0	999	1	3	1	N	S	P	10	1
31	21	SW	.73	1.04	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	22	SW	.68	1.03	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	23	SW	.58	.97	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	24	SW	.38	.64	.	1097.29	0	999	1	2	1	N	S	P	10	1
31	25	SW	.47	.76	.	1097.29	0	999	1	2	1	Y	S	P	10	1
32	1	SW	.45	.76	.	1097.29	5	175	2	2	1	N	S		10	1
32	4	SW	.36	.48	.87	1097.29	5	155	2	2	1	N	S		10	1
32	6	SW	.71	.	.	1097.29	5	165	2	2	1	N	S		10	1
32	8	SW	.48	.74	.	1097.29	5	165	2	2	1	N	S		10	1
32	9	SW	.23	.35	.	1097.29	3	199	2	2	1	N	S		10	1
32	12	SW	.45	.67	.	1097.29	2	107	2	2	1	N	S		10	1
32	13	SW	.36	.	.	1097.29	1	165	2	2	1	N	S		10	1
32	14	SW	.54	.	.	1097.29	10	175	2	2	1	N	S		10	1
33	1	PL	.71	1.21	.	1463.06	5	285	2	2	4	N	S	S	10	1
33	2	PL	1.01	1.63	.	1463.06	5	239	2	2	4	N	S	S	10	1
33	3	PL	.78	1.32	.	1463.06	5	265	2	2	4	N	S	S	10	1
33	4	PL	.50	.89	.	1463.06	5	265	2	2	4	N	S	S	10	1
33	5	PL	1.17	1.72	.	1463.06	10	271	2	2	4	N	S	S	10	1
33	6	PL	.66	1.16	.	1463.06	5	265	2	2	4	N	S	S	10	1
33	7	PL	.71	1.08	.	1463.06	0	999	1	2	1	N	S	S	10	1
33	8	PL	.70	1.20	.	1463.06	0	999	1	2	1	Y	S	S	10	1
33	9	PL	.66	1.02	.	1463.06	2	241	2	2	1	Y	S	S	10	1
33	10	PL	.85	1.41	.	1463.06	1	246	2	2	1	Y	S	S	10	1
33	11	PL	.56	1.01	.	1463.06	0	999	1	2	1	Y	S	S	10	1
33	12	PL	.86	1.41	.	1463.06	0	999	1	2	1	Y	S	S	10	1
34	1	PL	.55	.92	1.59	1463.06	10	125	2	2	2	N	S	S	10	1
34	2	PL	.75	1.00	1.84	1463.06	5	145	2	2	2	N	S	S	10	1
34	3	PL	.48	1.07	1.95	1463.06	5	125	2	2	2	N	S	S	10	1
34	4	PL	.59	1.03	.	1463.06	5	125	2	2	2	N	S	S	10	1
34	5	PL	.27	.55	1.30	1463.06	5	125	2	2	2	N	S	S	10	1
34	6	PL	.33	.51	1.19	1463.06	5	125	2	2	2	N	S	S	10	1

Table 2 (cont).

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXP	ROOT	SOURCE	TRT	ECOREG	AREA
34	7	PL	.75	1.49	2.62	1463.06	5	120	2	2	2	N	S	S	10	1
34	8	PL	.85	1.68	2.64	1463.06	3	122	2	2	2	N	S	S	10	1
34	9	PL	.43	.99	1.78	1463.06	0	999	1	2	2	N	S	S	10	1
34	11	PL	.39	.83	1.55	1463.06	3	122	2	2	2	N	S	S	10	1
34	12	PL	.82	1.42	2.40	1463.06	2	120	2	2	2	N	S	S	10	1
34	13	PL	.46	.99	1.92	1463.06	5	125	2	2	2	N	S	S	10	1
35	1	PL	.68	1.15	.	1463.06	5	25	2	2	3	N	S	S	10	1
35	2	PL	.82	1.26	.	1463.06	5	25	2	2	3	N	S	S	10	1
35	3	PL	.70	1.37	.	1463.06	5	5	2	2	3	N	S	S	10	1
35	4	PL	.58	1.07	.	1463.06	5	5	2	2	3	N	S	S	10	1
35	5	PL	.55	.98	1.68	1463.06	10	59	2	2	3	N	S	S	10	1
35	6	PL	.41	.89	1.88	1463.06	10	37	2	2	3	N	S	S	10	1
35	7	PL	.85	1.31	.	1463.06	3	25	2	2	3	N	S	S	10	1
35	8	PL	.77	1.30	.	1463.06	0	999	2	2	3	N	S	S	10	1
35	9	PL	.63	1.08	.	1463.06	3	25	2	2	3	N	S	S	10	1
35	10	PL	.68	1.24	.	1463.06	5	25	2	2	3	N	S	S	10	1
35	12	PL	.56	1.03	.	1463.06	3	25	2	2	3	N	S	S	10	1
35	13	PL	.80	1.30	.	1463.06	10	25	2	2	3	Y	S	S	10	1
36	1	PL	.45	.60	.79	1828.82	0	999	2	2	3	N	S		6	1
36	2	PL	.12	.24	.40	1828.82	0	999	2	2	3	Y	S		6	1
36	3	PL	.21	.43	.59	1828.82	5	275	2	2	4	N	S		6	1
36	3	SW	.13	.16	.22	1828.82	5	275	2	2	4	N	S		6	1
36	4	PL	.36	.51	.84	1828.82	5	297	2	2	4	N	S		6	1
36	5	PL	.28	.38	.64	1828.82	5	5	2	2	3	N	S		6	1
36	6	SW	.18	.26	.40	1828.82	5	11	2	2	3	N	S		6	1
36	7	PL	.30	.46	.79	1828.82	5	11	2	2	3	N	S		6	1
36	8	PL	.17	.29	.49	1828.82	10	22	3	2	3	N	S		6	1
36	9	PL	.51	.71	1.10	1828.82	7	333	2	2	4	N	S		6	1
36	10	PL	.40	.61	.89	1828.82	5	329	2	2	4	N	S		6	1
36	11	PL	.23	.34	.68	1828.82	5	355	2	2	4	N	S		6	1
36	12	PL	.44	.63	.93	1828.82	10	321	2	2	4	N	S		6	1
37	1	PL	.58	1.04	.	1889.78	40	121	4	2	3	N	S	D	6	3
37	2	PL	.83	1.16	.	1889.78	30	117	3	2	3	N	S	D	6	3
37	2	SW	.42	.62	.	1889.78	30	117	3	2	3	N	S	D	6	3
37	3	PL	.74	1.34	.	1889.78	5	119	3	2	3	N	S	D	6	3
37	4	PL	.47	.72	.	1905.02	40	93	3	2	3	N	S	D	6	3
37	5	PL	1.00	1.32	.	1905.02	5	105	3	2	3	N	S	D	6	3
37	5	SW	.41	.62	.	1905.02	5	105	3	2	3	N	S	D	6	3
37	6	PL	.52	.	.	1920.26	30	92	3	2	3	N	S	D	6	3
37	7	PL	.87	1.44	.	1889.78	15	90	3	1	3	Y	S	D	6	3
37	7	SW	.30	.	.	1889.78	15	90	3	1	3	Y	Y	D	6	3
37	8	PL	.65	1.05	.	1889.78	35	90	4	1	3	Y	S	D	6	3
37	8	SW	.43	.68	.97	1889.78	35	90	4	1	3	Y	S	D	6	3
37	9	PL	.61	.99	.	1889.78	35	95	3	1	3	Y	S	D	6	3
37	10	PL	.28	.47	.	1905.02	45	105	5	1	2	Y	S	D	6	3
37	11	SW	.49	.61	1.06	1905.02	40	105	4	2	3	N	S	D	6	3
37	12	SW	.48	.81	1.27	1920.26	40	105	4	2	3	N	S	D	6	3
37	13	PL	.47	.81	.	1920.26	50	110	5	1	3	Y	S	D	6	3
38	1	PL	1.27	2.03	.	1798.34	8	295	3	2	4	N	S	D	6	3
38	2	SW	.18	.27	.58	1798.34	5	81	2	2	4	N	S	D	6	3
38	4	PL	.54	.82	.	1813.58	5	115	2	2	3	N	S	D	6	3
38	5	PL	.94	1.38	.	1813.58	10	117	3	2	3	N	S	D	6	3
38	5	SW	.46	.	.	1813.58	10	117	3	2	3	N	S	D	6	3
38	6	PL	.62	1.09	.	1813.58	10	117	3	2	3	N	S	D	6	3
38	7	PL	.58	1.00	.	1828.82	10	278	2	2	4	N	S	D	6	3
38	8	PL	.71	1.10	.	1828.82	5	95	2	2	3	N	S	D	6	3
38	9	PL	.71	1.24	.	1798.34	5	115	2	1	3	Y	S	D	6	3
38	10	PL	.65	1.17	1.86	1798.34	20	115	3	2	3	N	S	D	6	3
38	10	SW	.37	.52	.	1798.34	20	115	3	2	3	N	S	D	6	3

Table 2 (cont).

BLK	PLOT	SP	HT5YR	HT7YR	HT10YR	ELEV	STEEP	ASPECT	TOPO	DRAIN	EXP	ROOT	SOURCE	TRT	ECOREG	AREA
38	11	PL	.88	.	.	1813.58	5	135	1	1	2	Y	S	D	6	3
38	12	PL	.65	1.26	2.21	1813.58	10	135	2	2	2	Y	S	D	6	3
38	12	SW	.30	.43	.	1813.58	10	135	2	2	2	Y	S	D	6	3
38	13	PL	.99	1.46	.	1813.58	10	130	2	2	2	N	S	D	6	3
38	13	SW	.33	.47	.	1813.58	10	130	2	2	2	N	S	D	6	3
38	14	PL	.81	1.28	.	1813.58	8	125	2	2	2	N	S	D	6	3
38	14	SW	.29	.36	.	1813.58	8	125	2	2	2	N	S	D	6	3
38	15	PL	.72	1.27	.	1828.82	3	135	2	2	3	N	S	D	6	3
38	15	SW	.24	.35	.	1828.82	3	135	2	2	3	N	S	D	6	3
38	16	PL	.90	1.29	.	1828.82	8	136	3	2	3	N	S	D	6	3
38	16	SW	.33	.41	.	1828.82	8	136	3	2	3	N	S	D	6	3
39	1	PL	.30	.36	.80	1767.86	5	235	2	2	3	N	S	D	6	3
39	1	SW	.20	.28	.77	1767.86	5	235	2	2	3	N	S	D	6	3
39	2	SW	.10	.15	.30	1767.86	5	235	2	2	3	N	S	D	6	3
39	3	PL	.50	.	.	1767.86	0	999	1	2	2	N	S	D	6	3
39	5	PL	.80	.	.	1767.86	0	999	2	2	2	N	S	D	6	3
39	6	PL	.61	.	.	1767.86	0	999	2	2	1	N	S	D	6	3
39	7	PL	.50	.	.	1767.86	0	999	1	2	4	N	S	D	6	3
39	7	SW	.17	.	.	1767.86	0	999	1	2	4	N	S	D	6	3
39	8	PL	.55	.	.	1767.86	0	999	1	2	3	N	S	D	6	3
39	9	PL	.66	.	.	1767.86	0	999	1	2	3	N	S	D	6	3
39	10	SW	.46	.60	1.00	1767.86	0	999	1	3	4	N	S	D	6	3
39	11	PL	.86	1.36	.	1767.86	0	999	1	1	4	N	S	D	6	3
39	12	PL	1.16	.	.	1767.86	0	999	1	2	4	N	S	D	6	3
40	1	PL	.49	.75	1.15	1783.10	10	187	3	2	3	N	S		6	3
40	1	SW	.16	.40	.79	1783.10	10	187	3	2	3	N	S		6	3
40	2	PL	.36	.60	1.08	1783.10	10	201	2	2	3	N	S		6	3
40	2	SW	.14	.21	.39	1783.10	10	201	2	2	3	N	S		6	3
40	3	SW	.20	.38	.53	1783.10	20	206	3	2	2	N	S		6	3
40	4	PL	.47	.73	1.17	1783.10	15	185	2	3	2	N	S		6	3
40	4	SW	.33	.42	.51	1783.10	15	185	2	3	2	N	S		6	3
41	1	PL	.83	1.46	2.44	1767.86	10	353	3	2	3	N	S	S	6	3
41	2	PL	.71	1.01	.	1767.86	10	5	3	2	3	N	S	S	6	3
41	3	PL	1.15	1.44	2.36	1767.86	10	15	3	2	3	N	S	S	6	3
41	3	SW	.33	.53	1.13	1767.86	10	15	3	2	3	N	S	S	6	3
41	4	PL	.91	1.44	.	1767.86	15	15	3	2	3	N	S	S	6	3
41	5	PL	1.08	1.74	.	1767.86	10	35	2	2	4	N	S	S	6	3
41	5	SW	.43	.62	.	1767.86	10	35	2	2	4	N	S	S	6	3
41	6	PL	.85	1.60	2.78	1767.86	10	35	2	2	4	N	S	S	6	3
41	6	SW	.43	.60	.	1767.86	10	35	2	2	4	N	S	S	6	3
41	7	PL	.81	1.52	.	1767.86	25	35	3	2	4	N	S	S	6	3
41	7	SW	.50	.82	.	1767.86	25	35	3	2	4	N	S	S	6	3
41	8	PL	1.08	1.76	.	1767.86	20	35	3	2	4	N	S	S	6	3
41	8	SW	.41	.54	.	1767.86	20	35	3	2	4	N	S	S	6	3

Number of cases read = 457 Number of cases listed = 457

Table 3. Summaries by Height (at 7 years) by Species and other Variables.

Summaries of HT7YR HEIGHT AT 7 YEARS
By levels of SP SPECIES
ECOREG

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			.9934	.5349	420
SP	PL		1.2622	.5206	241
ECOREG	6	SUBALPINE	.9365	.4193	65
ECOREG	9	BOREAL FOOTHILLS	1.6944	.4255	67
ECOREG	10	BOREAL UPLANDS	1.1908	.4500	109
SP	SW		.6315	.2803	179
ECOREG	6	SUBALPINE	.4857	.2336	53
ECOREG	9	BOREAL FOOTHILLS	.6806	.3004	65
ECOREG	10	BOREAL UPLANDS	.7058	.2499	61

Total Cases = 448
Missing Cases = 28 OR 6.3 PCT.

Summaries of HT7YR HEIGHT AT 7 YEARS
By levels of SP SPECIES
TOPO TOPOGRAPHIC CLASS

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			.9934	.5349	420
SP	PL		1.2622	.5206	241
TOPO	0		1.9270	.7297	2
TOPO	1	FLAT	1.4965	.4965	65
TOPO	2	GENTLE	1.2155	.5111	109
TOPO	3	MEDIUM	1.1842	.4579	44
TOPO	4	STEEP	.9589	.4056	14
TOPO	5	V. STEEP	.7212	.4207	7
SP	SW		.6315	.2803	179
TOPO	1	FLAT	.7419	.3055	54
TOPO	2	GENTLE	.5984	.2663	90
TOPO	3	MEDIUM	.5353	.2366	27
TOPO	4	STEEP	.5818	.1868	8

Total Cases = 448
Missing Cases = 28 OR 6.3 PCT.

Summaries of HT7YR HEIGHT AT 7 YEARS
By levels of SP SPECIES
ROOT ROOTING DEPTH LIMITING

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			.9934	.5349	420
SP	PL		1.2622	.5206	241
ROOT	0		2.4430	0.0	1
ROOT	N	NO	1.3015	.5113	208
ROOT	Y	YES	.9698	.4571	32
SP	SW		.6315	.2803	179
ROOT	N	NO	.6206	.2767	167
ROOT	Y	YES	.7831	.2983	12

Total Cases = 448
Missing Cases = 28 OR 6.3 PCT.

Table 3 (cont).

Summaries of HT7YR HEIGHT AT 7 YEARS
By levels of SP SPECIES
DRAIN DRAINAGE CLASS

Variable		Value	Label	Mean	Std Dev	Cases
For Entire Population				.9934	.5349	420
SP	PL			1.2622	.5206	241
DRAIN		0		1.9270	.7297	2
DRAIN		1	EXCESSIVE	1.0514	.3380	7
DRAIN		2	RAPID	1.1614	.4679	143
DRAIN		3	MODERATE	1.4778	.5797	76
DRAIN		4	POOR	1.1084	.3112	12
DRAIN		5	V. POOR	1.2950	0.0	1
SP	SW			.6315	.2803	179
DRAIN		1	EXCESSIVE	.6810	0.0	1
DRAIN		2	RAPID	.5912	.2995	105
DRAIN		3	MODERATE	.7150	.2452	61
DRAIN		4	POOR	.5548	.1854	12

Total Cases = 448
Missing Cases = 28 OR 6.3 PCT.

Summaries of HT7YR HEIGHT AT 7 YEARS
By levels of SP SPECIES
EXP EXPOSURE CLASS

Variable		Value	Label	Mean	Std Dev	Cases
For Entire Population				.9942	.5353	419
SP	PL			1.2622	.5206	241
EXP		0		1.9270	.7297	2
EXP		1	V. EXPOSED	1.2937	.5398	61
EXP		2	MOD. EXPOSED	1.2338	.4705	54
EXP		3	INTERMEDIATE	1.0663	.3866	62
EXP		4	MOD. PROTECTTED	1.3818	.6047	53
EXP		5	PROTECTED	1.7176	.3822	9
SP	SW			.6314	.2810	178
EXP		1	V. EXPOSED	.6774	.2888	65
EXP		2	MOD. EXPOSED	.6692	.3169	39
EXP		3	INTERMEDIATE	.5199	.2228	36
EXP		4	MOD. PROTECTTED	.6038	.2606	35
EXP		5	PROTECTED	.8030	.1045	3

Total Cases = 448
Missing Cases = 29 OR 6.5 PCT.

Table 3 (cont).

Summaries of HT7YR HEIGHT AT 7 YEARS
By levels of SP SPECIES
SOURCE

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			.9934	.5349	420
SP	PL		1.2622	.5206	241
SOURCE	P	PLANTED	1.2015	.4633	38
SOURCE	S	SEEDED	1.2805	.5622	155
SOURCE	U	UNCERTAIN	1.2512	.4184	48
SP	SW		.6315	.2803	179
SOURCE	P	PLANTED	.7643	.4442	3
SOURCE	S	SEEDED	.5992	.2675	143
SOURCE	U	UNCERTAIN	.7592	.2898	33

Total Cases = 448
Missing Cases = 28 OR 6.3 PCT.

Summaries of HT7YR HEIGHT AT 7 YEARS
By levels of SP SPECIES
TRT TREATMENT

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			.9934	.5349	420
SP	PL		1.2622	.5206	241
TRT		UNKNOWN	.5921	.3208	15
TRT	B	BURNED	1.3778	.6479	34
TRT	D	DRAGGED	1.1380	.3387	25
TRT	P	PLANTED	1.2960	.4708	47
TRT	S	SCARIFIED	1.3259	.4909	120
SP	SW		.6315	.2803	179
TRT		UNKNOWN	.4340	.2137	28
TRT	B	BURNED	.3688	.1204	15
TRT	D	DRAGGED	.4779	.1797	15
TRT	P	PLANTED	.7820	.2976	55
TRT	S	SCARIFIED	.6843	.2287	66

Total Cases = 448
Missing Cases = 28 OR 6.3 PCT.

Table 4. Actual and Predicted Heights by Age.

ECOREG	SP	AGE	NUM	ELEV	ADJELEV	PREDHT	ACTHT	MINHT	MAXHT	SDHT
6	PL	5	69	1771.62	1771.62	.631	.614	.119	1.270	.252
6	PL	6	72	1771.04	1771.04	.745	.785	.158	1.616	.330
6	PL	7	62	1768.84	1768.84	.875	.950	.237	2.032	.425
6	PL	8	52	1749.10	1749.10	1.017	1.112	.281	2.104	.496
6	PL	9	40	1731.67	1731.67	1.129	1.220	.340	2.440	.601
6	PL	10	35	1719.09	1719.09	1.242	1.254	.397	2.782	.636
6	SW	5	53	1649.68	1649.68	.343	.330	.095	.770	.148
6	SW	6	53	1646.52	1646.52	.396	.408	.130	.965	.183
6	SW	7	51	1640.86	1640.86	.461	.495	.148	1.260	.233
6	SW	8	43	1616.52	1616.52	.545	.588	.180	1.500	.306
6	SW	9	39	1593.19	1593.19	.642	.689	.201	1.758	.371
6	SW	10	36	1595.14	1595.14	.748	.784	.224	1.900	.375
9	PL	5	75	1165.57	1241.96	1.081	1.054	.275	1.822	.319
9	PL	6	72	1170.53	1243.70	1.274	1.364	.410	2.356	.378
9	PL	7	67	1177.82	1246.97	1.498	1.694	.615	2.952	.426
9	PL	8	46	1219.88	1268.41	1.697	1.957	.855	3.140	.517
9	PL	9	32	1249.70	1293.93	1.903	2.199	1.149	3.390	.551
9	PL	10	23	1315.96	1330.68	2.071	2.519	1.385	3.495	.565
9	SW	5	64	1105.87	1133.50	.513	.425	.119	.850	.182
9	SW	6	64	1105.87	1133.50	.605	.555	.156	1.055	.231
9	SW	7	62	1105.16	1133.64	.713	.702	.177	1.367	.290
9	SW	8	54	1121.56	1139.65	.834	.752	.167	1.616	.341
9	SW	9	45	1133.87	1146.96	.975	.854	.238	1.642	.363
9	SW	10	41	1141.90	1150.13	1.145	1.027	.259	1.915	.421
10	PL	5	108	1412.54	1413.49	.770	.722	.083	1.742	.287
10	PL	6	108	1412.54	1413.49	.910	.952	.181	2.285	.373
10	PL	7	108	1412.54	1413.49	1.077	1.198	.127	2.571	.446
10	PL	8	108	1414.23	1415.18	1.270	1.457	.231	2.956	.509
10	PL	9	97	1409.95	1411.01	1.520	1.711	.368	3.209	.582
10	PL	10	82	1404.70	1405.95	1.824	2.003	.501	3.658	.717
10	SW	5	65	1306.44	1307.43	.423	.451	.211	1.009	.166
10	SW	6	62	1304.76	1305.76	.499	.590	.289	1.230	.203
10	SW	7	58	1319.06	1319.95	.578	.721	.334	1.494	.244
10	SW	8	55	1347.79	1348.48	.657	.839	.365	1.502	.269
10	SW	9	48	1374.16	1374.61	.747	.998	.410	1.805	.309
10	SW	10	43	1395.01	1395.26	.855	1.191	.491	2.353	.386

Where:

ECOREG	-	Ecoregion
SP	-	Species
AGE	-	Age
NUM	-	Number of sections
ELEV	-	Average elevation (m)
ADJELEV	-	Adjusted average elevation: if elevation of a block
	-	is less than 1200 m for pine or 1100 m for spruce,
	-	then elevation is reset to these lower limits
	-	before the average elevation is determined.
PREDHT	-	Predicted height (m)
ACTHT	-	Actual height (m)
MINHT	-	Minimum observed height (m)
MAXHT	-	Maximum " " (m)
SDHT	-	Standard deviation for actual heights (m)

Table 5. Analyses of Variance Results for Pine

a) Height at 7 years by Ecoregion

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	19.9665	9.9832	52.7175	0.0
Within Groups	238	45.0706	.1894		
Total	240	65.0370			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 6	Grp 10	Grp 9	
.9365	Grp 6				(Subalpine)
1.1908	Grp10	*			(Boreal Uplands)
1.6944	Grp 9	*	*		(Boreal Foothills)

b) Height at 7 years by Exposure Class

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	5.1010	1.2752	5.0999	.0006
Within Groups	234	58.5123	.2501		
Total	238	63.6133			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 3	Grp 2	Grp 1	Grp 4	Grp 5	
1.0663	Grp 3						(intermediate)
1.2338	Grp 2						(moderately exposed)
1.2937	Grp 1	*					(very exposed)
1.3818	Grp 4	*					(moderately protected)
1.7176	Grp 5	*	*	*			(protected)

Table 5 (cont).

c) Height at 7 years by Drainage Class

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	5.4606	2.7303	11.0804	.0000
Within Groups	236	58.1527	.2464		
Total	238	63.6133			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 4	Grp 2	Grp 3	
1.1228	Grp 4				(poorly or very poorly drained)
1.1562	Grp 2				(excessive or rapid drainage)
1.4778	Grp 3	*	*		(moderate drainage)

d) Height at 7 years by Topographic Class

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	7.4028	1.8507	7.7043	.0000
Within Groups	234	56.2105	.2402		
Total	238	63.6133			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 5	Grp 4	Grp 3	Grp 2	Grp 1	
.7212	Grp 5						(very steep)
.9589	Grp 4						(steep)
1.1842	Grp 3						(medium)
1.2155	Grp 2						(gentle)
1.4965	Grp 1	*	*	*	*		(flat)

Table 5 (cont).

e) Height at 7 years by Treatment

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	3	.9328	.3109	1.2441	.2946
Within Groups	222	55.4805	.2499		
Total	225	56.4133			

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No range test as overall level of significance is only .2946

f) Height at 7 years by Regen source

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.191	1	.191	.643	.424
SOURCN	.191	1	.191	.643	.424
Explained	.191	1	.191	.643	.424
Residual	56.610	191	.296		
Total	56.800	192	.296		

258 Cases were processed.
65 CASES (25.2 PCT) were missing.

Table 6. Analyses of Variance Results for Spruce

a) Height at 7 years by Ecoregion

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	1.6201	.8100	11.5340	.0000
Within Groups	176	12.3605	.0702		
Total	178	13.9806			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 6	Grp 9	Grp 10	
.4857	Grp 6				(Subalpine)
.6806	Grp 9	*			(Boreal Foothills)
.7058	Grp10	*			(Boreal Uplands)

b) Height at 7 years by Exposure Class

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	4	.7563	.1891	2.4735	.0462
Within Groups	173	13.2242	.0764		
Total	177	13.9805			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 3	Grp 4	Grp 2	Grp 1	Grp 5	
.5199	Grp 3						(intermediate)
.6038	Grp 4						(moderately protected)
.6692	Grp 2						(moderately exposed)
.6774	Grp 1	*					(very exposed)
.8030	Grp 5						(protected)

Table 6 (cont).

c) Height at 7 years by Drainage Class

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	.6607	.3303	4.3648	.0141
Within Groups	176	13.3199	.0757		
Total	178	13.9806			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 4	Grp 2	Grp 3	
.5548	Grp 4				(poorly or very poorly drained)
.5921	Grp 2				(excessive or rapid drainage)
.7150	Grp 3		*		(moderate drainage)

d) Height at 7 years by Topographic Class

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	3	1.0258	.3419	4.6192	.0039
Within Groups	175	12.9548	.0740		
Total	178	13.9806			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 3	Grp 4	Grp 2	Grp 1	
.5353	Grp 3					(medium)
.5818	Grp 4					(steep)
.5984	Grp 2					(gentle)
.7419	Grp 1	*		*		(flat)

Table 6 (cont).

e) Height at 7 years by Treatment

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	3	2.6173	.8724	14.5136	0.0
Within Groups	147	8.8365	.0601		
Total	150	11.4538			

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Multiple Range Test
Student-Newman-Keuls Procedure
(*) Denotes pairs of groups significantly different at the .050 level

Mean	Group	Grp 1	Grp 2	Grp 4	Grp 3	
.3688	Grp 1					(burned)
.4779	Grp 2					(drag scarified)
.6843	Grp 4	*	*			(planted)
.7820	Grp 3	*	*	*		(scarified)

f) Height at 7 years by Regeneration Source

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	.080	1	.080	1.093	.297
SOURCN	.080	1	.080	1.093	.297
Explained	.080	1	.080	1.093	.297
Residual	10.553	144	.073		
Total	10.633	145	.073		

190 Cases were processed.
44 CASES (23.2 PCT) were missing.

APPENDIX 2

COMPARISON OF AVAILABLE RECLAMATION DATA WITH BASELINE GROWTH ESTIMATES

Luscar Sterco Pit 42-1/1987

This is the only available data set which has been collected in a manner closely resembling the proposed procedure. The only significant deviation is that annual growth is recorded for just the last year, not the last two seasons as in the suggested approach. Current annual increment in the baseline model is calculated by differentiation from total height at the end of the growing season; this means that the table value for year 6, for example, should be compared to the average growth for the sixth and seventh growing seasons. In the present data set, growth data apply to the sixth year since germination. The baseline increment for this period has been calculated from Table 8 in the main report as the average of values from years 5 and 6.

The site is located at 1400 m above sea level. Over 70% of the plots are exposed to westerly chinook winds. Pre and post-disturbance soils are assumed to be for the most part moderately well-drained.

Of 32 plots, 23 contained at least one acceptable seedling; implying a stocking level of 72 percent. This is below the 80 percent provincial (AFS) standard. This does not necessarily imply high mortality, since some of the unstocked plots had never been planted. Growth performance is compared with the baseline models in Table 1. Baseline values are shown for both 1400 and 1500 m elevation classes. Under the proposed system, that for the 1500 m class would probably be applicable, given the generally unfavourable aspect and exposure situation. The selection of the applicable class should be made on site, but will still be necessarily somewhat subjective. Average height and increment values are given of all stocked plots (of which there were 23), and of measurements including only undamaged container seedlings (of which there were 12). Seedling damage was reported as being either browse or past climate.

Increment results appear satisfactory relative to the baseline. Increment in undamaged plots is superior to the baseline expectation, and the average increment on all plots meets the predicted value for 1500 m. Stocking and damage levels should be the cause of some concern. It is suggested that the discrepancy between observed and baseline total height is probably related to previous climatic and browsing damage, and possibly to related planting shock from which the seedlings have now recovered.

Since these areas were planted, Luscar-Sterco have worked towards more closely controlled seedling hardiness, planting, and site-exposure amelioration to minimize initial stress. Company staff believe that seedling stress on the Pit 42-1 site could have been reduced, and growth performance improved, if present handling/planting systems had been followed.

Table 1. Comparison of Luscar Sterco data with regional baseline growth estimates for lodgepole pine.

	Baseline values		Actual values	
Parameter	1400 m	1500 m	all stocked plots	undamaged plots
Total height (cm)	91	74	39.3	44.6
Increment (cm)	14.1	11.5	11.9	15.0

When interpreting results in Table 1 and 2, the variation observed in baseline data should be remembered (see main report).

Obed South simulated mining sites

Data were obtained on approximately 1400 spruce and pine seedlings following the sixth growing season since outplanting. Seedlings were originally planted at a density of approximately 4220 trees per ha, and measurements are based on all surviving trees. Data are therefore not compatible with the proposed procedure, and will tend to underestimate growth performance relative to the baseline.

The level, north and south sites are situated at 1600, 1550, and 1530 m above sea level respectively. The level and north sites have unfavourable exposures to westerly winds, resulting in abnormal levels of climatic injury. The south site is generally more sheltered, but has unfavourable drainage conditions. For the purposes of a tentative comparison between the baseline estimates and achieved growth performance, the level and north sites were assigned to the model's 1700 m class, and the south slope to the 1600 m class. The resulting comparison is summarized in Table 2 and is based on seven years of growth since germination, with periodic annual increment being averaged over the last two years.

It is apparent that, probably because of losses in leader growth and other factors, average total height achieved to date is much below the baseline estimate. This is hardly surprising, given the levels of injury reported by the Company. With the exception of pine on the very exposed north site, and spruce on the south site (which has been subject to excessive grass competition), recent leader growth is remarkably close to the baseline estimates, considering the amount of leader damage which has been incurred.

Table 2. Comparison of Obed data with regional baseline estimates.

	Total height (cm)				Periodic annual increment (cm)			
Site	spruce		pine		spruce		pine	
	baseline	actual	baseline	actual	baseline	actual	baseline	actual
Level	35	22	57	37	4.9	4.8	8.1	9.1
North	35	19	57	22	4.9	4.8	8.1	6.4
South	39	23	71	39	5.5	4.1	10.0	9.3

Alberta Forest Service Coal Valley plots

These plots were established in 1973 by the AFS on recontoured spoil on south-west facing aspects at an elevation of about 1400 m. Bareroot pine and spruce (3-0) of unknown origin were planted. Again, data are not directly comparable with the baselines or the proposed method.

It is interesting to note in Table 3 that pine current annual increment and height are well below baseline values. However, in spruce (plot 10) periodic annual increment (p.a.i.) is comfortably higher than the highest values forecast in the baseline model, and total height is similar to the predicted values.

Table 3. Comparison of AFS Coal Valley data with regional baseline estimates.

Plot	Species	Parameter	Age (yrs)	Baseline values(cm) 1400m	1500m	Actual values (cm)
6	pine	height	8	127	103	44
		p.a.i.	9 & 10	25.3	20.5	14.5
7	pine	height	8	127	103	26
		p.a.i.	9 & 10	25.3	20.5	10.5
10	spruce	height	9	71	62	65
		p.a.i.	10 & 11	13.7	12.1	30.3

Smoky River plots

Measurements were provided for Engelmann spruce and lodgepole pine planted on reclaimed soil at No. 8 mine between 1972 and 1976. Height and height-growth were recorded between 1983 and 1987. Both total height and height growth levels appeared to be below the baseline values. However, the plot layout and measurement procedures were quite different from the baseline system, and little could be concluded from a comparison of the data.

Observations by the principle researchers support conclusions from the Obed and Luscar Sterco comparisons that climatic factors exert an overriding effect on early stand growth on reclaimed sites.[3] Furthermore, their observation that in recent years there has been a trend towards increase in the frost free period, decrease in precipitation, and increasing fluctuation in climate generally, suggests that climatic change may need to be taken more seriously when basing growth expectations on historic data.

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[3]. Macyk, T.M., Widman, Z.W. and Betts, V. Reclamation research in the Grande Cache area: an overview. Terrain Sciences, Alberta Research Council Report. In prep.