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MAPPING AND CHARACTERIZATION OF CUTOVER PEATLANDS FOR RECLAMATION PLANNING

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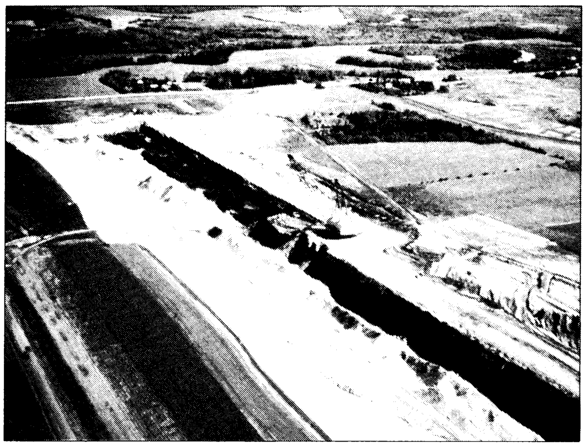

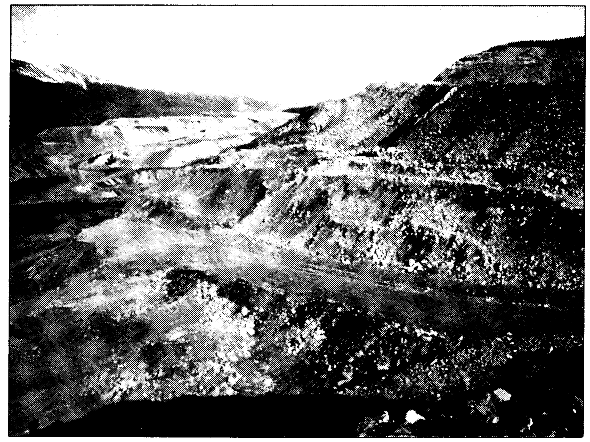

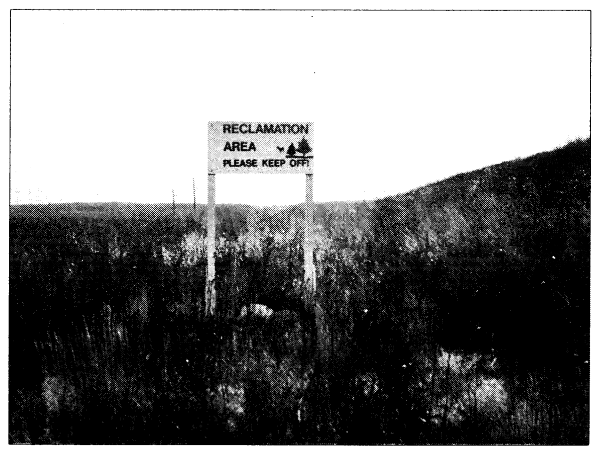

DISCLAIMER

This report is intended to provide government and industry staff with up-to-date technical information to assist in the preparation and review of Conservation and Reclamation Approvals, and development of guidelines and operating procedures. This report is also available to the public so that interested individuals similarly have access to the most current information on land reclamation topics.

The opinions, findings, conclusions, and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of government or industry. Mention of trade names or commercial products does not constitute endorsement, or recommendation for use, by government or industry.

REVIEWS

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ABSTRACT

Several hundred hectares of peatlands in Alberta have been harvested for horticultural peat moss since the 1960s and have been left unreclaimed. The need to reclaim them to a suitable land use is now recognized. Various kinds of information are required in order to assess land use alternatives for cutover peatlands. This study was initiated during the summer of 1991 with the objectives of developing a methodology for cost-effective soil survey and sampling of cutover peatlands, and of obtaining baseline chemical information and data interpretation for peat materials at one site. The overall purpose is to establish effective methods for obtaining the information required to examine alternatives for reclamation.

This report is presented in three parts. In Part I a methodology and protocol for adequate, cost-effective soil survey and sampling of cutover peatlands is outlined. The approaches and procedures that are presented were derived principally from established soil survey practices and are supplemented by information derived through an actual survey as documented in Part II of this report. This survey was carried out in an area of about one and one-half quarter sections (107 ha) near Evansburg, Alberta. Methods used in the survey consisted of aerial photographic interpretation of the study area, application of existing soil and vegetation classification systems, field soil and vegetation survey, elevation survey, soil sampling, development of a digital base map in a geographic information system, digitizing of spatial information, application of computer contouring and geostatistics, and laboratory analysis. Map products comprised elevation, peat soil/vegetation, peat isopach, mineral subsoil elevation, drainage system, inspection site location, and peat isopach error maps. Detailed vegetation data were obtained for a number of field sites. The maps along with analytical data were discussed in terms of appropriateness of methods used and usefulness of the information obtained.

The various maps produced in this project provide an effective means of describing the cutover peatland landscape. Geographic information systems enable overlaying of different types of information and generation of different types of maps. Such maps can be produced manually as well but in either case, it is highly important that a common base map for field survey and subsequent map compilation be developed at the beginning of a project in order to avoid possible problems with registration of maps and location of sites. A high intensity level of mapping with presentation of information at a scale of 1:5000 seemed appropriate for this study although lower mapping intensity levels presented at smaller scales would be appropriate for mapping areas with relatively low spatial variability in soil and vegetation types.

Emphasis in laboratory analysis should be placed on measures of pH and rubbed fibre as these have been shown in the literature to correlate with several other properties. Standard nutrient analyses are difficult to interpret for peat soils and suitable techniques for nutrient evaluation still need to be developed. Inclusion of soil and water samples from carefully selected sites enables preliminary assessment of environmental impacts, particularly with respect to quality of outflowing waters.

Systems for classifying and describing peat and peatlands are presented in Part III of the report. Terminology and definitions are presented to assist in developing familiarity with this area which is mostly addressed in specialized literature that may not be readily available.

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PREFACE

Peat extraction activity in Alberta for production of horticultural peat moss began on a small scale in the early 1960's and has since increased to the extent that approximately 5300 ha (13 100 acres) of public peatlands are currently held under 20 dispositions. Such industrial activity results in major disturbance to peatlands, and the area of peatlands affected has increased particularly within the last decade. Extraction operations were completed on several hundred hectares in the Evansburg area in the late 1970's but no reclamation activities have been carried out in these areas. Additional cutover peatlands will require reclamation on a semi-regular basis in the foreseeable future as new peatlands are brought into production. Information on the best methods to treat harvested peatlands is lacking, as are guidelines for the evaluation of the various alternatives for reclamation. In order to assess land-use alternatives, it has been suggested that at least the following information would be required (Stenbeck 1985):

1. Local and micro-climatic conditions.
2. Hydrology and drainability after peat harvesting.
3. The thickness of the peat remaining after harvesting.
4. The physical characteristics of the peat (type of peat, degree of humification).
5. The chemical characteristics of the peat (pH, nutrient content, sulphides, heavy metals).
6. The type of mineral soil (physical and chemical characteristics of the mineral subsoil).
7. The topography of the underlying soils and bedrock.

According to Stenbeck (1985), the drainability and the physical and chemical characteristics of the peat remaining after the top peat moss layers are removed are of decisive importance when deciding whether the reclamation should result in a wet landscape (e.g., reversion to wetland) or a dry landscape (e.g., agriculture and forestry land uses). In Alberta, data on the chemical and physical properties of this material in cutover peatlands are not available, except by extrapolation from limited data on undisturbed peatlands in other parts of the province. Concerns include the nature of the mineral substrate material (texture, stoniness), ion concentrations, the possible presence of reduced sulphur, low pH, limnic peat materials, and the potential release of heavy metals in quantities that can have an impact on plant growth as well as on quality of drainage waters in relation to uses such as suitability for wildlife and livestock drinking water (Turchenek 1990). As this type of work has not been carried out previously, an approach to reclamation initially requires development of a methodology for the acquisition of cutover peatland baseline information and data interpretation. This is particularly important considering the lack of existing baseline information on cutover peatlands that have been abandoned for several years. Methods of soil/land inventory, sampling, and analysis that will have applicability to future projects also need to be developed. The inventory should include delineating the existing drainage system (natural and artificial), elevations (peat surface and mineral surface contours), peat thickness (isopach map), and field determination of state of decomposition. Sampling and analysis need to be carried out to determine general peat chemical attributes, trace or heavy metal levels, and nutrient status of surface soils.

The specific objectives of this study were:

1. To develop a methodology and protocol for adequate, cost-effective soil survey and sampling (for analysis) of peatlands commensurate with the variability of peat properties; and;
2. To obtain baseline chemical information and data interpretation for basal peat materials at one site.

PART I. PROCEDURES FOR MAPPING AND CHARACTERIZATION OF SOILS AND VEGETATION IN CUTOVER PEATLANDS

1. INTRODUCTION

Information about numerous cutover peatland characteristics is required to evaluate alternatives for reclamation (Stenbeck 1985). A methodology for adequate, cost-effective soil survey and sampling of cutover peatlands is outlined in this part of the report. The approaches and procedures suggested herein are derived principally from established soil survey practices and are supplemented by information derived through an actual survey as documented in the second part of this report. Soil mapping is the identification, description and delineation on a map of different types of soil based on soil properties directly observed in the field or on inferences from sources such as aerial photographs (Agriculture Canada Expert Committee on Soil Survey 1981). The objectives of a soil survey focus on soils information, but commonly may include acquisition of data about other landscape elements such as geomorphology or vegetation. A soil survey may thus be similar to an ecological land survey in which combinations of terrain, hydrological, climatic, floral and faunal features, and the relationships among them, are described and mapped.

The information required to assess land use alternatives, as summarized in the Preface, is primarily physical in nature. In most situations of cutover peatland survey, the work will be carried out immediately after completion of peat harvesting activities. However, in Alberta and elsewhere, there are situations in which harvesting was completed several years ago and natural revegetation has occurred to greater or lesser extents. The inclusion of vegetation as a component of the land survey in these cases could provide useful information in evaluating potential land use.

The approach taken in presenting procedures for mapping and characterization of cutover peatlands involves focusing on soils and accessory physical characteristics (hydrology, climate, terrain and geomorphology), and suggesting procedures for vegetation mapping based partly on approaches in ecological land classification.

2. SYNOPSIS OF PROCEDURES

The following table summarizes the steps in a survey of cutover peatlands. The next section provides a discussion of each of the activities.

Table 1.1 Summary of Survey Procedures

Planning Stage - definition of objectives and information needs - conceptual design of database - level of detail considerations (1:5000 map scale recommended)
Pre-Field Stage - background research and review - base map development - pre-typing of aerial photographs - selection of standards for description
Field Stage - study area reconnaissance - plan for desired inspection density - elevation and peat thickness survey - soil and vegetation survey - sampling and laboratory analysis (soil chemical and physical properties, nutrient levels, and water quality)
Post-Field Stage - analysis and compilation of data - development of mapping units, legend and map - derivation of single factor maps - report preparation

3. DESCRIPTION OF PROCEDURES

3.1 PLANNING STAGE

3.1.1 Establishing Objectives and Information Needs

The objectives of mapping and specification of information needs must be clearly established in any mapping and evaluation project. With respect to cutover peatlands, the objective is clearly to acquire baseline information for evaluation of potential land uses, as indicated previously. The information requirements are as outlined in the Preface. Additional considerations in the early stages of a project relate to possible constraints, especially availability of funding, manpower and time. Gathering data in the field is a major expense, particularly in detailed surveys. Options for cost-saving need to be considered. Discussion of some of the procedures described in the following sections includes options that can enter into cost saving considerations of project costs.

3.1.2 Database Design

A survey is a form of information gathering system that can be designed in various ways in terms of content and form. Content refers to the actual information and to information characteristics such as accuracy and precision. Form relates to the mode of data presentation , namely as text, tables, maps and figures, as well as to whether or not the information is in manually produced hard copy format or in digital format. Large information systems such as that of the provincial government (e.g., forest cover, soil surveys, ecological land surveys) are now digitally based, but hard copy products are available to users. The necessary computer hardware and software may not be available for small projects, and the information system may be totally manually produced, or produced by a combination of manual and computing procedures. Computerized geographic information systems could have the added advantage of enabling detailed analysis of different post harvest scenarios. The approach taken herein entails development of a cutover peatland database that can be produced manually. However, methods for deriving and presenting information by computer techniques are noted as well.

3.1.3 Level of Detail

Two factors determine the appropriate level of detail for cutover peatland mapping. Firstly, in a qualitative sense, the stated objectives dictate that the level of detail be high. Secondly, a mapping scale of 1:5000 is required under the provincial 'Peatland Inventory Requirements for Surface Material Lease (SML) Applications' (Tedder, 1993; this document is reproduced in Part III, Section 5 of this report). It seems appropriate that both pre- and post-harvest peatland mapping be presented at the same scale since this would present opportunities for direct comparison of 'before' and 'after' scenarios, and for operational efficiencies such as development of only one base map instead of two or more.

The concept of level of detail refers mainly to the precision of map information, but also has connotations of accuracy. It is related to 'mapping scale', but cannot be equated with it. Explanation of these concepts becomes lengthy and complicated, and the reader is referred to Agriculture Canada Expert Committee on Soil Survey (1981) and Hole and Campbell (1985) for detailed discussions. The concept of 'survey intensity level' is applied in soil surveys in Canada to identify in a general way the amount of precision embodied in a survey (Agriculture Canada Expert Committee on Soil Survey 1981). 'Survey intensity level' carries implications of map scale and level of detail; five levels have been operationally defined (Agriculture Canada Expert Committee on Soil Survey 1981).

The mapping scale discussed thus far corresponds to the highest survey intensity level (Level 1). Definitive characteristics of this level are that there be at least one soil inspection in every delineation, and that boundaries be checked along their entire lengths in open country, or over 30 percent in woodland. An alternative guideline for any mapping scale is that there should be 0.2 to 2 field inspections for every square cm of map area. Maps for high intensity level surveys are mainly published at scales of 1:5000 and 1:10 000. Consequently, one inspection can represent a range of 0.1 to 5 ha for this level of mapping, although it is preferable that a relatively high inspection density is attained for 1:5000 as opposed to 1:10 000 mapping. The appropriate descriptive soil taxonomic unit is the soil series or phase of a soil series (Agriculture Canada Expert Committee on Soil Survey 1981; Environmental Conservation Service Task Force 1981). A soil series is a taxon at the lowest (most detailed) level in the hierarchical systems of soil classification used in Canada, the United States and elsewhere. Series have similar kinds and arrangements of horizons whose texture, colour, structure, consistence, thickness, reaction and composition fall within narrow ranges. (See Part III, Section 1.4, for a more detailed description of the soil classification system).

The map scale, and features such as minimum size delineation and average size delineation, characterize the spatial precision of mapping. Soil series and phases of series, along with various other physical attributes, define a level of descriptive precision of mapping; i.e., series provide more precise descriptions of soils than classes at the subgroup, great group or order levels of classification. Accuracy, on the other hand, refers to the degree of correspondence between the map and observed conditions in the field. It can be measured quantitatively by detailed field checking using statistical sampling protocols after a map is produced.

The inspection density has implications with regard to precision, as indicated above, but can also be a general indicator of the accuracy or reliability of a map. An inspection represents a control point from which to extrapolate information. An inspection density of one observation per hectare, for example, indicates that a single soil pit or similar observation is extrapolated, on average, to an area of one hectare. Checks of soil maps that have conformed to survey intensity level guidelines have indicated that reasonable accuracy levels are generally attained. Recent work in which soil survey accuracy was reviewed from the world literature and in which evaluations of accuracy were carried out in Alberta showed that accuracy levels ranged from 50 to 80 percent when 'exact match' approaches were used. Evaluations based on 'degree of similarity' assessments indicated accuracy levels in the area of 90 percent (Nikiforuk et al. 1993). These evaluations were carried out on maps of considerably smaller scale (1:50 000) than that considered here, but they suggest that guidelines such as '0.2 to 2 inspections per square cm of map area' provide adequate coverage and accuracy.

It was indicated above that a high survey intensity and a presentation scale of 1:5000 are recommended for cutover peatland survey and that a relatively high inspection density (e.g., one per ha) would be appropriate for this scale. This inspection density would translate into an intensive field program. Another factor to consider is that the inspection density required to achieve a reasonable level of accuracy is dependent on the variability of soils in the cutover peatland. Relatively low inspection densities can be justified where it can be shown that the peat soils and deposits are uniform. This can be carried out by doing the survey with an inspection density at the lower limit of the recommended range (i.e., one observation per 4 or 5 hectares) and then evaluating the trends and possibly calculating simple statistics such as the means and coefficients of variation of soil properties. For example, if a gradual and predictable trend in peat properties over a survey area is demonstrated, then the production of a peat map can be carried out with relatively high precision and accuracy. If much variability is found, this points to the need for more data and further survey can be carried out by selecting additional inspection sites.

More rigorous methods for assessing sampling adequacy are available in the form of a number of geostatistical methods. It is not the intent to present any of these methods here. Overview information on these methods can be found in various references (e.g., Upchurch and Edmonds 1991). Geostatistical software specifically developed for environmental evaluations is applicable to mapping peatlands (e.g., EPA software developed by Englund and Sparks 1988). An example of contouring and applying geostatistical techniques to evaluate variability and sampling adequacy using software developed for geological sciences is presented in Part II of this report. This analysis showed that one inspection per 4 ha (inspections on a 200 m grid) was an adequate inspection density for determining peat thickness in a part of the peatland where soil properties were fairly uniform, but that other areas were highly variable and required a higher inspection density.

Some of the information required for cutover peatlands will require 'single factor' presentation of data as opposed to a thematic mapping approach as with soils. Surface elevation and peat thickness data are most effectively displayed by use of isoline maps. The precision of such maps can be defined by the contour interval. The level of precision required for drainage design and water level control in some potential applications (e.g., agriculture, forestry) needs to be somewhat less than one metre. An interval of 0.5 m is required for surface elevation and peat thickness by the 'Peatland Inventory Requirements for Surface Mineral Lease (SML) Applications'. Consequently, 0.5 m is suggested as an appropriate level of precision for mapping cutover peatlands.

In summary, a high intensity level survey is required for mapping cutover peatlands. A map presentation scale of 1:5000 is recommended. High intensity level survey requires a minimum of one inspection per 4 to 5 ha of survey area. This may be sufficient if uniformity or high predictability in soil and land attributes can be demonstrated. A higher inspection density, approaching one per ha or less, will be needed to adequately map areas with relatively high variability.

3.2 PRE-FIELD ACTIVITIES

3.2.1 Background Research and Review

Survey of cutover peatlands simply involves addition of information to an existing database in situations where pre-harvest mapping has been carried out. Where no pre-harvest survey information exists, background information can be collected from existing photographs, reports, and maps as follows:

1. Aerial photographs - vegetative surface cover (if any), drainage ditch system, surface soil moisture conditions, surface ponding;
2. Soil and surficial geology surveys - nature of underlying mineral material; mineral soil types within peatland areas;
3. Company records - if available, peat moss company records may include pre-harvest elevation and thickness data, and post-harvest thickness information for the remaining peat in some locations;
4. Topographic maps - surface elevation prior to harvest; newer 1:20 000 maps produced by the Provincial Mapping Program provide more detailed and possibly quite recent information;
5. Climate maps and reports - data for growing degree days, frost free periods, and other information is available from Alberta Agrometeorology Advisory Committee (1987), Longley (1968) and reports of the Atmospheric Environment Service, Environment Canada.

3.2.2 Base Map Development

Acquisition of a base map should be one of the first steps in undertaking a mapping project. Base maps at 1:20 000 scale developed by the Provincial Mapping Program should be obtained in hard copy format, or in digital format if mapping is to be carried out by computer methods. A hard copy base map at the final presentation scale (1:5000 or 1:10 000) should then be developed from the 1:20 000 base map. Concurrently, an aerial photograph to be used as a field working map should be enlarged to exactly the same scale to enable overlay of the base map on the photograph. Carrying out these procedures at the outset of a project will enable subsequent data compilation and referencing of locations to be done with respect to one base. Field working copies of the base map should be produced for overlaying on aerial photographs, for indicating locations of soil and vegetation inspection points, and for preparing preliminary versions of maps.

3.2.3 Pre-typing Aerial Photographs

The most readily available aerial imagery of appropriate scale is 1:15 000 black and white IR photography. Even this scale, however, may be too small for recognition of features to be represented on maps of 1:5000, or even 1:10 000 scale. True colour or false colour IR photography of 1:5000 or 1:10 000 scale can be obtained specifically for the project if funds permit. Supplementing black and white photography with oblique colour photographs taken by flying over the map area can be an effective and economical alternative to the above.

3.2.4 Selecting Standards for Description

Existing soil, peat, and vegetation classification systems are appropriate for mapping cutover areas. Many classification systems are hierarchical and are, therefore, adaptable to a wide range of mapping scales. The classification systems that have been developed and that are recommended for application to mapping peatlands are as follows:

1. Peat material classification (based on degree of decomposition, botanical composition and trophic status);
2. Drainage classification system;
3. Vegetation classification system, and;
4. Soil classification.

These systems are presented in Part III of this report.

3.3 FIELD COMPONENT

3.3.1 Study Area Reconnaissance

An overview or reconnaissance of the area to be surveyed constitutes the first in-field procedure. In a cutover peatland area, this would need to be done by foot as vehicle access can be somewhat limited. The purpose is to gain a general perspective of the area to be surveyed, and more specifically to familiarize mappers with the setting, to provide an opportunity to evaluate and adjust the field sampling plan, and to permit review of the pre-typing.

3.3.2 Options for Attaining Desired Inspection Density

The intent here is to summarize operational aspects of attaining the inspection density appropriate to a high intensity level survey.

The recommended interval for determining surface elevation is 200 m. This provides an inspection density of one per 4 ha which is near the lower limit for high intensity survey. Peat thickness data should be collected at the same sites. It is suggested that peat profile data also be collected at each of these sites if it appears to be representative of a mapping unit.

Additional inspection points for peat profile descriptions can be selected by the judgement sampling approach; i.e., sampling in which a sample's representativeness of the population is based on the mapper's judgement rather than on independent, objective criteria as in a systematic sampling approach (Myers and Shelton 1980). A sufficient number of data points for various peat and peatland characteristics will be generated in this manner if the trends are uniform and predictable.

Additional inspection points need to be selected if trends are not uniform. If the land surface is variable, additional elevation data points will need to be selected. One approach involves selection of an inspection site within each cell created by the original 200 m grid. In each cell, the actual site selected can be based on observed variation such as a dip in the land surface or apparent thinning of the peat layer.

Areas of high variability in various peat properties can be observed in the course of a survey and additional sampling may become apparent. Inspection points can then be selected using the judgement sampling approach or by a combined approach as indicated above. It may be observed that there is much variation in peat thickness but not necessarily in other properties. In this case, only depth probings need be taken to ensure sufficient data points for contouring purposes.

3.3.3 Elevation and Peat Thickness Survey

Surface elevation contour mapping is required for depicting subtle and imperceptible slopes important for drainage design in reclamation, and for providing a surface datum on which to base peat thickness and elevation of the mineral subsoil surface. The least complicated and most accurate method of determining elevation changes between points along the ground involves use of a leveling rod and a transit or engineer's level. This method only gives elevation differences and a reference point of known elevation must be located in the vicinity to serve as a starting point. Any convenient starting point can be assigned an arbitrary base level of elevation if only the relative elevations are required; i.e., without expressing elevations in relation to mean sea level. Procedures for leveling are further described in references such as Myers and Shelton (1980).

The measurement of elevations on a grid pattern is controlled by measuring distances and angles with a tape measure and a transit. An alternative method that may be more convenient involves use of a Global Geopositioning System (GPS). This system can measure position very accurately but the technology may still be too expensive. With a GPS unit, a survey could be carried out by pacing out along a crude grid pattern, precluding the need for measuring angles and distances. The resulting grid may not represent a precisely square pattern, but this is not needed for subsequent derivation of elevation contours.

Peat thickness measurements should be carried out at the same sites as elevation measurements. This will enable calculation and contouring of the elevation of underlying mineral surfaces. It is possible, but not preferable, to derive elevations of the underlying mineral surface if data are not collected for both elevation and peat thickness at the same sites. This can be done by subtraction of interpolated thickness data from interpolated elevation data, and is most readily accomplished by geostatistical computer procedures. An example of this is provided in Part II of this report.

3.3.4 Field Survey of Soils and Vegetation

A peat soil and vegetation survey can be conducted by traversing the study area on foot and selecting inspection sites for soils and vegetation on the basis of both a judgement sampling approach and on locations of elevation measurements. Free survey involving judgement sampling is generally considered to be the most rapid and cost effective mapping approach (Agriculture Canada Expert Committee on Soil Survey 1981). Purposive sampling refers to selection of sites considered to be representative of mapping units pre-typed by aerial photograph interpretation. Efforts should be made to ensure that there nevertheless is a more or less even spatial distribution of inspection points in attempting to characterize the mapping units.

The peat soils and subsoil peat and mineral strata are examined using a spade and a sampler. The most commonly used sampler is the Macaulay peat auger (described by Day et al. 1979; illustrated in Figures 2.9 and 2.10). Inspection sites are selected on the basis of perceived changes in drainage and vegetation that could reflect soil conditions combined with changes noted by aerial photograph interpretation. Locations of sites are determined by reference to aerial photographs and to elevation survey grid points.

Soil attributes described in the field should include: peat layer differentiation and thickness; estimate of von Post degree of decomposition; estimate of rubbed fibre content; pH (using pH paper); general botanical composition of peat layers; layer thickness; depth to mineral subsoil; colour; and texture, colour and apparent origin of underlying mineral materials. On the basis of rubbed fibre and von Post estimates, peat layers can be classified as Ov, Of, Om or Oh horizons (O- organic soil horizon; v- very fibric peat, >75% fibre; f- fibric peat, 40 to 75% fibre; m- mesic peat, 10 to 40% fibre; h- humic peat, <10% fibre; see Part III, Section 2 for definitions). Except for 'Ov', these peat type designations are derived from the Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey 1987). An 'Ov' designation is suggested to enable more detailed differentiation of peat layers. Definitions of the above terms and classification systems used for describing some of the peat properties are presented in Part III of this report.

Site inspection attributes that should be recorded include: drainage condition; depth to water table, where possible; and extent of vegetation cover and non-vegetated soil. Major vegetation species or groups are identified at each site, and their cover recorded using a simple system such as a 'dominant, significant, minor' abundance scale. Relatively complete plant species lists and more quantitative abundance data are best obtained through the services of an experienced vegetation consultant. Data should be collected on the basis of sites that, based on prior survey and reconnaissance, appeared to represent the most common, recurring plant community types.

Drainage conditions at the inspection sites should be inferred from the depth to water table. The time of year and recent weather conditions must be considered in this evaluation. A simple classification scheme for describing drainage was adapted from the system used for soil surveys (Agriculture Canada Expert Committee on Soil Survey 1983) for the purposes of the survey project reported in Part II of this report. This system is presented in Part III.

3.3.5 Sampling and Laboratory Analysis

3.3.5.1 Soil Chemical and Physical Properties. Laboratory analyses are required for verifying some types of field observations and for detecting soil components that may have implications with regard to environmental quality. Measures of pH and rubbed fibre have great importance since they have been shown to relate most closely with nutrient status, agricultural capability, site quality for tree growth, as well as other properties. Determinations of total carbon, cation exchange capacity, exchangeable cations and ash are useful but can have lower priority since they are correlated with each other and with pH and fibre content (Lucas 1982; Walmsley 1977). Hence, measures of these can be semi-quantitatively determined from such correlations. Total elements, including nitrogen, are related to soil nutrient status, and others may indicate potential environmental problems. Such analyses must have relatively high priority if potential environmental impacts are to be among considerations in a reclamation plan. Analyses are costly and care in selecting sample sites is needed.

It is difficult to prescribe environmental sampling protocols as each situation has unique features that must be considered to attain adequate sampling. It is suggested, however, that the soil variability determined from field survey be used as a guide to peat sampling. High variability in the nature of the peat materials will indicate the need for relatively more sampling than in situations with apparent low variability in the materials. In general, a representative profile of every soil type that is mapped should be sampled. Profiles with unusual features such as presence of sedimentary peat layers or abnormally high or low field pH values should be sampled for analysis.

3.3.5.2 Soil Nutrient Status. Nutrient levels in soils are dynamic since they are being replenished in soil by mineralization and at the same time are taken up by plants. In cutover peatlands with little or no vegetative cover, it is difficult to evaluate amounts of nutrient accumulation versus losses down the profile due to leaching. Agricultural guidelines for evaluating nutrient content indicate that the best time to take samples is during the fall, but this is mainly due to the fact that spring sampling is made difficult by frost remaining in the soil for a long time. Sampling for nutrient measurements at the time of the peatland survey may nevertheless provide useful information for fertility evaluations. Analyses of samples taken from non-vegetated cutover peatlands will indicate the nutrient levels available for establishment of vegetation. The pH, degree of decomposition and plant origin of the peat provide an approximation of general fertility status; that is, the ability of the soil to sustain the nutrient supply to plants. Measures of mineralizable nutrients may provide the most valid indications of fertility status, but research is required to determine appropriate methods. Further information about nutrients in peat soils from an agricultural crop growth perspective can be found in Lucas (1982) and Sherstabetoff (1987).

Samples taken from surface soil horizons can be used for fertility evaluations. The recommended soil sampling depth for agricultural purposes is 0 to 15 cm, and obtaining additional samples from 15 to 30 cm and 30 to 60 cm is suggested for more thorough evaluations of nutrient status (Alberta Agriculture 1988).

3.3.5.3 Water Quality. Analysis for water quality parameters is recommended in order to determine if peatland drainage waters meet water quality guidelines. Spot checking of water quality parameters in cutover peatland ponds and ditches can be a useful component of the survey as the results can influence land use decisions. Analyses of receptor stream waters should be included to determine extent of dilution of those constituents that exceed water quality guidelines within the peatland. A large number of water quality parameters can be addressed. These are listed along with guidelines for their limits in Part III of this report. The guidelines are reproduced from CCREM (1987), and focus on water quality for aquatic life and for livestock drinking water (applicable to non aquatic wildlife such as ungulates). There are no guidelines in Alberta regarding types and numbers of samples to take for water quality analysis in relation to environmental impact assessments. Analysis of samples from only a few well-selected sites is recommended for establishing a baseline condition for comparing water quality after reclamation measures are undertaken. In the case of organic water quality parameters, most of the CCREM guidelines pertain to anthropogenic chemicals. Unless some type of chemical contamination is suspected, analyses should be focused on naturally occurring organic substances.

3.4 POST FIELD ACTIVITIES

3.4.1 Analysis and Compilation of Data

Some classification and mapping decisions may be difficult to complete until non-field acquisition of data is completed. This may include soil chemical analyses, plant species identification, and tabulation of field data followed by examination for degree of uniformity or variability. Concurrently, any adjustments to polygon lines on the field maps can be made.

3.4.2 Development of the Map, Mapping Units and Legend

The mapping process essentially consists of recognizing similarities and subsequently grouping entities according to their likeness. For high intensity level mapping it was earlier suggested that the basic unit for differentiating soils in cutover peatlands should be the soils series or phase of series. The segregation of the landscape into units of similar soils is usually carried out in the field component, but polygons and line positions can be refined on the basis of additional post-field information collected as indicated in Section 3.4.1 above.

Mapping units will also have been described in the field, and the post field activity involves describing them according to a uniform format, checking for redundancy, and so on. The map unit description, using soil series criteria, includes: depth, reaction (pH), type of peat, nature of underlying mineral material, and abundance of coarse materials such as logs and stumps (Agriculture Canada Expert Committee on Soil Survey 1987). Accessory soil characteristics include slope, drainage regime and total depth of peat. The vegetation type can become part of the map unit description in older cutover peatlands with surface cover. This has potential for proliferation of map unit numbers because more than one type of soil or vegetation can be associated with the other. The vegetation component of the mapping unit should normally consist of a single type, but it is possible to have complexes of two or more types.

Mapping units are most readily identified using a numbering system. These numbers then serve as the key or symbol to be used to identify polygons on the peatland map. The soil and vegetation components of a mapping unit can be described together under one symbol. However, in the map exercise described in Part II, it was found that separate soil and vegetation mapping units were easier to develop. The polygon identifiers then became combinations of soil and vegetation unit symbols, using numerals for soils and alphabetic symbols for vegetation (e.g., Unit 2b).

3.4.3 Single Factor Maps

A single factor map depicts a single property or attribute. Such maps display variation in a land feature by means such as polygon, rastor, or isoline representations. Numerous soil chemical and physical properties can be represented by such maps. However, most are handled through the soil survey mapping units and are represented as polygon maps. For purposes such as planning a drainage system in cutover peatland reclamation scenarios, more precise information will be needed for surface elevation, peat thickness and the elevation of the underlying mineral soil. The focus is therefore on isoline (or contour) maps since elevations are normally handled in this manner.

Elevation contour and peat thickness maps can be produced quite accurately by manual interpolation of field data, especially if the amount of variability is not high. Likewise, an elevation contour map of the mineral soil subsurface can be derived provided peat thickness data have been obtained at the same sites as elevation data. Computing methods are needed where data have not been obtained from the same points.

Several computer software packages for contouring are available. It is considered important that the software be chosen such that data can be moved to and from a geographical information system (GIS). This enables presentation of results on the same base map as other non-contoured information, and if desired, enables the super-position of contour information on other layers within a GIS (e.g., super-position of elevation contours on a soil map). Automated contouring provides a rapid method for processing field data and deriving maps and, in a GIS environment, has advantages as indicated above. However, access to automated contouring may not be available, and manual methods would be required. An elevation contour map was manually prepared with results very similar to that of the automated contouring method applied in this project (Part II). Peat isopach maps would likewise be easily produced by manual methods. Contour maps of mineral subsoil elevations would be somewhat more difficult to produce due to the additional effort required to calculate the elevations. This is an uncomplicated task in cases where peat thickness data are obtained at exactly the same locations as surface elevation data. Where the data are obtained from different locations, there would be an additional, and relatively difficult, task of interpolating data points for peat thickness to data points of surface elevation (or vice versa).

3.4.4 Report

The final procedure in the mapping process involves preparation of a report in which the main purpose is to provide detailed descriptions of the map area. Data can be presented in the forms of tables and graphs. Photographs can be helpful in demonstrating the nature and variability of mapping units.

Hard copy map information can be produced using a variety of formats. While suitable maps can be produced in black and white, the use of colour or gray shading to enhance both thematic and single factor maps is highly recommended. A format that may be especially helpful to users consists of superimposing map information on an aerial photographic mosaic base. Presentation of planimetric and hydrographic information is essential in any of these formats.

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PART II. SURVEY OF A CUTOVER PEATLAND IN THE EVANSBURG AREA, ALBERTA

1. INTRODUCTION

This part of the report presents the results of a study to obtain baseline chemical information and data interpretation for basal peat materials at one cutover peatland site. This project was carried out to provide information for a site requiring reclamation, as well as to test cutover peatland survey techniques and thereby assist in the development of procedures as outlined in Part I.

2. STUDY AREA

The study area is located near Evansburg, Alberta, and comprises portions of Sections 28, 29, 32 and 33 in Township 53, Range 8, West of the 5th Meridian (Figure 2.1). It encompasses an area of 107 ha, or about 1.5 quarter sections. The study area is within the Fison's Western Ltd. lease and has a history of peat harvesting by other companies dating back to the 1960s. The study area is located on a glaciolacustrine plain within the Moist Mixedwood Subregion of the Boreal Mixedwood Ecoregion; climatic, vegetational and other landscape characteristics of this ecoregion have been described by Strong and Leggatt (1992).

3. METHODS

3.1 BASE MAP AND AERIAL PHOTOGRAPHS

Aerial photograph interpretation was carried out using 1:15 000, black and white IR aerial photographs dated 88-09-11, supplemented by 1:15 840 black and white IR photos dated 61-09-27. A 1:5000 aerial photograph of the study area was obtained by enlarging one of the 1:15 000 photographs dated 88-09-11. A copy of this photograph was used for peat soil/vegetation mapping, for assisting in determination of site locations in the field, and for producing a preliminary base map.

Oblique, colour photographs were also used to assist in delineation of land units. The photographs were obtained by helicopter overpass at heights of 150 m (500 feet) and 300 m (1000 feet) above the ground. The photographs were taken during early September, 1991, after senescence of much of the vegetation. Photography from different years was examined in order to trace the history of peat harvesting and thereby determine the initiation dates of vegetation regeneration in different parts of the study area.

The primary base map for indicating locations of elevation data points was derived from 1:50,000 NTS maps and from Alberta Transportation road location maps.

A base map providing the information common to maps used or developed in the project, and allowing for the precise registration of field maps, was derived from 1:20 000 digital base files distributed by the Land Information Services Division (LISD), Alberta Environmental Protection. The transfer of base data was carried out using the procedure provided by LISD for the processing of COGIF data (base map data are saved in the COGIF format), and the procedure for the transfer of DXF data to the pcARC/INFO geographic information system (ESRI 1988a,b).

3.2 ELEVATION CONTOUR MAPPING

Surface elevation contour mapping was carried out in order to depict subtle and imperceptible slopes important for drainage design in reclamation, and to provide a surface datum on which to base peat thickness and elevation of the mineral subsoil surface. Elevation data were obtained using a level and leveling rod. Differences in elevation were determined between points on the ground on a 200 m grid pattern, thus attaining a density of one data point per 4 ha. Additional points were selected where unique features such as mineral soil knolls, drainage ditches and mounds of excavated peat were encountered. An elevation reference point was selected by determining a location of the nearest contour line as depicted on a 1:50 000 National Topographic Series map (dated 1979) of the area.

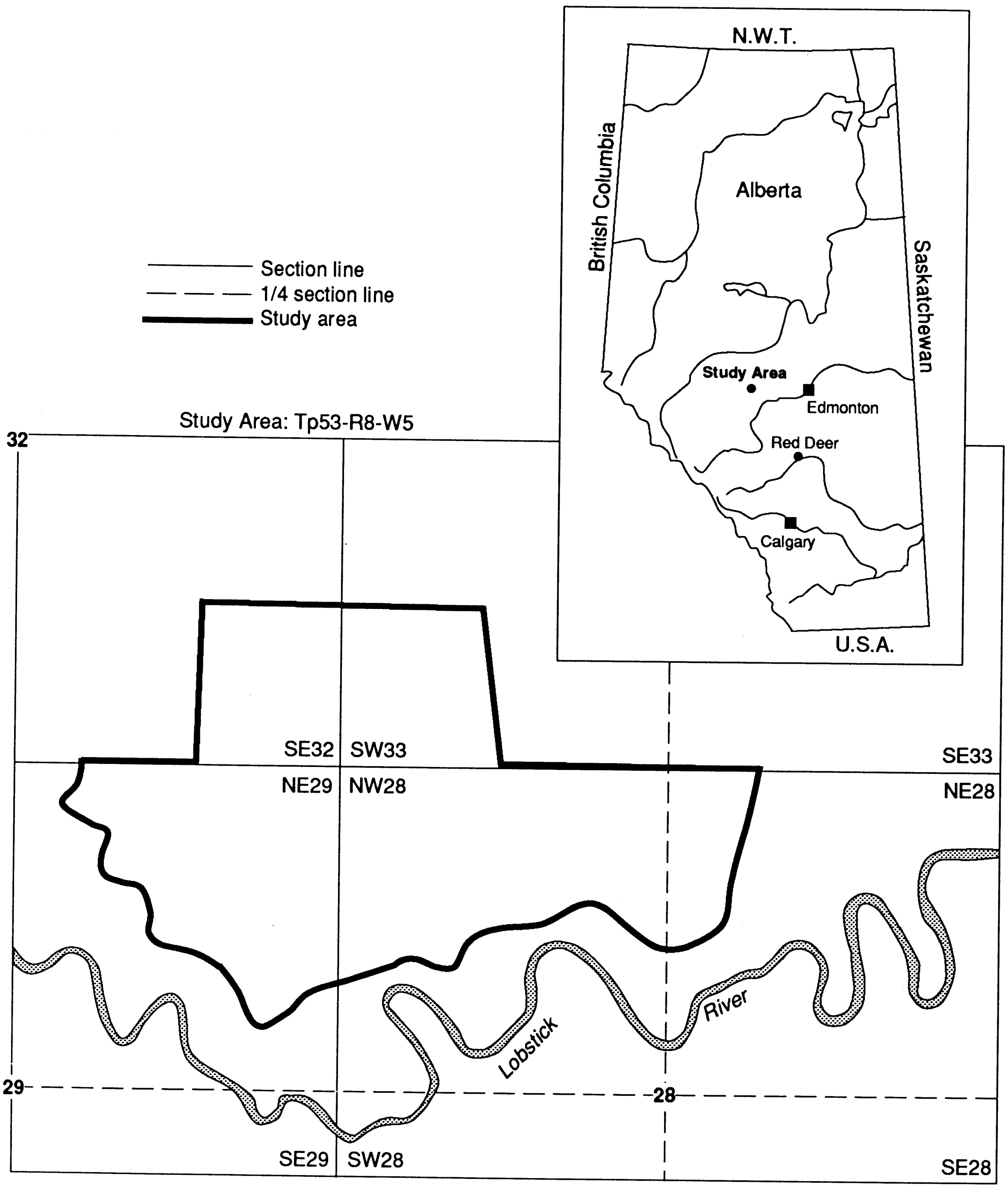

Figure 2.1 Location of the cutover peatland study area.

The original elevation information included data points for road surface, ditch bottom, ditch water level, ditch spoil pile, and other elevations. These data were not used in the contouring procedure as they would have resulted in a dense, complicated pattern of contours. The major objective was to produce a contour map of the seemingly flat surface of the cutover peatland, and this was achieved by excluding measurements that were not on the flat peatland surface. A contour interval of 0.50 m was suitable considering the low relief.

Elevation points from the field map were digitized in pcARC/INFO. Digitized elevation data were transformed from digitized to ground coordinates using quarter section corners bordering the study area as reference points. The correct ground coordinates for these points were obtained from the base map and the locations of the transformed elevation data were checked with the base map. The elevation readings for each point were linked with the corresponding elevation point locations, and as a result the 'coverage' containing the elevation values and their locations was created.

For contouring, elevation data (XYZ triplets) were transferred from pcARC/INFO to the CPS Radian contouring package (Radian Corporation 1990). A matrix of grid points at 100 m intervals was generated from the field elevation data using a CPS Radian gridding algorithm. Using this grid the contour lines of surface elevation were generated. Contours were generated at 0.5 m intervals starting at the elevation of 84.0 m. The elevation grid was blanked outside the study area boundary in order to confine the contours within the study area.

The convergent algorithm in CPS Radian was used for gridding. This algorithm uses a distance-weighting technique such that data points closer to a grid point have a larger influence on the grid point value than control points further away. Multiple iterations of calculating grid nodes from control points are carried out until a goodness-of-fit is reached such that the grid accurately reflects the control data. Further details of the procedures can be found in Radian Corporation (1990).

Contours generated using CPS Radian were transferred to pcARC/INFO. These formed the 'coverage' with contour lines in which each line had been assigned its elevation value. The contour map was plotted using a CALCOMP 1043GT vector plotter.

3.3 PEAT SOIL AND VEGETATION MAPPING

3.3.1 Field Survey Procedures

A peat soil and vegetation survey was conducted by traversing the study area on foot and making inspections using a purposive sampling approach. The peat soils and subsoil peat and mineral strata were examined using a spade and a Macaulay (Russian) sampler (described by Day et al. 1979; illustrated in Appendices, Section 6.1). Inspection sites were selected on the basis of perceived changes in drainage and vegetation that could reflect soil conditions combined with changes noted by aerial photograph interpretation. Locations of sites were determined by reference to aerial photographs and to elevation survey grid points that had been marked with flagging tape. In total, 63 inspection sites were visited, providing an inspection density of one site per 1.7 ha.

Soil attributes described in the field included: peat layer differentiation and thickness; estimate of von Post degree of decomposition; estimate of rubbed fibre content; pH (using pH paper); general botanical composition of peat layers; layer thickness; depth to mineral subsoil; colour; and texture, colour and apparent origin of underlying mineral materials. On the basis of rubbed fibre and von Post estimates, peat layers were classified as Ov, Of, Om or Oh horizons (O- organic soil horizon; v- very fibric peat, >75% fibre; f- fibric peat, 40% to 75% fibre; m- mesic peat, 10% to 40% fibre; h- humic peat, <10% fibre; see Glossary for definitions). Criteria and methods were those of the Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey 1983, 1987). An exception is the 'Ov' designation that was introduced for the purposes of this survey to enable more detailed differentiation of peat layers. The lower limit of 75% fibre for this category was adopted from the soil classification system used in the United States (Soil Survey Staff 1975).

Site inspection attributes that were recorded included: drainage condition; depth to water table, where possible; and extent of vegetation cover and non-vegetated soil. Major vegetation species or groups were identified at each site, and their cover was recorded using a simple 'dominant, significant, minor' abundance scale. As the surveyors were not expert at identifying many plant species, relatively complete plant species lists and their abundances were obtained through the services of a vegetation scientist. A subset of ten sites that, based on prior survey and reconnaissance, appeared to represent the most common, recurring plant community types was selected for detailed vegetation descriptions. Plant species lists and tabulations of species abundances were compiled by a vegetation consultant.

Drainage conditions at the inspection sites were inferred from the depth to water table. These descriptions reflected relatively dry conditions as the field work was carried out during the latter part (mid to late August) of a somewhat dry summer. A classification system for drainage regime was not used in the field survey. However, the field observations were later used to devise a classification system in order to provide a simple descriptive scheme for use in the legend. This system is described in Part III of the report.

3.3.2 <u>Classification Systems</u>

A number of classification systems were used to describe peat and peatland features. These are presented in some detail in Part III. The systems described are: peat material classification, comprising classes for botanical composition, degree of decomposition and trophic (nutrient) status; drainage regime classification; vegetation classification, and; soil classification.

3.4 PEAT ISOPACH MAPPING

Peat thickness data were obtained for each inspection site during the course of soil and vegetation investigations in the field. Peat thickness refers to the total thickness of the peat deposit, between its surface and its contact with mineral subsoil. No data for thickness of peat in spoil piles was included in producing the peat isopach map and, as with elevation contours, the contouring product represents only the in situ, non-harvested peat.

The occurrence of mineral knolls (i.e., small mineral soil uplands within the peatland) presented unique problems in deriving contours by computer methods. These knolls were delineated as soil polygons on the original field map. These delineations were digitized as soil polygon lines in the pcARC/INFO database and set to appear as '0.0 m' contour lines on the peat thickness map. A mechanism to blank these areas with no peat cover was employed to force the gridding algorithm to produce contours that would go around them rather than through them. Otherwise, the gridding, contouring, transfer of the contours to pcARC/INFO, and plotting were carried out using the same procedures as for the processing of surface elevation contours (Section 3.2). The contouring procedures were used to produce a peat isopach map having a thickness contour interval of 0.5 m.

3.5 DRAINAGE SYSTEM MAPPING

The study area is crossed by numerous drainage ditches of various sizes. Two size classes of the ditches, large (about 1 m or more across and about 1 to 2 m deep) and small (less than 1 m across and about 0.5 to 1 m deep) were distinguished by examination of aerial photographs, and the direction of water flow in the ditches was depicted using arrows. The direction of flow was difficult to determine in some situations and the most likely direction was inferred from other information such as locations of outlets. It was also apparent that beaver dams had backed up and/or diverted water flow in some parts of the peatland.

The largest ditches are depicted in the 1:20 000 provincial base map for the area. All other ditches were traced from an aerial photograph onto a hard copy of the base map and then digitized. A drainage system map was generated by merging the minor drainage network from the field map and the major drainage network from the base map. Digitizing of the minor drainage network and its transformation to ground coordinates was carried out using the procedure for processing of elevation data (Section 3.2). Extraction of data from the digital base map for location of the major drainage network was carried out using pcARC/INFO data manipulation functions. This digital information was combined with the base map in the GIS and was then plotted.

3.6 CONTOUR MAPPING OF MINERAL SUBSOIL ELEVATION

Grid matrices were generated in the procedures for generation of both the surface elevation contour and peat isopach maps. A grid of the mineral subsoil elevation was obtained by subtracting the grid of peat thickness from the grid of surface elevation. Contouring of the resultant grid and transfer of contour lines to pcARC/INFO was done using the procedures for the processing of surface elevation data (Section 3.2). The contour interval was 0.5 m.

3.7 LABORATORY CHARACTERIZATION OF PEAT MATERIALS

Soil samples for laboratory analysis were taken using a Macaulay sampler and were kept frozen until analysis could be carried out. Samples were taken from complete profiles (to mineral subsoil) at 6 sites and from surface layers only (0 to 20 and 20 to 40m) at an additional 4 sites. Analyses consisted of the following: pH ($CaCl_2$), rubbed fibre content, cation exchange capacity (CEC), exchangeable cations, total C, total N, electrical conductivity and ions in saturated extract (if alkaline), and total elements including various heavy/toxic elements. The pH of soil samples was measured in a 2:1 slurry of 0.01 M $CaCl_2$ (McKeague 1978). Total carbon content was measured with a LECO CR12 carbon analyzer (Leco Corporation 1979). $CaCO_3$ equivalent was determined by the acid dissolution method of Bascomb (1961). Electrical conductivity and soluble ions were determined in saturated paste extracts prepared as described by McKeague (1978). The pastes were filtered through 0.45μm filter papers and analyzed for pH, electrical conductivity, alkalinity, Cl, S, Ca, Mg, Na and K by ICP-AES (Inductively Coupled Plasma Atomic Emission Spectrometer) and Technicon AutoAnalyzer. Cation exchange capacity (CEC) and exchangeable cations were determined by extraction with a normal (1 M at pH7.0) ammonium acetate solution (McKeague 1978), where NH4 ions were determined with a Tecator Kjeltec Auto 1030 Analyzer distillation and titration unit, and the exchangeable cations by ICP-AES.

Particle size analysis was carried out according to the simplified hydrometer method described by Gee and Bauder (1979). Rubbed fibre content was determined by measuring the quantity of peat remaining on a 100 mesh (0.15 mm) screen after processing samples with a milk-shake stirrer (Day et al. 1979). Ash content was measured by igniting peat samples in a muffle furnace at 550°C. All measurements were expressed on an oven-dried weight basis.

Total elemental analysis of some of the peat samples was carried out by digestion with a concentrated HNO_3-$HClO_4$ acid mixture in a teflon bomb heated in a CEM microwave digestion unit. The solution concentrations of Al, Fe, Zn, Mn, Ca, Mg, Na, K, Sr, P, Ba, Cd, Pb, Cu, Li, Ti, Co, Cr, V, Se, Mo, B, S, Si and As were measured by ICP-AES. Mercury (Hg) was analyzed separately by atomic absorption spectroscopy.

3.8 EVALUATION OF FERTILITY STATUS OF SURFACE SOILS

Samples from the top one or two layers at each sample site were analyzed for plant nutrients at the Alberta Soils and Feed Testing Laboratory. The nutrient analyses included NO_3-N, NH_4-N, SO_4-S, PO_4-P, K, Cu, Mn, pH and electrical conductivity. The layers were at 0 to 20 and 20 to 40 cm intervals, or intervals similar to this based on observable changes in the peat soil. The methods of analysis, described in detail by Alberta Agriculture (1988), are as follows: NO_3-N and NH_4-N by potassium chloride extraction; SO_4-S by calcium chloride extraction; PO_4-P by a modified Bray procedure using an ammonium fluoride-sulphuric acid extractant; potassium by an ammonium acetate extractant; copper and manganese by a DTPA extraction method; and pH and electrical conductivity with a 1:2 soil:water mixture.

3.9 EVALUATION OF WATER QUALITY

Water samples were obtained from drainage ditches, ponds and surface pools using polyethylene containers. Seven samples were taken. Electrical conductivity and pH measurements were made the day after sampling. Samples were then filtered and refrigerated for total elemental and anion analyses. pH was measured using a Radiometer combination electrode and Radiometer PHM82 pH meter. Electrical conductivity was measured using a Yellow Springs Instruments conductivity cell and Model 32 conductance meter. Total elements in solution (Ca, Mg, K, Na, Al, Fe, Mn, P, S, Cr, V, Ti, Cd, Cu, Pb, Zn, Li, Sr, B, Ba, Mo, Ni, Se, As, Co and Si) were measured by ICP-AES.

3.10 EVALUATION OF SAMPLING ADEQUACY FOR PEAT THICKNESS

Geostatistical techniques have been developed and applied for evaluating the spatial variation in landscape attributes. In the case of using isolinear maps, such as the isopach map in this study, a measure of the variance at each point in the grid matrix generated from data points can be calculated. Coefficients of variation of the isolines can also be generated and depicted on the maps with such data. The maps can then be used to identify inadequately sampled areas. These procedures were carried out in this project using the software of Geostat Systems International Inc.

4. RESULTS AND DISCUSSION

4.1 ELEVATION CONTOUR MAPPING

Map 1, Appendix 6.4, shows the contours of the ground surface elevations in the cutover peatland study area. The data points used for deriving Map 1 are presented in Map 6. The contour map depicts the general downward slope of the land surface from the north and northwest toward the south. Two of the higher mineral soil islands in the area are represented by concentric contours. There are numerous other mineral islands in the area, but these are generally only slightly elevated in comparison to the surrounding peatlands. The usefulness of the elevation map with regard to reclaiming the cutover peatland is related to planning of land surface manipulation, revegetation and drainage. Examples include planning for filling-in of drainage ditches, determining which ditches should be left open in the design of an integrated drainage network, possible need for new ditches, and contouring peat surfaces.

Operational aspects of using levels and leveling rods in peatland situations are unique due to the soggy and soft nature of the material. Extra effort is needed to obtain accurate readings as compared to 'hard ground' surveys. In some situations, the peat surface is hummocky with microrelief of up to about 0.5 m within distances of about 1 to 5 m. It is recommended that the average level of the surface be assessed in these situations, and that the elevation be determined at this level. Elevation measurements in this study (not presented in this report) included data for tops of spoil piles, ditch bottoms and road surfaces. Collection of such data is recommended as they are useful for purposes such as planning earth moving activities to level the area and to fill in ditches.

4.2 PEAT SOIL AND VEGETATION MAPPING

4.2.1 Peat Soils and Deposits

The various peat soil and vegetation units identified during the field mapping component of this project are presented in Map 2. Locations of the field inspection sites are indicated in Map 7. The peat soils and deposits of the cutover peatland study area were described using the criteria: peat thickness, degree of decomposition, trophic status, botanical origin of the peat, drainage regime, and soil classification (Section 3.3). A legend for describing the mapped peat soils and deposits was developed on the basis of these criteria. The legend accompanies Map 2. The following are more detailed descriptions of the peat soil and stratigraphic units.

Unit 1 - <1.0 m deep; about 0.5 m fibric, oligotrophic sphagnum (bog) peat overlying mesic, mesotrophic moss-sedge (fen) peat; moderately saturated; main soil subgroups are

Terric Mesic Fibrisol and peaty Orthic Luvic Gleysol; fine textured glaciolacustrine subsoil.

Unit 2 - <1.0 m deep; about 0.5 m fibric, oligotrophic sphagnum peat overlying mesic and fibric, mesotrophic moss-sedge peat; moderately saturated; main soil subgroup is Terric Mesic Fibrisol; fine textured glaciolacustrine subsoil.

Unit 3 - <1.0 m deep; mesic and fibric, mesotrophic moss-sedge peat with thin (<0.3 m) fibric cap; some woody peat at depth; moderately saturated; main soil subgroup is Terric Mesisol; fine textured glaciolacustrine subsoil.

Unit 4 - <1.0 m deep; about 0.5 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; may have thin, decomposing (mesic) cap; highly saturated; main soil subgroup is Terric Fibrisol; fine textured glaciolacustrine subsoil.

Unit 5 - 1.0 to 2.0 m deep; mesic and fibric, mesotrophic, moss-sedge peat; very highly saturated; main soil subgroup is Terric Mesisol; fine textured glaciolacustrine subsoil.

Unit 6 - 1.0 to 2.0 m deep; mesic and fibric, mesotrophic, moss-sedge peat; some fibric layers; highly saturated; main soil subgroups are Terric Mesisol, Terric Fibric Mesisol and Typic Mesisol; fine textured glaciolacustrine subsoil.

Unit 7 - 1.0 to 2.0 m deep; mesic, mesotrophic, moss-sedge peat with thin (<0.5 m) fibric cap; moderately saturated; main soil subgroups are Terric Mesisol and Fibric Mesisol; fine textured glaciolacustrine subsoil.

Unit 8 - 1.0 to 2.0 m deep; about 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; very highly saturated; main soil subgroups are Mesic Fibrisol and Terric Mesic Fibrisol; fine textured glaciolacustrine subsoil.

Unit 9 - 1.0 to 2.0 m deep; about 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; significant shallow (<1.0 m) peat; very highly saturated with some relatively dry areas; main soil subgroups are Mesic Fibrisol and Terric Mesic Fibrisol; fine textured glaciolacustrine subsoil.

Unit 10 - 1.0 to 2.0 m deep; about 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; some shallow (<1.0 m) peat; moderately saturated; main soil subgroups are Mesic Fibrisol and Terric Mesic Fibrisol; fine textured glaciolacustrine subsoil.

Unit 11 - 1.0 to 2.0 m deep; about 0.5 to 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; some woody layers; relatively dry; main soil subgroups are Fibric Mesisol and Fibric Mesisol; fine textured glaciolacustrine subsoil.

Unit 12 - >2.0 m deep; about 0.5 to 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; highly saturated with relatively dry areas of non-vegetated peat; main soil subgroups are Mesic Fibrisol and Typic Fibrisol.

Unit 13 - >2.0 m deep; about 0.5 to 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; highly saturated; main soil subgroup is Mesic Fibrisol.

Unit 14 - >2.0 m deep; about 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; thin mesic surface layer; very highly saturated; main soil subgroup is Fibric Mesisol.

Unit 15 - mineral soil with thin (<0.5 m) peat cap; fine textured glaciolacustrine subsoil; generally disturbed surface; imperfectly to poorly drained; main soil subgroup is peaty Orthic Luvic Gleysol.

Unit 16 - mineral soil with thin (<0.5 m) peat cap; fine textured (heavy clay) glaciolacustrine subsoil; generally disturbed surface; moderately well drained; main soil subgroup is Orthic Gray Luvisol.

Unit 17 - >2.0 m deep; mixed fibric and mesic peat in large piles; relatively dry.

Unit 18 - >2.0 m peat in area with numerous peat piles and ponds; mostly fibric, oligotrophic, sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; variable drainage regime, although much is inundated and highly saturated; main soil subgroups are Mesic Fibrisol and Fibric Mesisol.

Unit 19 - Mixed mineral material and peat in drainage ditch/spoil pile complexes; generally well drained spoil piles.

Unit 20 - Mostly mineral material in old, overgrown road bed; generally well drained.

Unit 21 - Open water areas such as remnants of deeply excavated areas or overflowing drainage ditches.

Unit 22 - >2.0 m peat; complex of open water with fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; very highly saturated; main soil subgroups are Mesic Fibrisol and Typic Fibrisol.

Unit 23 - Road and ditch complex.

Unit 24 - >2.0 m; about 1 m fibric, oligotrophic sphagnum peat over mesic and fibric, mesotrophic moss-sedge peat; complex of very highly saturated peat with areas of dry, non-vegetated peat in linear patterns along ditches; main soil subgroups are Mesic Fibrisol and Typic Fibrisol.

4.2.2 Vegetation

Vegetation in the cutover peatland study area is highly complex, apparently resulting from variable soil type, drainage, time since end of peat harvesting, water table fluctuation, soil chemistry and possibly other unidentified factors. Consequently, a large number of vegetation classes were recognized (Map 2). These classes are described on the legend accompanying the map and are also described in more detail below. Naming of the map units described below followed the Canadian Vegetation Classification System (National Vegetation Working Group 1990); the sequence is the same as in the legend but is given in text, as opposed to tabular, form. This sequence is: Physiognomic Type, Growth Form, Cover Class, Height Class and Dominant Species.

Unit a - Herb, Graminoid, Sparse, Low, cotton grass; consists of sporadic or bunched occurrence of *Eriophorum vaginatum* with a considerable amount of barren ground.

Unit b - Herb, Graminoid, Closed, Low and Intermediate, reed grass/bulrush; near continuous cover with *Scirpus cyperinus* and *Calamagrostis canadensis*

Unit c - Herb, Graminoid, Closed, Low, reed grass/sedge; dense cover of *Calamagrostis canadensis-Carex* spp.; pockets of *Calamagrostis canadensis- Eriophorum vaginatum* cover.

Unit d - Herb, Graminoid, Sparse, Low and Intermediate, cotton grass/sedge/bulrush; *Carex* spp., *Scirpus cyperinus* and *Eriophorum vaginatum* cover with inclusions of barren, non-vegetated ground.

Unit e - Herb, Graminoid, Closed, Low, sedge/moss; dense *Carex* spp. with *Sphagnum* and other moss species.

Unit f - Herb, Graminoid, Open, Intermediate, cattail; mainly *Typha latifolia.*

Unit g - Shrub, Mixed, Open, Low and Intermediate, Labrador tea/swamp birch; *Ledum groenlandicum-Betula* spp.-*Sphagnum* spp.

Unit h - Shrub, Deciduous, Open, Intermediate, swamp birch/cotton grass; medium to open shrub cover; *Betula* spp.-*Eriophorum vaginatum-Polytrichum strictum* cover type

Unit j - Shrub, Deciduous, Sparse, Intermediate, willow/reed grass/cotton grass; open cover of *Salix* spp. with *Calamagrostis canadensis-Scirpus cyperinus*; pockets of barren ground with sparse *Eriophorum vaginatum* cover.

Unit k - Shrub, Deciduous, Sparse, Intermediate, willow/reed grass/sedge; complex of open shrub cover and open vegetation; *Salix* spp.-*Calamagrostis canadensis -Scirpus cyperinus* cover with dense *Calamagrostis canadensis-Carex* spp. areas.

Unit m - Shrub, Deciduous, Open, Tall, willow/balsam poplar; *Salix* spp.-*Populus balsamifera* cover with numerous understory species.

Unit n - Shrub, Deciduous, Sparse, Intermediate, willow/swamp birch/aspen/paper birch; *Salix* sp.-*Betula* spp.-paper birch- *Populus tremuloides* cover with *Calamagrostis canadensis* , *Eriophorum vaginatum, Polytrichum strictum, Lycopodium* sp., and others.

Unit p - Shrub, Deciduous, Sparse, Intermediate, swamp birch/Labrador tea/sedge; complex of sparse to medium cover with open vegetation; *Betula* spp.-*Eriophorum vaginatum-Carex* spp.-*Calamagrostis canadensis-Ledum groenlandicum-Polytrichum strictum.*

Unit q - Shrub and tree, Mixed, Closed, Intermediate to tall, swamp birch/Labrador tea/white spruce; shrubland with some forest areas; *Betula* spp.-*Picea glauca-Ledum groenlandicum*-feather mosses such as *Pleurozium schreberi.*

Unit r - Shrub, Mixed, Open, Intermediate, swamp birch/willow/Labrador tea; *Betula* spp.-*Ledum groenlandicum, Salix* spp., and *Sphagnum* spp.

Unit s - Shrub, Deciduous, Sparse to closed, Intermediate to tall, mixture of species; highly variable cover on ditches and spoil piles; mainly shrubland but with mixed forest and open areas.

Unit t - Tree, Evergreen, Closed, Intermediate, black spruce/Labrador tea; native bog vegetation typified by *Picea mariana-Ledum groenlandicum-Sphagnum* spp. cover.

Unit u - Tree, Deciduous, Sparse, Intermediate, aspen/willow; upland vegetation typified by *Populus tremuloides* revegetating disturbed mineral soils.

Unit v - Tree, Evergreen, Closed, Intermediate to tall, aspen/white spruce; native *Picea glauca-Populus tremuloides* cover at the margins of the cutover areas.

Unit w - Non-vegetated; almost entirely barren ground with very few *Rubus* spp., *Betula* spp., *Salix* spp. and other species associated mainly with spoil piles.

Unit x - Herb and Shrub vegetation consisting of a complex of various other units in a peatland complex of ponds and spoil piles.

Unit z - Herb, Graminoid, Sparse, Low, cotton grass/moss; consists of sporadic or bunched occurrence of *Eriophorum vaginatum* with a considerable amount of barren ground.

Detailed examination of vegetation communities of the study area was carried out at 10 sites that were either at or near the soil inspection and sampling sites. Percentage cover estimates of species at these sites are presented in Appendix 6.2. The objective was to obtain complete species lists for representative sites of some of the main vegetation communities in the study area. The vegetation apparently varied according to moisture gradients and possibly nutrient gradients. Time since abandonment of the peatland may be a factor in community development as well. Additional research is recommended for determining the relationships between natural revegetation and the factors noted above. A detailed study of the vegetation in this area in relation to environmental gradients, as carried out by Smart et al. (1989) for a cutover bog in the UK, could provide useful information about natural revegetation which could be applied in determining reclamation approaches.

4.2.3 General Discussion

The cutover peatland study was characterized by high variability in peat thickness, drainage regime, and vegetation type, and by occurrence of mineral 'knolls' in the peatland. Consequently, the legends for soils and vegetation were somewhat complex, and the peat soil/vegetation map was quite detailed. The presentation scale of 1:5000 is appropriate for this level of mapping detail. Such detailed maps can be difficult to use, especially if land use alternatives are to be considered for each mapping unit. A simpler categorization of the land units would be easier to interpret and the information presented in Map 2 could be simplified by grouping according to characteristics of greatest interest. For example, all soils of a specific depth category and moisture regime could be grouped, the result being a map with considerably fewer map units.

This is readily accomplished with a geographic information system, and can be manually carried out by, for example, colour coding map polygons. In other cutover areas in the province, general observations by the authors have indicated that variability is likely not as high as in the study area of this project because extraction methods have been more uniformly applied and because of relatively uniform morphology of the underlying mineral soils. Hence, it would be expected that maps for these areas would be less complex than Map 2.

4.3 DEVELOPMENT HISTORY

A series of aerial photographs was examined to determine the history of peat harvesting in the study area. Clearing commenced in 1961 along the periphery of NW 28 and by the end of the decade, harvesting was underway in most of NW 28. The remainder of the study area was cleared in the 1970-74 period. Widespread harvesting was done from 1974-78 over most of the area. Only small areas in SE 32 (map unit 9a) and most of SW 33 were harvested as late as 1981.

No harvesting was done on some cleared areas in SW 33 (map unit 4r) and a linear strip in NW 28 (map units 7g, 13g, 16u). These areas are characterized by visible brush rows and relatively advanced regeneration dating from 1970-74.

The only activity after 1981 was the excavation of a major north-south ditch between SE 32 and SW 33. Fluctuating water levels due to beaver dam construction and outlet culvert modifications have occurred since the early 1980s.

4.4 PEAT THICKNESS

A computer-generated peat isopach map is presented in Map 3. The map displays the high variability in peat thickness across the study area, although somewhat more uniform zones can be distinguished. The thickest peats occur in the central and northwest parts of the area. The southwest portion is characterized by numerous mineral soil uplands with little or no peat. Similar mineral soil areas and generally shallow peats occur in the east part of the study area.

The map shows large, interconnected areas of peat <0.5 m thick in the western, central and northeast parts of the area (areas within which the mineral exposures occur). These results are not considered to have accurately depicted peat thickness in these areas. The western part of the study area was considered to be a complex of shallow (<1.0 m) with deeper (1.0 to 2.0 m) peat for purposes of mapping soils (Map 2). This was based on extrapolation from the few deeper peats observed in the area and from aerial photograph interpretation. The soil map shows deeper peat units in the central regions, and a mixture of shallow and deeper peats in the northeast part of the area. The contouring results are considered to be a consequence of the low density of data points for these areas. The few areas of deeper peat are contours based on isolated data points which are too distant from other points to form continuous contours. The effects of sampling density on deriving isopach and other maps is discussed in section 4.10.

Peat isopach information can be helpful in evaluating alternative land uses for cutover peatlands. For example, shallow peat deposits with mineral soil inclusions may be more suitable for agricultural or forestry applications than would deep peats. This kind of information is also useful for planning the drainage system of the reclaimed peatland.

4.5 CONTOUR MAPPING OF MINERAL SUBSOIL ELEVATION

Elevation contours of the mineral soil base of the peatland are presented in Map 4. This map displays greater variation in elevations as compared to the surface elevation map due to the mineral soil exposures that occur in some areas. The map demonstrates how peatlands may have formed in the lowest landscape positions and eventually built up and outward to isolate mineral knolls in the western and eastern parts of the study area.

The method used to derive Map 4 consisted of subtracting the peat isopach grid from the surface elevation grid. It was indicated in Section 4.4 that the scarcity of data points in some areas likely resulted in generation of erroneous contours. Any errors would also be transferred to the mineral subsoil map. Elevation and peat thickness data were obtained at different locations in the study area. Although the grid subtraction procedure is theoretically sound for deriving subsurface elevations, there is less possibility of error if both elevation and thickness measurements are obtained at the same locations.

It is recommended, therefore, that elevation and thickness data be obtained at the same locations in future projects. Elevation data are preferably collected using a grid pattern. This may not totally suit soil and vegetation mapping requirements, but peat thickness measurements, at a minimum, should be made at the same locations as elevation measurements, while the general peat soil survey can proceed using free survey (judgement sampling) techniques (as indicated in Part I of this report).

4.6 DRAINAGE SYSTEM MAPPING

Peatlands are ditched in order to lower the water table and thereby provide access for machinery used in land clearing and in collection of peat moss. The drainage ditches in the study area have eroded to some extent or have had significant peat sedimentation, but they nevertheless remain functional in most areas. The larger ditches have been dammed by beavers in various locations and the drainage dynamics have undoubtedly been influenced by these dams. The locations of the various ditches need to be known in order to plan the drainage network for various reclamation scenarios and to assist in determining which ditches should be filled in and which should be retained.

Drainage ditches in the study area are depicted on Map 5. Arrows indicate the direction of flow. Flow directions and outlets were difficult to detect on aerial photographs in some situations. For example, in the northwest part of the study area, numerous small ditches appear to have no outlet. Small ditches such as these have likely become non-functional and were abandoned as the peat surface was lowered by harvesting. This area is very wet, possibly as a consequence of the outlets for these ditches having been altered in some way.

Peat and mineral soil materials from the large (>1 m across) ditches are piled on both sides of the ditches in most cases. Thus, the drainage system map can be interpreted as ditches plus associated spoil materials adjacent to them. In the case of the large main ditches, the spoil piles are quite high and wide, and they represent sufficiently large areas for recognition as unique land units in the peat soil/vegetation map.

4.7 LABORATORY CHARACTERIZATION OF PEAT MATERIALS

Laboratory characterization of peat materials was carried out in order to confirm field observations and descriptions, and to evaluate chemical characteristics that influence plant growth and the quality of runoff waters. Field descriptions and analytical data for 10 sampled sites are presented in Appendix 6.3, Tables 2.4 to 2.13.

Rubbed fibre analysis indicated that fibre determinations during field inspections were underestimated. Consequently, some peat layers classed in the field as 'mesic' (10% to 40% fibre) in degree of decomposition were in fact 'fibric' (>40% fibre), particularly those samples that were near the 40% cutoff.

The active acidity (pH value) is of interest in that surface peats showed some very low pH levels. These are typical of sphagnum peats. Higher pH values occur in fen peats which occur at the surface in areas where all of the sphagnum peat has been removed in harvesting operations.

Other peat characteristics are comparable to those found for native peatland sites in other areas (National Wetlands Working Group 1988; Turchenek et al. 1984). Low exchangeable base levels and base saturation percentages generally correlated positively with pH. These parameters indicate low fertility status in these soils and correspond to low levels of other nutrients as indicated in section 4.8.

The total elemental contents of the peat samples generally occur within the lower parts of ranges of elements in peat as summarized by Lucas (1982) in Part III, Table 3.2. Most of the peat samples could be characterized as oligotrophic based on comparison with Table 3.2. Calcium levels indicate that most of the peats are in the dystrophic and mesotrophic nutrient classes as defined in Part III. Potassium levels are very low in most surface soils and increase with depth in the soil profiles. Sulphur levels in some samples are higher than the mean for eutrophic peats in Table 3.2, but are well within the range presented. Some elements, namely Cu, K and Fe are very low with respect to the elemental range. Manganese was the only element that appeared to be relatively high but still within the range in Table 3.2. Table 3.2 does not include data for the elements Sr, As, V, Se, Li, Ti, Cd, Cr, and Hg. Contents of Sr and V are comparable to levels in a study of Finnish bogs by Sillanpaa (1972). The levels of Hg and Cd appear to be very low, but data for comparison of these and other trace metals are almost nonexistent in the literature as noted by Shotyk (1988). The levels of most elements increase in the bottom layers of the peat profiles likely because of inclusion of mineral material. It is concluded that in the profiles examined, there are no exceptionally high levels of elements. However, normal levels in the peat deposit do not necessarily indicate that no impacts on water quality will occur, and water sampling and analysis would be required to determine if a reclamation practice may affect drainage water quality.

4.8 EVALUATION OF SURFACE SOIL FERTILITY STATUS

Nutrient levels in surface soils of 10 sampled sites are presented in Table 2.1 Ingeneral, surface soil pH values and nutrient levels were very low. The pH values (pH determined on peat samples mixed in water as opposed to 0.01 $CaCl_2$ solution), ranged from 3.9 to 5.7; they were highest in sites with very shallow peat caps on mineral soil (sites 33 and 50) and in a site with mainly fen peat occurring adjacent to a mineral upland. Low pH values are associated with sphagnum peats. In terms of agricultural production, pH levels of about 5.0 to 6.0 are optimum for many kinds of crops. Liming organic soils to levels above 6.0 may be detrimental to crop growth due to reduced availability of Mn, Zn, B and P (Lucas 1982). Liming soils of low pH is not recommended because peat has a high buffering capacity and the amounts (and costs) of lime required to raise the pH significantly would be prohibitive (Sherstabetoff 1987). Hence, sphagnum peats are generally not recommended for agricultural development because of costly measures required to cope with their acidity and low fertility.

Nutrient levels were compared to soil test levels that are considered to be sufficient for crop growth in peat soils (Sherstabetoff 1987). Adequate nutrient levels are considered to be:
55 to 70 kg ha^{-1} N (in the top 0.6 m);
55 to 70 kg ha^{-1} P (in the top 0.15 m);
20 to 45 kg ha^{-1} SO_4-S (in the top 0.6 m), and;
280 to 340 kg ha^{-1} K (in the top 0.15 m). A bulk density of 200 kg m^{-3} was assumed in converting the data in Table 2 (given in mg kg^{-1}) to a comparable soil test basis (in kg ha^{-1}). The comparisons below are not valid in terms of availability of nutrients for the growing season as in the case of assessing crop requirements; soil tests reflect levels available prior to, or at the beginning of, the growing season, while samples in this project were taken near the end of the growing season. Thus, soil test levels in this project provide only a level for comparison and cannot be taken as indicative of actual availability of nutrients.

Levels of nitrogen were low at most sites. Levels of NO_3-N were nil at many sites. Exceptions were Site 49, which was located in a cutover area with no vegetation, and Site 46, which was located on a peat pile, also with little or no vegetation. It appears that mineralized N occurs in significant amounts due simply to lack of vegetation to use it, and possibly due to lack of recent rains which would likely leach it to some extent. The pH values at these sites were low and comparable to other vegetated sites in which little N was detected. The N levels thus do not seem to be related to soil type and chemistry. This observation lends credence to the above statement that the data should not be interpreted in terms of availability of N. A single sampling does not indicate the N supplying capability - even if this capability is relatively high, all the N may be rapidly taken up by vegetation. An independent test of

Table 2.1 Nutrient analysis of surface soils from the cutover peatland reclamation study area.

Site	Horizon	Depth	pH[1]	EC[2]	BD[3]	NH_4-N		NO_3-N		PO_4-P	
		cm		dS m^{-1}	kg M^{-3}	µg mL^{-1}	mg kg^{-1}	mg mL^{-1}	mg kg^{-1}	mg mL^{-1}	mg kg^{-1}
49	Of1	0-20	3.9	0.4	0.17	39	229	5	29	1	6
	Of2	20-65	4.3	0.1	0.10	13	130	1	10	0	0
50	Om	20-0	5.7	0.4	0.37	5	14	0	0	4	11
45	Of1	0-15	3.9	0.2	0.26	4	15	0	0	1	4
	Of2	15-60	4.9	0.2	0.17	2	12	0	0	0	0
16	Of1	0-15	5.3	0.2	0.19	3	16	0	0	1	5
	Of2	15-50	5.4	0.2	0.16	2	12	0	0	0	0
46	Of1	0-20	4.3	0.4	0.21	12	57	7	33	0	0
	Of2	20-55	4.3	0.3	0.19	4	21	6	32	1	5
26	Of1	0-10	4.4	0.2	0.05	2	40	0	0	3	60
	Om1	10-30	4.7	0.2	0.22	2	9	0	0	1	5
33	Om1	0-15	5.2	0.2	0.28	8	29	0	0	1	4
	Om2	15-30	5.5	0.2	0.27	5	19	0	0	0	0
38	Of1	0-20	4.2	0.3	0.14	2	14	0	0	1	7
	Of2	20-40	4.7	0.3	0.16	2	12	0	0	0	0
41	Of1	0-20	4.4	0.2	0.15	3	20	0	0	0	0
	Of2	20-40	4.5	0.2	0.19	2	11	0	0	0	0
41	Of1	0-20	4.1	0.2	0.13	3	23	0	0	0	0
	Of2	20-40	4.0	0.2	0.12	2	17	0	0	0	0

continued .....

Table 2.1 Concluded.

Site	Horizon	Depth	SO_4-S		K		Cu		Mn	
		cm	µg mL^{-1}	mg kg^{-1}	µg mL^{-1}	mg kg^{-1}	µg mL^{-1}	mg kg^{-1}	mg mL^{-1}	mg kg^{-1}
49	Of1	0-20	22.3	131	13	76	0.5	2.9	8.0	47
	Of2	20-65	3.8	38	3	30	0.4	4.0	5.7	57
50	Om	20-0	24.8	67	108	292	0.9	2.4	24.2	65
45	Of1	0-15	6.2	24	32	123	0.4	1.5	3.1	12
	Of2	15-60	5.0	29	3	18	0.4	2.4	36.4	214
16	Of1	0-15	5.4	28	25	132	0.4	2.1	26.8	141
	Of2	15-50	5.4	34	1	6	0.4	2.5	46.6	291
46	Of1	0-20	16.5	79	6	29	0.5	2.4	24.5	117
	Of2	20-55	13.3	70	5	26	0.5	2.6	28.2	148
26	Of1	0-10	6.6	132	79	-	0.4	8.0	8.7	174
	Om1	10-30	5.7	26	18	82	0.4	1.8	3.5	16
33	Om1	0-15	7.6	27	46	164	0.5	1.8	36.0	129
	Om2	15-30	9.5	35	14	52	0.4	1.5	14.4	53
38	Of1	0-20	25.4	181	6	43	0.4	2.9	20.9	149
	Of2	20-40	32.8	205	0	0	0.4	2.5	27.8	174
41[4]	Of1	0-20	3.8	25	0	0	0.3	2.0	7.2	48
	Of2	20-40	4.7	25	0	0	0.3	1.6	5.6	29
41a	Of1	0-20	4.1	32	5	38	0.3	2.3	7.4	57
	Of2	20-40	5.1	42	5	42	0.5	4.2	6.7	56

[1] pH determined in H_2O.
[2] EC = electrical conductance.
[3] BD = air dry bulk density of sample passed through 2.0 mm sieve.
[4] 41 = vegetated, wet site; 41a = non-vegetated, dry microsite adjacent to 41.

mineralizable N would be more appropriate for such assessments.

All P levels were low in comparison to soil test values. Site 26 had the highest levels but these too were relatively low. Sulphate-S levels were higher than recommended soil test levels in sites 26, 46, 49 and 50. Others were in the area of about one-half of this amount. Levels of K in the peat soils averaged only 60 kg ha^{-1}, much below the recommended test levels.

The DTPA extractable Cu levels in Table 2.1 appear to be low. Total Cu levels are more closely related to required levels for plant growth (Lucas 1982). Sufficiency in Cu is indicated by total Cu levels in excess of 20 to 30 mg kg^{-1} soil. Total Cu contents from Tables 2.4 to 2.13, Section 6.3 indicate that most of the sampled sites are indeed low (in fact, some extractable Cu levels were higher than total levels, suggesting that the contents were near the limits of accuracy). Extractable Mn appears to occur in significant amounts in the cutover area. However, these are difficult to relate to levels of sufficiency for plant growth since neither total nor extractable Mn have been shown to correlate with growth (Lucas 1982).

In summary, soil nutrient analyses showed that the fertility status of most soils in the study area were low or very low in terms of levels recommended for crop growth. This was anticipated in view of the sphagnum moss composition and the low pH of many of the surface peat materials. The implication is that considerable amendment with lime and fertilizers would be required for agricultural utilization of cutover peat soils. It is likely that similar amendments would be required for reclamation with native plant species or with commercial forest species. Recent research in Alberta has demonstrated that native tree species respond to nitrogen, phosphorus and potassium fertilization (Mugasha et al. 1993). However, research is required to determine responses of trees and other native species in cutover peatland soil situations.

The analyses provide only a 'snapshot' of nutrient status. Plant nutrient availabilities depend on several factors including microbial activity, total levels available for mineralization, temperature, and redox status. A more thorough evaluation of nutrient status would require assessment of the nutrient supplying capability via mineralization and other studies.

4.9 EVALUATION OF WATER QUALITY

Results of water chemical analyses are presented in Table 2.2. Locations of water sampling sites are described by reference to soil inspection sites (Map 7) as follows:

1. Soil pore water collected from soil pit at site 41.
2. Drainage ditch water sample west of the junction of the major east-west and north-south ditches; just north of soil site 40.
3. Pond near site 40.
4. Drainage ditch near site 64.
5. Drainage ditch near site 6.
6. Drainage ditch near site 4.
7. Drainage ditch just above culvert located southeast of site 51 in the south part of the study area.

Water sample 1 represents pore seepage water from a freshly dug soil pit. Water sample 3 was taken from a beaver pond that drained into one of the main ditches. Sample 7 was located near the outlet of one of the main drainage ditches; this ditch had been excavated deeply into mineral soil for several hundred metres above this point. All other samples were taken from ditches within the cutover peatland.

The pH of the soil pore water was low and comparable to many of the surface soil pH values in the study area. The pH of sample 7 was above neutral; this probably reflects interaction of the peatland runoff waters with the mineral soil in the ditch. There apparently was reaction with carbonate and other constituents of the mineral subsoil exposed in the ditches, this being of sufficient extent to raise the pH, increase alkalinity, and increase levels of elements such as Ca and Mg. The pH levels in the other ditches were near neutral, also indicating interaction with exposed subsoil peats and mineral materials. Similar observations reported elsewhere have suggested that contact of peatland drainage waters with mineral

Table 2.2 Water quality characteristics at seven sample sites[1] in the cutover peatland study area.

Parameter	Unit	Water Sample Number						
		1	2	3	4	5	6	7
pH		4.6	6.4	6.8	6.4	6.8	6.5	7.3
EC[2]	$\mu S\ cm^{-1}$	62	57	58	87	110	105	240
Alkalinity	$mg\ L^{-1}$	22	27	25	32	45	35	165
Cl^-	$mg\ L^{-1}$	55.4	4.3	4.7	5.6	7.3	7.6	3.2
$N0_3^-$	$mg\ L^{-1}$	0.07	0.07	0.08	0.07	0.10	0.14	0.04
S	$mg\ L^{-1}$	1.93	0.80	2.14	4.96	4.86	3.3	2.54
P	$mg\ L^{-1}$	0.14	0.034	0.10	0.49	0.40	0.82	0.23
Si	$mg\ L^{-1}$	5.01	2.30	0.14	1.62	1.34	10.72	4.30
As	$mg\ L^{-1}$	bdl	bdl	bdl	bdl	bdl	bdl	bdl
B	$mg\ L^{-1}$	bdl	bdl	bdl	bdl	bdl	0.0	bdl
Mo	$mg\ L^{-1}$	0.034	0.040	0.019	0.015	0.011	0.012	0.011
Cr	$mg\ L^{-1}$	0.003	bdl	bdl	bdl	bdl	0.002	0.004
Ca	$mg\ L^{-1}$	13.21	12.94	13.26	17.13	26.37	19.92	49.15
Mg	$mg\ L^{-1}$	5.15	4.97	5.30	7.46	9.75	7.84	17.71
K	$mg\ L^{-1}$	0.88	1.27	2.12	2.28	3.84	4.86	2.39
Na	$mg\ L^{-1}$	6.38	4.27	4.66	3.76	4.69	5.26	8.33
Fe	$mg\ L^{-1}$	1.06	1.50	1.31	2.71	2.80	7.63	2.34
Al	$mg\ L^{-1}$	0.61	0.14	0.12	0.20	0.27	2.91	0.040
Zn	$mg\ L^{-1}$	0.18	0.050	0.043	0.045	0.046	0.048	0.040
Cu	$mg\ L^{-1}$	0.15	0.040	0.042	0.038	0.096	0.040	0.043
Ni	$mg\ L^{-1}$	0.001	bdl	bdl	0.000	0.001	0.008	0.000
Cd	$mg\ L^{-1}$	0.003	0.002	0.002	0.001	0.001	0.001	0.001
Pb	$mg\ L^{-1}$	0.017	0.024	0.013	0.009	0.014	0.018	0.016
Mn	$mg\ L^{-1}$	0.067	0.083	0.047	0.209	0.151	0.276	0.015
Sr	$mg\ L^{-1}$	0.072	0.075	0.075	0.101	0.147	0.113	0.283
Ba	$mg\ L^{-1}$	0.014	0.012	0.014	0.020	0.020	0.074	0.068
V	$mg\ L^{-1}$	0.003	0.003	0.002	0.003	0.003	0.010	0.004
Se	mgL^{-1}	0.029	0.002	0.023	0.009	0.008	0.016	0.004
Li	$mg\ L^{-1}$	0.019	0.017	0.019	0.018	0.026	0.032	0.035
Ti	$mg\ L^{-1}$	0.002	bdl	bdl	0.004	0.000	0.082	0.001
Co	$mg\ L^{-1}$	0.003	0.001	0.002	0.001	0.001	0.002	0.001

1 See text for sample site locations.

2 Abbreviations: EC = electrical conductance; bdl = below detection limit.

materials in ditches serves as a mitigating factor in the influence of these waters on downstream receptors such as streams and lakes (Turchenek 1990).

The levels of various constituents of the water samples were compared to guidelines for water quality for freshwater aquatic life and for livestock drinking water (CCREM 1987; Part III Section 7). Parameters in the sampled waters that exceeded the guidelines for aquatic life were Cl, Fe, Zn, Cu, Pb, and Se. No parameters exceeded the guidelines for livestock drinking water quality as these are considerably higher than those for aquatic life. Assessing the implications of these levels of water constituents must include consideration of whether these guidelines should be applied to the waters in situ (i.e., ditches as aquatic habitat) and, in the case of downstream water quality, of the extent to which these will be diluted. No water samples were taken from the Lobstick River for comparison.

4.10 EVALUATION OF SAMPLING ADEQUACY

4.10.1 Peat Soil/Vegetation Mapping

Adequacy of inspection density for developing the 1:5000 peat soil/vegetation map was evaluated in terms of guidelines for soil survey intensity levels developed by the Agriculture Canada Expert Committee on Soil Survey (1981). These guidelines were reviewed in section 3.1.3, Part I. The following discussion is related mainly to the guideline is that there should be inspections for every 0.2 to 2 cm^2 of map area.

There are 114 polygons delineated in Map 2. The map area is 107 ha, which is represented by 428 cm^2 on the soil map. The number of field inspections involving down-hole soil observations was 63, or about one inspection per 6 to 7 cm^2 (or one per 1.7 ha) . Thus, depending on the criteria used, Map 2 should have been based on about 114 observations or 428/2=214 field inspections (2 inspections per ha). The southeast part of the study area was represented by the largest number of delineations (about one per ha, or one per 4 cm^2), but even this does not meet the criteria for high intensity level mapping. Presentation of the map in this project at a scale of 1:5000 implies a relatively high level of detail with possible inaccuracy in some areas. An appropriate map presentation scale for this mapping intensity level is 1:10 000 for which the guideline is about one inspection per 4 ha.

One reason for the large number of polygons in Map 2 relates to combination of both soil and vegetation information. The number of mapping units and polygons generally increases as the number of criteria for establishing the mapping units increases. If soil and vegetation were mapped individually, there would be fewer polygons on each map. Producing separate soil and vegetation maps is an alternative to presenting the information. In most future cutover peatland scenarios, it is anticipated that surveys would be carried out soon after completion of harvesting activities as opposed to 10 or more years later (as was the situation in this project). There would, therefore, be no vegetation to map, and mapping would focus on peat soil and landscape mapping.

Increasing the inspection density in this project to about 2 inspections per ha would have quadrupled the resources necessary to complete such a survey. It becomes necessary to weigh the benefits of such a mapping intensity in terms of reclamation planning requirements. It is concluded that for most peatland reclamation planning purposes, a mapping intensity level based on a general guideline of about one inspection per 4 ha (i.e., about 16 sites per quarter section, and corresponding to a presentation scale of 1:10 000) would be appropriate . These same guidelines have been considered to be suitable for other mapping projects related to land reclamation; e.g., soil survey of the Battle River coal mining area (Macyk and Maclean 1987).

It is concluded from the above that the number of soil/vegetation polygons mapped per unit area in this study, as well as the level of detail in the legend, do not correspond to a high survey intensity level for which a presentation scale of 1:5000 would be appropriate. The map scale in this study was too large, implying greater accuracy and precision than can be possible based on the inspection intensity. A survey with sampling density of one inspection per 2 to 4 ha, using a legend with criteria similar to that in this study, is a suitable survey intensity when considered in terms of required resources and usefulness for land use evaluations. A map scale of 1:10 000 is appropriate for the level of survey. However, having indicated that 1:10 000 is an appropriate map scale, a scale of 1:5000 is nevertheless the preferred presentation scale as indicated in Part I, Section 3.1.3. It is appropriate to present this information at this scale provided an indication of reliability such as number of inspections per unit area is given.

4.10.2 Peat Isopach Mapping

Adequacy of sampling was also evaluated by applying geostatistical methods to determine the error levels in peat isopach maps produced by contouring methods. Initially, an experimental variogram of peat thickness was calculated using 53 of the data points. Data points inside the mineral knolls or boundaries of mineral knolls with assigned 0.0 m peat thickness were excluded.

Characteristics of some of the variogram properties were described according to Journel and Huijbregts (1978). The experimental variogram was omnidirectional with an averaging angle of 180.0 degrees and lag of 100.0 m. A spherical variogram model (Journel and Huijbregts 1978) fitted to this variogram had the following parameters: sill, expressing the total variance - 0.72; range, expressing the spatial dependencies among samples - 80.0 m; and nugget effect, expressing the random component in variance - 0.57.

The high nugget effect (88% of the total variation) and the short range (less than 1 lag) suggest that the distribution of the peat thickness is highly random and samples are correlated over the short distance only. On the other hand, the lack of variogram structure (short range, high nugget effect) may reflect the small sample size or the uneven distribution of samples over the study area rather than the actual properties of the peat thickness. Mineral landscapes are predictable to some extent (Hall and Olson 1991), and peat thickness should therefore also be predictable. It is concluded that the variogram result indicating high randomness in peat thickness was not likely due to natural variation, but the number of samples was insufficient to indicate this. There is, moreover, the possibility that high variability was induced by removal of varying thicknesses of peat layers during harvesting operations.

The coefficient of variation (CV) of peat thickness is presented in Map 8. The CV represents the ratio of the standard kriging errors to estimates of peat thickness derived using the ordinary kriging technique (Journel and Huijbregts 1978). The estimate of peat thickness at any point represents an average (based on an algorithm using weighting factors for surrounding points), while the kriging error is an expression of the standard deviation of the mean. The CV is expressed as a percentage, and the CV map shows the 'quality' of the sampling scheme used for the estimation of the peat thickness. Areas with higher coefficients of variation indicate a less adequate sampling scheme than areas with lower (relative) coefficients of variation.

On map 8, high CVs (60% to 70%) are observed in the western part of the study area; these are areas with sparse sampling. Areas with denser sampling (east part of the study area) have lower CVs (30% to 50 %) . It is concluded that if there were to be any further sampling, it be concentrated in the areas of high CV. In planning a sampling scheme one should also avoid clustered samples as they do not improve estimation (high CV near clusters of samples).

The portion of the study area to the east and south of the two intersecting major ditches was represented by almost half (30) of the site inspections in this study and is about 35 ha in area. The sampling density here was, therefore, about one inspection per ha. The remainder of the study area would require a similar sampling density to attain coefficients of variation of 30% to 50%. Higher density sampling in the southeast portion is also required if decreasing the CV is desired. This analysis indicates that increasing the sampling density to levels corresponding to Level I survey intensity levels for soils (Section 4.10.1) is necessary to increase the precision of isopach maps. It was noted above that clustered samples do not improve depth estimates. It follows that relatively uniform sampling would reduce CVs and sampling density may not need to increase greatly, but the influences of both of these are difficult to quantify. The general conclusion appears to be that achieving CVs lower than 30% to 50% (with improved confidence levels following from this) requires considerably more sampling than one inspection per 4 ha as suggested in the previous section for soil survey.

Peat depth is a criterion in distinguishing soil mapping units and it would appear that reliable peat isopach information is required for producing a reliable soil map. However, many soil features may not be as variable as peat thickness and would require relatively few observations to determine their distribution. A sampling procedure that accommodates these cutover peatland characteristics is as follows;
(1) collect peat thickness data on a 200 m grid (one datum per 4 ha) at the same sites as surface elevation determinations; (2) carry out soil survey by purposive sampling methods, collecting thickness information at each site, and; (3) collect additional data only for peat thickness.

Simple equipment such as a steel rod or an Oakfield soil sampler can be used to obtain thickness data. A large number of sites can be probed per unit of time as compared to taking samples for descriptive purposes using a Macauley sampler. A suggested design for doubling the number of thickness measurements from those accompanying the surface elevation measurements consists of taking a measurement in the centre of each square formed by the elevation grid.

4.11 EVALUATION OF AERIAL PHOTOGRAPHY FOR SOIL AND VEGETATION MAPPING

Aerial photographic interpretation was carried out in this project using 1:15 000, black and white IR aerial photographs dated Sept. 11, 1988, supplemented by 1:15 840 black and white IR photos dated Sept. 27, 1961. In addition, oblique photographs of the study area taken in September, 1991, at 150 m and 300 m above the land surface were used to assist in delineation of surface soil and vegetation features. The colour and large scale of the latter proved to be very helpful in detecting features that could not be observed on the black and white photos of smaller scale. This suggests that for mapping at a scale of 1:5000, colour aerial photography at a scale similar to the mapping scale would be more appropriate.

The above is supported by conclusions of an evaluation of remote sensing data for soils information in the TransAlta Utilities mine area near Lake Wabamun (MacGillivray et al. 1987). Medium and large scale (1:30 000, 1:12 000 and 1:10 000) colour infrared imagery was considered to have the highest overall value for identifying landform and vegetation features. Infrared imagery is also effective in distinguishing features due to differences in moisture levels. Smaller scales were considered more useful for physiographic interpretations in which a relatively broad view was required. At large mapping scales (>1:10 000), colour tones related to wetness, vegetation type, properties of bare soil surfaces and other features are helpful in mapping, and colour or colour infrared imagery is the most appropriate for these.

A general recommendation following from the above is that colour or colour infrared aerial photographs would be most appropriate for mapping cutover peatlands. Contracting of aerial photographic services would be required as these are not normally available through Maps Alberta, except for some specific locations in the province. Timing of photography is also important. Early to mid summer would likely be suitable in terms of enabling differentiation of soil moisture regimes. Spring photography could be disadvantageous for inferring moisture regimes due to ponding of snow meltwater at that time of year. Relatively dry conditions would likewise render fall photography unsuitable. In situations where vegetation has already become established , early to mid summer is also the most suitable period for photography as the vegetation will be in a growth stage and thus readily distinguishable from other features.

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6. APPENDIX TO PART II

6.1 PHOTOGRAPHS ILLUSTRATING LANDSCAPES, VEGETATION AND PEAT SAMPLING IN THE STUDY AREA

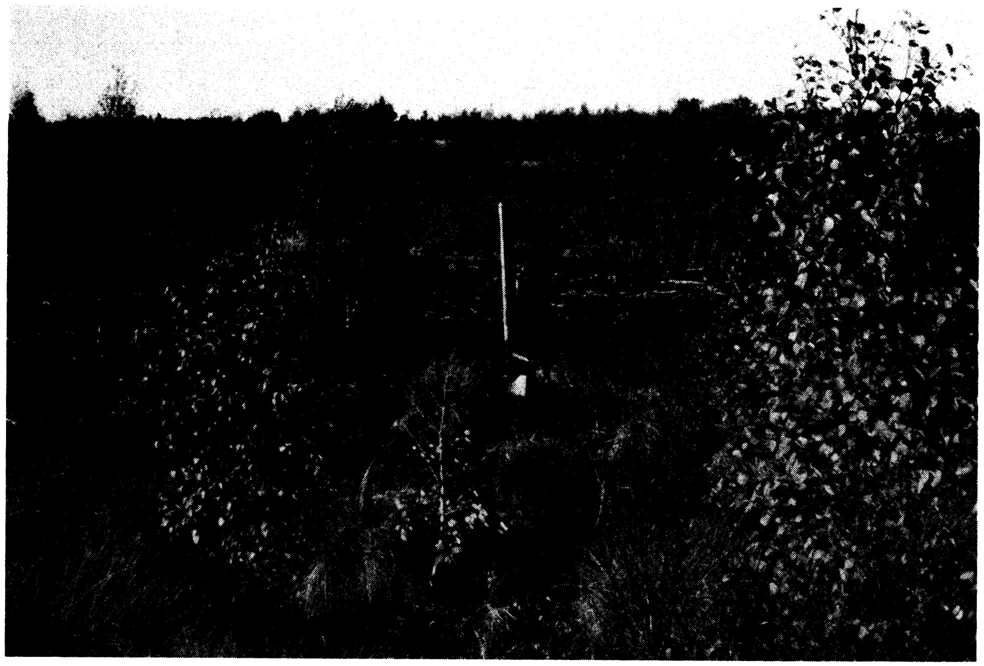
Photographs of aerial and ground-level views of the cutover peatland study area are presented in this section. Photos 2.1 and 2.1 were taken by D. Karasek, Public Land Management Branch, Alberta Agriculture, Food and Rural Developemnt. Photos 2.3 to 2.8 were taken by W.S. Tedder during the spring and late summer of 1991. Photos 2.9 and 2.10 were taken by L.W. Turchenek

Photograph 2.1 Southerly view of the study area along drainage ditch. Pond/spoil pile complex at upper right of ditch crossing.

Photograph 2.2 Northerly view of northwest part of study area showing linear patterns of exposed peat and wet vegetated peat.

Photograph 2.3 Temporary spring ponding in unit 12a (Map 2) in the eastern part of the study area.

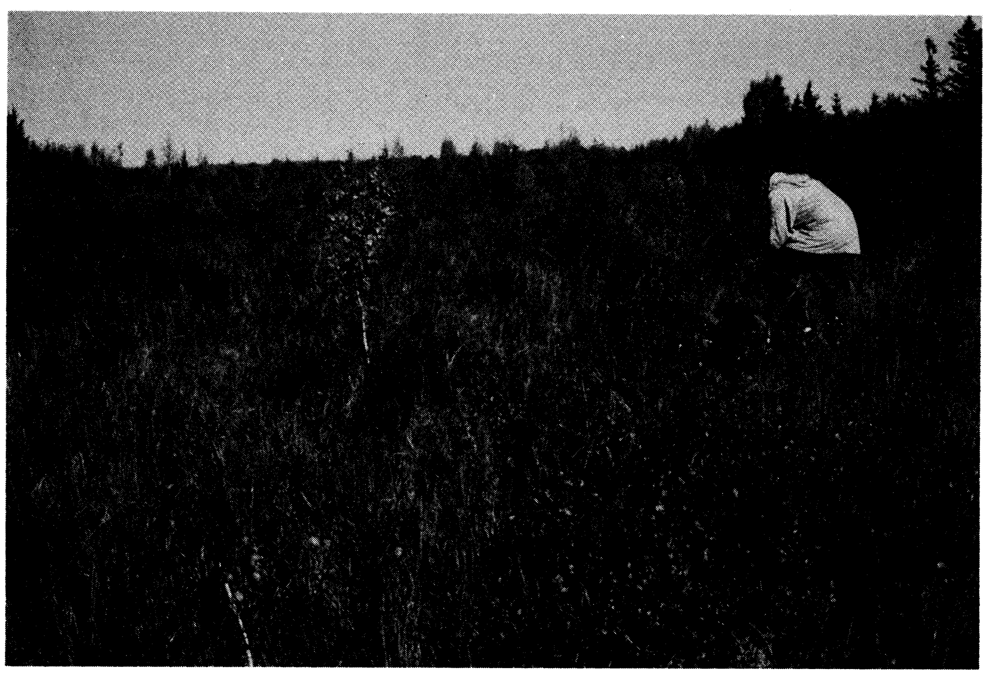
Photograph 2.4 Peat ridges and piles in unit 24x. Larger piles characterize the pond/spoil pile complex in unit 18z.



Photograph 2.5 Sparse shrubland of moderately saturated to relatively dry units such as 11p and 1n.

Photograph 2.6 Reed grass and sedge community in the highly saturated soil of unit 6c.

Photograph 2.7 Variety of drainage regimes and vegetation associated with drainage ditches and spoil piles.



Photograph 2.8 Labrador tea and swamp birch cover, with dense understory of mosses and sedges, characteristic of unit 7g.

Photograph 2.9 Macauley peat sampler being used in a natural peatland.

Photograph 2.10 Illustration of a Macauley sampler with a peat core.

6.2 VEGETATION SPECIES DATA FOR THE CUTOVER PEATLAND STUDY AREA

Table 2.3 Percentage cover of species in some of the main vegetation types in the cutover peatland study area.

Site[1]	5	50	7	6	37	38	9	16	26	45
Vegetation type[2]	a	u	q	h	e	p	b	c	g	r
Bare patches	60	+	+	20	5	10	+	+	+	+
Vascular Plants										
Achillea millefolium		2								
Agrostis scabra							1			
Andromeda polifolia									1	
Arctostaphylos uva-ursi		5								
Aster X maccallae		+[3]					+			
Betula- dead scrags							5			
Betula glandulosa				12		1			5	
Betula neoalaskana	3		15			10	5	1	15	15
Betula pumila			2	12	5	7	+	1	25	
Bidens cernua							1			
Calamagrostis canadensis	+	30		5	15	10	25	65	30	5
Carex aquatilis					25	20		10	5	2
Carex curta				5	1			+		
Carex disperma					2	5			2	
Carex limosa					1					
Carex paupercula									5	
Carex praegracilis							+			
Carex rostrata							5	1		
Carex scoparia								+		
Cinna latifolia		+								
Epilolobium ciliatum	+	5	+				1		5	
Equisetum sylvaticum		2								
Eriophorum vaginatum	40		+	1	15	10	1	20	5	1
Fragaria vesca							1			
Fragaria virginiana		5								
Geum rivale		1								
Larix laricina				1	1				1	
Ledum groenlandicum			2	1	1	20			20	40
Lycopodium annotinum						1			+	
Lycopodium clavatum				+		1				
Oxycoccum microcarpus						1				5

continued . . .

Table 2.3 Continued.

Site[1]	5	50	7	6	37	38	9	16	26	45
Vegetation type[2]	a	u	q	h	e	p	b	c	g	r
Petasites palmatus		1								
Petasites sagittatus		1								
Phleum pratense		+								
Picea glauca		+	70	+	1	5				5
Picea mariana						1			2	
Pinus contorta						1				
Poa palustris	+	+	+		1	5	2	1		
Populus balsamifera		7								
Populus tremuloides		5			+				1	
Potentilla norvegica							+			
Ranunculus sp.							+			
Ribes sp.		1								
Rorippa palustris							1			
Rubus acaulis		+							2	1
Rubus arcticus									2	
Rubus chamaemorus			5							2
Rubus idaeus	+	2								
Rumex occidentalis							2			
Rumex triangulivalis							+			
Salix bebbiana		10								
Salix candida			2							
Salix exigua		2					1	1		
Salix maccalliana		15	2							
Salix pyrifolia				+	2	2	5	10	+	30
Scirpus cyperinus							60	3		
Smilacina trifolia			+							
Solidago canadensis		25								
Trifolium sp.		1								
Vaccinium uliginosum				+		1				
Vaccinium vitis-idaea			35			1				20
Viola sp.		1								
Typha latifolia							2			

continued . . .

Table 2.3 Concluded.

Site[1]	5	50	7	6	37	38	9	16	26	45
Vegetation type[2]	a	u	q	h	e	p	b	c	g	r
Bryophytes and lichens										
Amblystegium serpens								10		
Aulacomnium palustris		1	2		5		1	5		
Calliergon giganteum								+		
Calliergon stramineum					1					
Campylium stellatum			+				1	+		
Cladonia cariosa		+								
Cladonia chlorophaea				1		1				
Cladonia cornuta				1						
Cladonia gracilis			2							
Cladonia phyllophora				1						
Dicranella cerviculata		10		10						
Dicranum montanum			1							
Drepanocladus aduncus			1				1	1		
Drapanocladus exannulatus					1			+		
Helodium blandowii		+						1		
Pleurozium schreberi			1							
Polytrichum strictum	+		2	5	20	50		2	10	15
Ptilium crista-castrensis			1							
Sphagnum angustifolium			+		20				80	2
Sphagnum fallax					10					
Sphagnum fuscum						1			3	30
Sphagnum magellanicum					20			1	5	2
Sphagnum russowii										2
Sphagnum squarrosum					1			+		
Sphagnum warnstorfii					1					
Tomenthypnum nitens					1			1		

1 Site numbers correspond with soil inspection sites on Map 7.
2 Type according to vegetation legend of Map 2.
3 + = very low percentage cover, << 1%.

6.3. ANALYTICAL DATA FOR SOIL PROFILE SAMPLES COLLECTED IN THE CUTOVER PEATLAND STUDY AREA

Field descriptions and laboratory data are presented in Tables 2.4 to 2.13 for 10 sites sampled in the cutover peatland study area.

Table 2.4 Description of a peat profile at Site 16[1] Typic Fibrisol on fibric, mesotrophic sedge - brown moss peat.

Field Description

Of1	0-15 cm	dark brown; von Post 4; sedge peat with minor moss
Of2	15-50 cm	dark brown; von Post 4; moss peat, minor sedge; few wood fragments
Om	50-80 cm	dark brown; von Post 4; moss peat, minor sedge; few wood fragments; volcanic ash layer at 62 cm.
Of3	80-110 cm	dark brown; von Post 4; moss peat, minor sedge; few wood fragments
Of4	110-125 cm	brown; von Post 4; sedge - moss peat; common wood fragments
IIAhg	125-127 cm	black; organo-mineral transition layer
IICg	127-130+ cm	dark gray; clay; massive

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC	Ca	Mg	K	Na	Base Sat. %
								cmol(+)kg^{-1}					
Of1	42.6	4.6	8.9	-	53.5	1.47	36.4	142.4	72.8	19.4	0.0	0.5	65
Of2	60.4	4.8	6.8	-	55.4	0.96	57.7	151.4	81.9	20.5	0.0	0.4	68
Om	38.0	5.2	19.1	-	46.5	0.91	51.0	150.0	89.4	19.6	0.0	0.6	73
Of3	61.4	5.2	9.0	-	54.0	0.74	72.7	171.7	112.8	23.6	0.0	0.8	80
Of4	48.6	5.3	13.0	-	52.7	1.48	35.7	172.4	114.7	21.7	0.0	0.5	79
IIAhg	-	-	-	-	-	-	-	-	-	-	-	-	-
IICg	-	6.5	-	0.8	1.7	-	-	42.5	26.1	9.7	0.5	0.2	86

continued . . .

1 The following notes apply to Tables 2.4 to 2.13.

See Map 7 for locations of soil inspection sites.

Abbreviations and symbols: - (dash) = not applicable or not determined; Ov - highly fibric peat; Of - fibric peat; Om - mesic peat; Oh - humic peat; pH = pH measured in 0.01N $CaCl_2$ solution; OC = organic carbon; N = nitrogen; C:N = organic carbon to nitrogen ratio; CEC = cation exchange capacity, and ions following CEC are exchangeable cations; Base sat. = base saturation, the sum of Ca, Mg, K, and Na divided by the CEC; bdl = below detection limit.

Table 2.4 Concluded.

Total Elemental Contents

	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg
	mg kg^{-1}													μg kg^{-1}
Of1	14.6	1.7	2.4	5.4	17.7	0.65	0.3	0.8	15.4	175.4	266.9	2.9	3.6	212
Of2	8.3	0.8	0.5	5.0	11.6	0.39	0.1	0.8	16.2	3.1	260.0	3.1	2.0	149
Om	7.7	1.4	1.0	5.2	99.6	0.37	0.1	1.1	14.7	2.9	368.9	4.3	2.9	147
Of3	10.3	0.9	0.0	6.3	14.4	0.42	0.1	1.5	27.7	3.4	486.2	6.8	3.2	176
Of4	40.6	5.8	1.0	7.0	24.8	1.29	3.2	15.5	32.5	3.2	557.8	10.4	5.4	177

Total Elemental Contents - Continued

	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca
	mg kg^{-1}		g kg^{-1}			mg kg^{-1}						g kg^{-1}	
Of1	108.3	80.3	0.7	2.1	2.4	7.4	292.8	1.7	98.1	2.0	6.1	1.4	18.13
Of2	127.0	51.2	0.3	1.7	2.5	5.5	62.8	0.8	93.2	2.0	2.3	0.7	20.47
Om	148.1	64.7	0.5	2.6	2.5	8.2	150.1	2.0	196.7	1.8	16.8	3.8	23.54
Of3	175.9	59.1	0.2	3.2	2.9	7.8	161.4	0.8	180.4	2.1	5.2	0.7	29.52
Of4	192.5	82.5	0.4	10.4	2.8	13.8	394.1	7.9	122.3	2.0	13.6	1.5	31.80

Table 2.5 Description of the peat profile at Site 26 - Terric Mesic Fibrisol on mesic and fibric mesotrophic sedge - moss peat with thin spagnic cap.

Field Description

Ov	0-10 cm	pale brown; von Post 1; sphagnum peat, including live sphagnum
Om1	10-30 cm	dark brown; von Post 4; sedge - moss peat; few wood fragments
Of1	30-60 cm	dark brown; von Post 4, sedge - moss peat; few wood fragments
Of2	60-115 cm	dark brown and very dark brown; woody sedge - moss peat; many wood fragments
Om2	115-123 cm	black; von Post 7-8; amorphous; few fibres; few wood fragments
IICg1	123-133 cm	dark gray; heavy clay; massive; some visible fibres
IICg2	133-140+ cm	gray; heavy clay; massive

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC	Ca	Mg	K	Na	Base Sat. %
								cmol(+)kg^{-1}					
Ov	84.2	3.5	5.8	-	50.6	0.89	56.6	113.8	28.8	11.0	2.8	0.5	38
Om1	35.2	4.1	8.2	-	54.1	1.39	38.9	150.6	59.6	13.4	0.0	0.4	49
Of1	66.0	4.7	9.2	-	54.7	1.14	48.1	171.9	97.2	19.2	0.0	0.5	68
Of2	48.1	5.0	11.4	-	52.1	1.47	35.3	151.3	87.8	16.2	0.0	0.4	69
Om2	30.5	5.3	19.3	-	48.0	2.07	23.1	153.2	94.6	17.0	0.0	0.5	73
IICg1+2	-	6.7	-	0.12	0.6	-	-	49.8	32.2	11.4	0.6	0.3	89

continued . . .

Table 2.5 Concluded.

Total Elemental Contents

	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg
	mg kg^{-1}													µg kg^{-1}
Ov	18.5	1.2	4.3	6.3	10.3	0.64	0.1	0.8	5.1	1775.6	137.7	1.3	2.1	145
Om1	8.4	2.6	1.4	5.3	25.0	0.50	0.3	0.7	5.7	113.4	16.9	3.1	3.0	129
Of1	3.8	1.3	1.2	6.1	21.5	0.56	0.6	0.8	14.5	3.2	126.1	5.5	3.0	48
Of2	12.5	1.6	0.7	6.5	41.9	0.64	0.8	3.5	20.3	3.2	199.2	6.5	2.7	24
Om2	36.5	12.4	2.7	8.4	27.7	1.20	1.0	13.8	19.1	93.4	278.8	9.3	8.2	48

Total Elemental Contents - Continued

	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca
	mg kg^{-1}		g kg^{-1}			mg kg^{-1}						g kg^{-1}	
Ov	42.0	53.6	0.8	1.3	1.4	6.8	610.8	0.8	145.4	2.0	4.7	0.7	6.97
Om1	98.9	108.5	0.6	2.0	1.7	6.8	237.5	1.6	86.5	1.8	7.8	1.4	15.90
Of1	165.2	91.2	0.4	2.1	2.4	8.1	125.2	1.7	112.4	2.0	8.1	1.2	26.35
Of2	142.3	82.3	0.4	3.5	2.1	9.0	135.2	1.9	123.3	2.0	15.2	1.8	23.18
Om2	172.1	141.4	0.6	7.0	2.4	13.8	787.9	11.2	116.0	2.0	25.6	3.4	27.55

Table 2.6 Description of the peat profile at Site 33 - peat Rego Gleysol on fine-clayey glaciolacustrine materials.

Field Description

Om1	0-15 cm	dark brown; von Post 4; very fine fibrous to amorphous; sedge-moss peat
Om2	15-30 cm	dark brown; von Post 4; very fine fibrous to amorphous; sedge-moss peat
IIAhg	30-35 cm	black; organo-mineral muck
IICg	35-50+ cm	gray; clay loam; massive.

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC	Ca	Mg	K	Na	Base Sat. %
								cmol(+)kg^{-1}					
Om1	35.8	4.7	13.5	-	52.3	1.26	41.6	160.9	67.7	16.3	0.2	0.3	52
Om2	32.3	5.0	20.4	-	49.5	1.26	39.2	189.1	91.6	19.4	0.0	0.3	59
IIAhg	-	5.2	89.9	-	6.2	0.27	22.7	65.6	30.6	10.8	0.3	0.3	64
IICg	-	5.5	-	0.08	0.6	-	-	28.1	14.6	7.2	0.4	0.2	79

Total Elemental Contents

	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg
	mg kg^{-1}													µg kg^{-1}
Om1	20.2	3.3	0.9	6.9	22.8	0.62	2.9	5.6	19.1	282.2	336.6	13.5	5.8	23
Om2	56.9	7.7	2.9	9.0	37.1	1.19	3.5	9.4	24.6	221.0	521.8	21.8	9.9	14
IIAhg	113.4	19.5	16.8	25.4	62.4	0.86	12.5	25.6	10.8	1455.6	238.1	18.3	25.2	41

Total Elemental Contents - Continued

	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca
	mg kg^{-1}		g kg^{-1}			mg kg^{-1}						g kg^{-1}	
Om1	163.7	103.2	0.6	3.2	2.4	13.7	493.3	5.5	87.7	1.9	22.7	1.9	20.28
Om2	247.4	177.7	0.6	6.0	2.8	24.2	745.1	15.8	87.4	1.8	39.4	4.6	27.39
IIAhg	88.4	316.6	0.5	0.8	4.7	28.1	1178.2	28.0	186.4	1.9	122.3	20.1	8.04

Table 2.7 Description of the peat profile at Site 38 - Mesic Fibrisol on fibric, oligotrophic sphagnum peat overlying mesic, mesotrophic sedge - brown moss peat.

Field Description

Of1	0-20 cm	brown; von Post 3; sphagnum peat; some burn layers
Of2	20-40 cm	brown; von Post 3; sphagnum peat
Of3	40-80 cm	brown; von Post 3; sphagnum peat
Of4	80-120 cm	brown; von Post 4; sedge-moss peat; few wood fragments
Om	120-190 cm	brown; von Post; sedge-moss peat; few wood fragments
IICg	190-200+ cm	gray; heavy clay; massive

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC (cmol(+)kg^{-1})	Ca	Mg	K	Na	Base Sat. %
Of1	-	3.6	6.14	-	51.5	0.84	61.1	171.5	62.6	16.3	0.0	0.2	46
Of2	63.1	4.2	7.43	-	54.3	0.83	65.2	162.4	80.2	20.5	0.0	0.1	62

Total Elemental Contents

	Zn (mg kg^{-1})	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg (µg kg^{-1})
Of1	4.9	0.4	1.0	6.3	13.3	0.74	0.8	0.8	6.4	29.3	132.0	1.4	2.7	264
Of2	5.3	0.6	0.6	7.0	13.0	0.64	1.7	0.7	4.9	3.2	166.2	2.2	3.1	112

Total Elemental Contents - Continued

	Sr (mg kg^{-1})	Ba (mg kg^{-1})	P (g kg^{-1})	S (g kg^{-1})	Mg (g kg^{-1})	As (mg kg^{-1})	Si	V	Na	Mo	Se	Al (g kg^{-1})	Ca (g kg^{-1})
Of1	99.6	46.8	0.3	4.1	2.0	6.7	120.6	0.8	55.2	2.1	7.2	0.8	15.70
Of2	130.6	42.4	0.3	8.3	2.6	7.7	90.9	0.8	43.9	2.0	8.4	0.7	20.80

Table 2.8 Description of the peat profile at Site 41 - Mesic Fibrisol on mixed fibric and mesic, mesotrophic, sedge-moss peat overlain by thin sphagnic cap.

Field Description

Of1	0-20 cm	light brown with darker layers; von Post 4; sphagnum peat
Of2	20-40 cm	light brown; von Post 4; sphagnum peat
Om1	40-65 cm	dark brown; von Post 4; moss peat with minor sedge peat; few wood fragments
Of3	65-105 cm	von Post 3-4; sedge-moss peat
Of4	105-140 cm	von Post 4; sphagnum peat with minor sedge peat; few wood fragments
Om2	140-155 cm	von Post 4; sedge-moss peat
Of5	155-260 cm	von Post 4; sedge-moss peat
Om3	260-280 cm	von Post 5; sedge-moss peat; few wood fragments

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC	Ca	Mg	K	Na	Base Sat. %
								cmol(+)kg^{-1}					
Of1	51.4	3.6	4.81	-	54.5	1.07	51.0	130.1	36.4	12.4	0.0	0.2	38
Of2	54.7	3.8	3.95	-	56.2	1.26	44.6	115.6	33.8	10.8	0.0	0.2	39

Total Elemental Contents

	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg
	mg kg^{-1}													μg kg^{-1}
Of1	8.3	1.2	0.0	7.1	15.0	0.71	0.4	0.8	1.1	3.2	43.2	1.0	2.7	40
Of2	7.2	0.6	0.0	6.6	12.7	0.56	0.5	0.7	0.8	2.8	30.6	1.0	2.2	28

Total Elemental Contents - Continued

	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca
	mg kg^{-1}		g kg^{-1}			mg kg^{-1}						g kg^{-1}	
Of1	55.5	47.6	0.4	1.7	1.6	7.2	80.2	0.9	58.3	2.0	8.2	0.9	9.13
Of2	52.4	46.0	0.4	2.0	1.4	6.4	83.6	0.7	65.3	1.7	8.0	0.7	8.26

Table 2.9 Description of the peat profile near Site 41.

Field Description

Samples at 0-20 cm (Of1) and 20-40 cm (Of2) were taken at a site about 10 m from Site 41. This site differs from that described above in that the surface peat is very dry and unvegetated. The material is predominantly sphagnum peat.

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC (cmol(+)kg^{-1})	Ca	Mg	K	Na	Base Sat. %
Of1	59.4	3.2	3.88	-	55.3	1.04	53.3	145.1	28.0	12.7	0.0	0.0	28
Of2	63.9	3.2	-	-	54.0	0.93	58.2	147.0	26.8	12.3	0.0	0.1	27

continued . . .

Total Elemental Contents

	Zn (mg kg^{-1})	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg (µg kg^{-1})
Of1	10.7	1.7	0.4	6.4	14.7	0.61	0.8	0.8	0.5	50.0	55.7	0.7	3.0	45
Of2	8.8	0.7	0.6	7.2	12.6	0.60	0.6	0.7	1.2	33.1	49.0	0.7	2.6	22

Total Elemental Contents - Continued

	Sr (mg kg^{-1})	Ba	P (g kg^{-1})	S	Mg	As (mg kg^{-1})	Si	V	Na	Mo	Se	Al (g kg^{-1})	Ca
Of1	35.7	45.1	0.4	2.1	1.7	6.2	78.8	1.5	33.5	1.9	10.9	0.8	7.07
Of2	34.2	40.4	0.3	2.1	1.6	7.3	78.0	0.9	36.6	1.9	11.8	0.7	6.65

Table 2.10 Decription of a peat profile at Site 45 - Terric Fibrisol on fibric, oligotrophic sphagnum peat overlying fibric, mesotrophic brown moss-sedge peat.

Field Description

Of1	0-15 cm	very dark brown; von Post 4; sphagnum peat
Of2	15-60 cm	dark brown; von Post 4; sphagnum peat; few wood fragments
Of3	60-75 cm	brown and dark brown; von Post 4; brown moss - sedge peat;
Of4	75-95 cm	dark brown; von Post 7; amorphous materials with some sedge fibres and wood fragments
IICg	95-100+ cm	gray; clay; massive

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC (cmol(+)kg^{-1})	Ca	Mg	K	Na	Base Sat. %
Of1	48.9	3.2	7.2	-	52.1	1.37	38.0	153.7	33.4	9.8	0.0	0.1	28
Of2	57.7	4.3	7.0	-	55.2	1.05	52.8	158.8	71.3	19.3	0.0	0.2	57
Of3	59.2	4.6	6.6	-	56.2	1.24	45.2	146.3	70.5	18.3	0.0	0.4	61
Of4	49.3	4.8	16.4	-	50.7	1.36	37.3	148.7	75.7	17.1	0.0	0.5	63
IICg	-	5.6	-	0.12	3.4	-	-	46.0	23.6	9.7	0.4	0.3	74

continued . . .

Tbale 2.10 Concluded.

Total Elemental Contents

	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg
	mg kg^{-1}													μg kg^{-1}
Of1	11.9	0.1	6.2	3.2	18.4	0.00	0.1	0.8	11.3	147.3	13.6	3.0	2.1	160
Of2	6.1	0.3	2.6	3.5	14.5	0.11	0.7	0.7	17.1	3.0	203.6	5.7	2.5	171
Of3	7.2	0.1	3.0	4.1	8.8	0.48	1.4	2.6	23.0	3.2	286.3	7.5	3.1	239
Of4	7.7	4.3	2.5	6.9	21.8	0.57	1.6	5.9	26.8	96.4	334.0	10.1	6.8	211

Total Elemental Contents - Continued

	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca
	mg kg^{-1}		g kg^{-1}			mg kg^{-1}						g kg^{-1}	
Of1	54.8	63.3	0.7	1.9	1.2	6.5	209.4	0.8	22.9	2.0	4.8	1.1	8.30
Of2	125.7	63.7	0.4	2.0	2.4	8.0	70.0	0.7	47.0	1.9	3.5	0.8	18.30
Of3	127.5	55.4	0.4	3.0	2.3	10.3	229.6	1.0	83.1	2.0	4.6	0.8	17.19
Of4	150.9	78.7	0.6	3.1	2.2	13.7	895.5	7.5	106.7	2.0	23.5	3.5	19.01

Table 2.11 Description of the peat profile at Site 46 - mixed peat in large spoil pile.

Field Description

Of1	0-20 cm	dark brown; somewhat dry; mixed sphagnum and brown moss peats; few wood fragments
Of2	20-55 cm	dark brown; mixed moss peat with minor wood fragments
Of3	55-85 cm	dark brown; more moist and compact than surface layers, mixed moss peat composition; minor wood fragments

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC	Ca	Mg	K	Na	Base Sat. %
								cmol(+)kg^{-1}					
Of1	47.3	3.7	7.3	-	53.5	1.37	39.2	156.1	54.6	11.4	0.0	0.0	42
Of2	60.8	3.8	13.6	-	48.8	1.24	39.2	155.6	62.4	11.5	0.0	0.0	47
Of3	54.5	3.9	8.7	-	51.8	1.51	34.2	169.9	69.1	11.5	0.0	0.0	47

Total Elemental Contents

	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg
	mg kg^{-1}													µg kg^{-1}
Of1	18.0	2.5	1.8	5.6	19.9	0.36	0.8	1.1	9.0	27.9	107.6	4.6	2.7	218
Of2	25.2	2.8	1.4	6.6	16.8	0.32	2.4	5.2	9.7	56.2	161.1	6.4	3.9	208
Of3	39.0	4.0	0.0	5.6	15.9	0.75	2.8	8.4	15.8	33.3	200.1	10.3	3.7	200

Total Elemental Contents - Continued

	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca
	mg kg^{-1}		g kg^{-1}			mg kg^{-1}						g kg^{-1}	
Of1	98.5	78.3	0.5	2.6	1.4	8.2	210.5	1.7	0.7	1.8	6.9	1.4	15.76
Of3	118.4	114.6	0.5	7.7	1.5	14.2	179.5	2.9	0.8	2.1	13.0	1.2	17.59

Table 2.12 Description of a peat profile at Site 49[1] - Mesic Fibrisol on fibric, oligotrophic sphagnum peat overlying fibric and mesic, mesotrophic brown moss-sedge peat.

Field Description

Of1	0-20 cm	light brown; von Post 2; sphagnum peat
Ov	20-65 cm	light brown; von Post 3; sphagnum peat
Om	65-120 cm	light brown; von Post 4; brown moss peat
Of2	120-165 cm	yellowish brown, von Post 4; brown moss-sedge peat; many wood fragments
Of3	165-225 cm	brown; von Post 4; brown moss-sedge peat; few wood fragments
Oh	225-260 cm	very dark gray; mucky; slightly sticky; amorphous with some visible fibres and root fragments
IICg	260-280+ cm	banded gray and light gray; clay loam; massive; sticky

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC	Ca	Mg	K	Na	Base Sat. %
								cmol(+)kg^{-1}					
Of1	59.9	3.1	4.0	-	54.5	1.09	50.2	136.2	24.2	8.7	bdl	0.5	25
Ov	85.4	3.4	3.6	-	53.8	0.66	81.8	147.8	38.5	14.0	bdl	0.4	36
Om	36.5	4.2	9.8	-	52.0	1.86	28.0	114.2	38.9	9.8	bdl	0.3	43
Of2	45.5	4.7	5.3	-	56.0	2.36	23.7	105.9	52.1	10.7	bdl	0.5	60
Of3	47.1	5.0	9.1	-	54.3	2.69	21.	97.7	51.9	10.1	bdl	0.5	64
Oh	-	5.5	63.3	-	22.8	1.55	140	79.6	44.4	10.6	0.6	0.3	70
IICg	-	-	-	-	14.2	-	-	68.4	36.6	9.3	0.8	0.3	69

Table 2.12 Concluded.

Total Elemental Contents

	Zn	Cu	Pb	Li	Ti	Cd	Co	Ni	B	K	Mn	Fe	Cr	Hg
	mg kg^{-1}													µg kg^{-1}
Of1	14.9	0.4	3.2	0.6	12.5	0.23	0.1	0.8	13.6	134.7	44.0	0.8	1.7	201
Ov	14.8	0.8	2.3	1.7	7.6	0.08	0.1	0.8	12.4	70.9	47.2	1.1	1.3	66
Om	11.8	1.1	2.3	2.4	54.9	0.47	0.1	0.8	10.9	51.8	46.4	1.6	1.6	70
Of2	20.6	2.5	4.4	2.7	9.5	0.24	1.1	1.2	17.8	66.3	75.2	3.5	2.1	63
Of3	33.4	4.6	4.6	3.4	10.6	0.32	2.6	5.0	21.5	139.1	86.7	4.9	3.2	79
Oh	170.4	25.7	12.4	14.1	41.1	0.77	5.8	21.3	13.1	1643.1	107.5	9.2	17.1	216

Total Elemental Contents - Continued

	Sr	Ba	P	S	Mg	As	Si	V	Na	Mo	Se	Al	Ca
	mg kg^{-1}		g kg^{-1}			mg kg^{-1}						g kg^{-1}	
Of1	29.2	47.0	0.4	1.7	1.1	5.9	193.2	0.8	93.5	1.9	0.8	0.9	5.69
Ov	55.8	38.9	0.2	1.2	1.7	5.1	78.0	0.8	85.4	2.0	2.5	0.5	9.12
Om	68.7	51.1	0.6	2.8	1.2	7.0	154.9	1.1	178.1	2.0	7.3	2.4	9.53
Of2	91.2	72.2	0.6	4.2	1.4	6.1	195.1	0.8	107.5	2.0	0.4	0.6	12.89
Of3	92.8	104.3	0.6	6.0	1.4	7.2	491.0	2.5	116.8	2.0	5.1	1.2	13.08
Oh	90.9	218.7	0.7	5.8	3.1	16.5	1190.8	17.0	114.9	1.9	53.6	9.9	11.33

Table 2.13 Description of a mineral soil profile at Site 50 - peaty Orthic Luvic Gleysol developed on fine clayey glaciolacustrine materials.

Field Description

Om	20-0 cm	sod-like with abundant roots
Aheg	0-8 cm	gray: many, fine prominent reddish brown to red mottles; clay loam; weak, coarse platy breaking to moderate, fine to coarse granular; distinct, wavy boundary
Aeg	8-13 cm	gray; many, medium prominent reddish brown to red mottles; clay; strong, medium, angular blocky; clear, wavy boundary
Bg	13-42 cm	gray; many, medium, prominent reddish brown to red mottles; heavy clay; strong, fine angular blocky; clear, smooth boundary
BCg	42-75 cm	gray; common, fine, prominent reddish brown to red mottles; heavy clay; massive
Cg	75-100 cm	gray; few, fine, prominent, light reddish brown mottles; heavy clay; massive

Laboratory Analysis

Horizon	Rubbed Fibre	pH	Ash %	$CaCO_3$ %	OC %	N %	C:N	CEC	Ca	Mg	K	Na	Base Sat. %
								cmol(+)kg^{-1}					
Om	-	5.4	3.9	-	39.9	1.42	28.0	146.1	87.1	19.6	0.8	0.2	74
Aheg	-	4.9	-	0.08	3.1	0.20	15.6	52.3	23.8	7.2	0.5	0.3	61
Aeg	-	4.9	-	0.04	1.1	-	-	34.9	17.7	6.7	0.5	0.1	72
Bg	-	4.9	-	0.12	0.6	-	-	48.8	24.6	10.6	0.8	-	-
Cg	-	7.8	-	1.64	1.1	-	-	-	-	-	-	-	-

6.4. MAPS

2.1 Surface Elevation Contour Map

2.2 Peat Soil/Vegetation Map and Legend

2.3 Peat Isopach Map

2.4 Elevation Contour of Mineral Subsoil Map

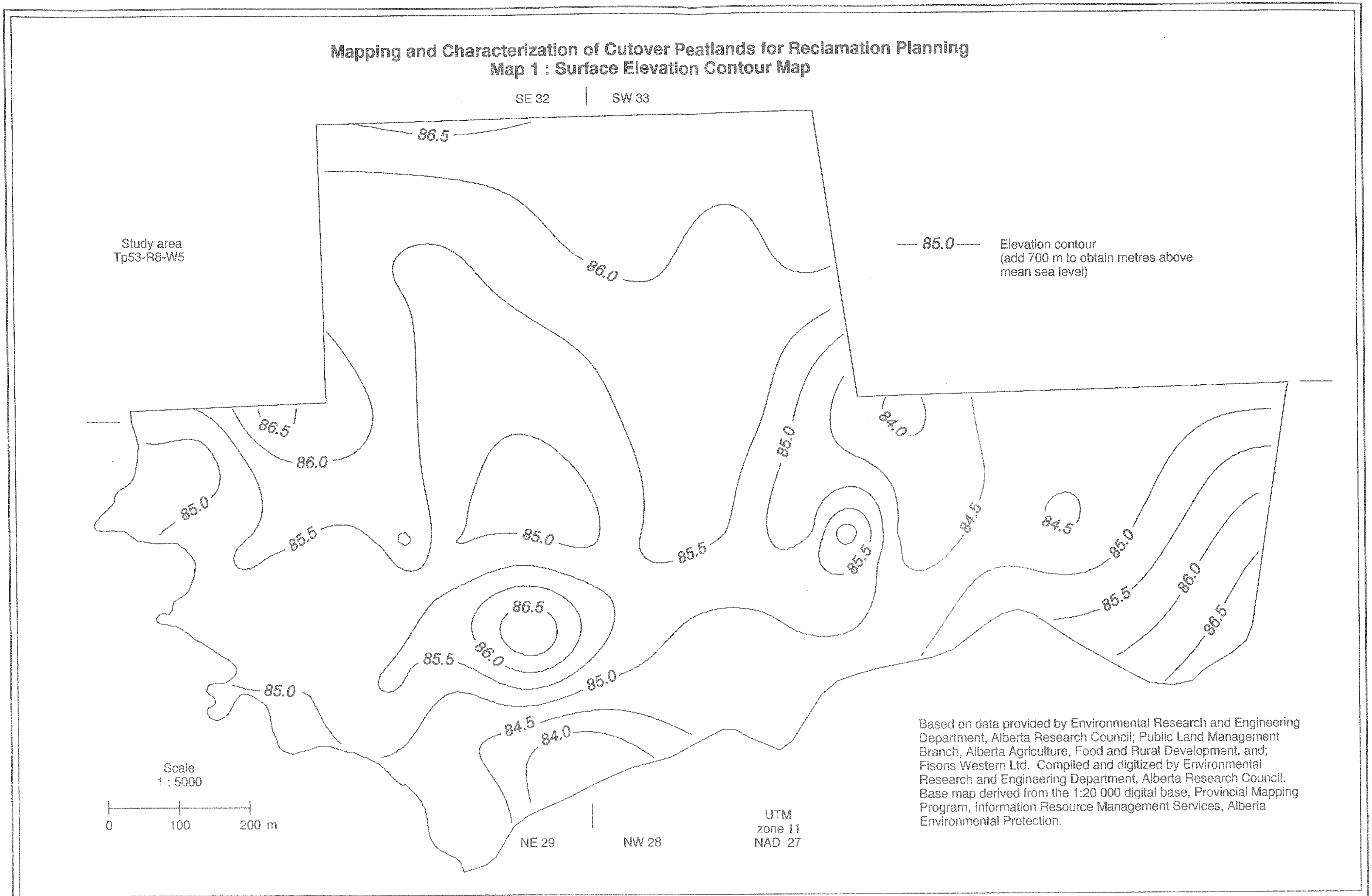
2.5 Drainage System Map

2.6 Location of Surface Elevation Data Points

2.7 Location of Soil Inspection Sites

2.8 Coefficient of Variation for Peat Thickness

Map 1. Surface Elevation Contour Map


Mapping and Characterization of Cutover Peatlands for Reclamation Planning
Map 1 : Surface Elevation Contour Map
SE 32
SW 33
Study area
Tp53-R8-W5
85.0
Elevation contour
(add 700 m to obtain metres above mean sea level)
86.5
86.0
85.5
85.0
84.5
84.0
Scale
1 : 5000
0
100
200 m
NE 29
NW 28
UTM
zone 11
NAD 27
Based on data provided by Environmental Research and Engineering Department, Alberta Research Council; Public Land Management Branch, Alberta Agriculture, Food and Rural Development, and; Fisons Western Ltd. Compiled and digitized by Environmental Research and Engineering Department, Alberta Research Council. Base map derived from the 1:20 000 digital base, Provincial Mapping Program, Information Resource Management Services, Alberta Environmental Protection.

Map 2. Peat Soil/Vegetation Map Legend

Mapping and Characterization of Cutover Peatlands for Reclamation Planning
Map 2: Peat Soil / Vegetation Map

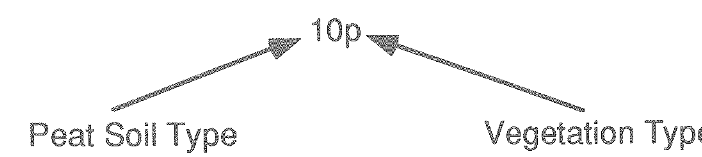
PEAT SOIL TYPE

UNIT	DESCRIPTION
1	<1.0 m fibric bog peat over mesic fen peat; moderately saturated, minor mineral soils.
2	<1.0 m fibric bog peat over mesic fen peat; moderately saturated.
3	<1.0 m mesic and fibric fen peat; moderately saturated.
4	<1.0 m fibric bog peat over mesic fen peat; highly saturated.
5	1.0 to 2.0 m mesic and fibric fen peat; very highly saturated.
6	1.0 to 2.0 m mesic and fibric fen peat; highly saturated.
7	1.0 to 2.0 m mesic fen peat with thin (<0.5 m) fibric cap; moderately saturated.
8	1.0 to 2.0 m fibric bog peat over mesic and fibric fen peat; very highly saturated.
9	1.0 to 2.0 m fibric bog peat over mesic and fibric fen peat; some shallow (<1.0 m) peat; very highly saturated with some relatively dry areas.
10	1.0 to 2.0 m fibric bog peat over mesic and fibric fen peat; some shallow (<1.0 m) peat; moderately saturated.
11	1.0 to 2.0 m fibric bog peat over mesic and fibric fen peat; relatively dry.
12	>2.0 m fibric bog peat over mesic and fibric fen peat; highly saturated with relatively dry areas of non-vegetated peat.
13	>2.0 m fibric bog peat over mesic and fibric fen peat; highly saturated.
14	>2.0 m fibric bog peat over mesic and fibric fen peat; thin mesic surface layer; very highly saturated.
15	Mineral soil with thin (<0.5 m) peat cap; imperfectly to poorly drained.
16	Mineral soil; moderately well drained; generally disturbed surface.
17	>2.0 m mixed fibric and mesic peat in large spoil piles.
18	>2.0 m peat in area with numerous peat piles and ponds; mainly highly and very highly saturated; mostly fibric bog peat over mesic and fibric fen peat.
19	Mixed mineral material and peat in drainage ditch/spoil pile complexes.
20	Mostly mineral material in old road bed.
21	Open water areas.
22	>2.0 m fibric bog peat over mesic and fibric fen peat; very highly saturated with much open water.
23	Road and ditch complex.
24	>2.0 m fibric bog peat over mesic and fibric fen peat; complex of very highly saturated peat with dry areas of non-vegetated peat in linear pattern along drainage ditches.

VEGETATION TYPE

Symbol	Physiognomic Type	Growth Form	Cover	Height	Dominant Species
a	Herb	Graminoid	Sparse and no cover	Low	cotton grass
b	Herb	Graminoid	Closed	Low and intermediate	reed grass/ bulrush
c	Herb	Graminoid	Closed	Low	reed grass/ sedge
d	Herb	Graminoid	Sparse and no cover	Low and intermediate	cotton grass/ sedge/bulrush
e	Herb	Graminoid	Closed	Low	sedge/moss
f	Herb	Graminoid	Open	Intermediate	cattail
g	Shrub	Mixed	Open	Low and intermediate	Labrador tea/ swamp birch
h	Shrub	Deciduous	Open	Intermediate	swamp birch/ cotton grass
j	Shrub	Deciduous	Sparse	Intermediate	willow/reed grass/cotton grass
k	Shrub	Deciduous	Sparse	Intermediate	willow/reed grass/sedge
m	Shrub	Deciduous	Open	Tall	willow/balsam poplar
n	Shrub	Deciduous	Sparse	Intermediate	willow/swamp birch/aspen/ paper birch
p	Shrub	Deciduous	Sparse	Intermediate	swamp birch/ Labrador tea/ sedge
q	Shrub and tree	Mixed	Closed	Intermediate to tall	swamp birch/ Labrador tea/ white spruce
r	Shrub	Mixed	Open	Intermediate	swamp birch/ Labrador tea/ willow
s	Shrub	Deciduous	Sparse to Closed	Intermediate to tall	mixture of species in ditch/spoil pile complex
t	Tree	Evergreen	Open	Intermediate	black spruce/ Labrador tea
u	Tree	Deciduous	Sparse	Intermediate	aspen/willow
v	Tree	Evergreen	Closed	Intermediate to tall	white spruce/ aspen
w	Non vegetated	n/a	No cover	n/a	very few willow, raspberry, birch
x	Herb-Non vegetated	Graminoid	Open and no cover	Low	cotton grass/ moss
z	Herb, Shrub and Tree	Mixed	Mixed	Mixed	mixture of species in pond/spoil pile complex

MAP SYMBOL



PEAT SOIL SATURATION CLASSES

Very highly saturated - water table within 0.20 m from surface and subject to spring flooding
Highly saturated - water table 0.20 to 0.50 m from surface
Moderately saturated - water table 0.50 to 1.00 m from surface
Relatively dry - water table>1.00 m from surface

VEGETATION COVER CLASSES

Sparse - <25% cover
Open - 25 to 60% cover
Closed - >60% cover

VEGETATION HEIGHT CLASSES

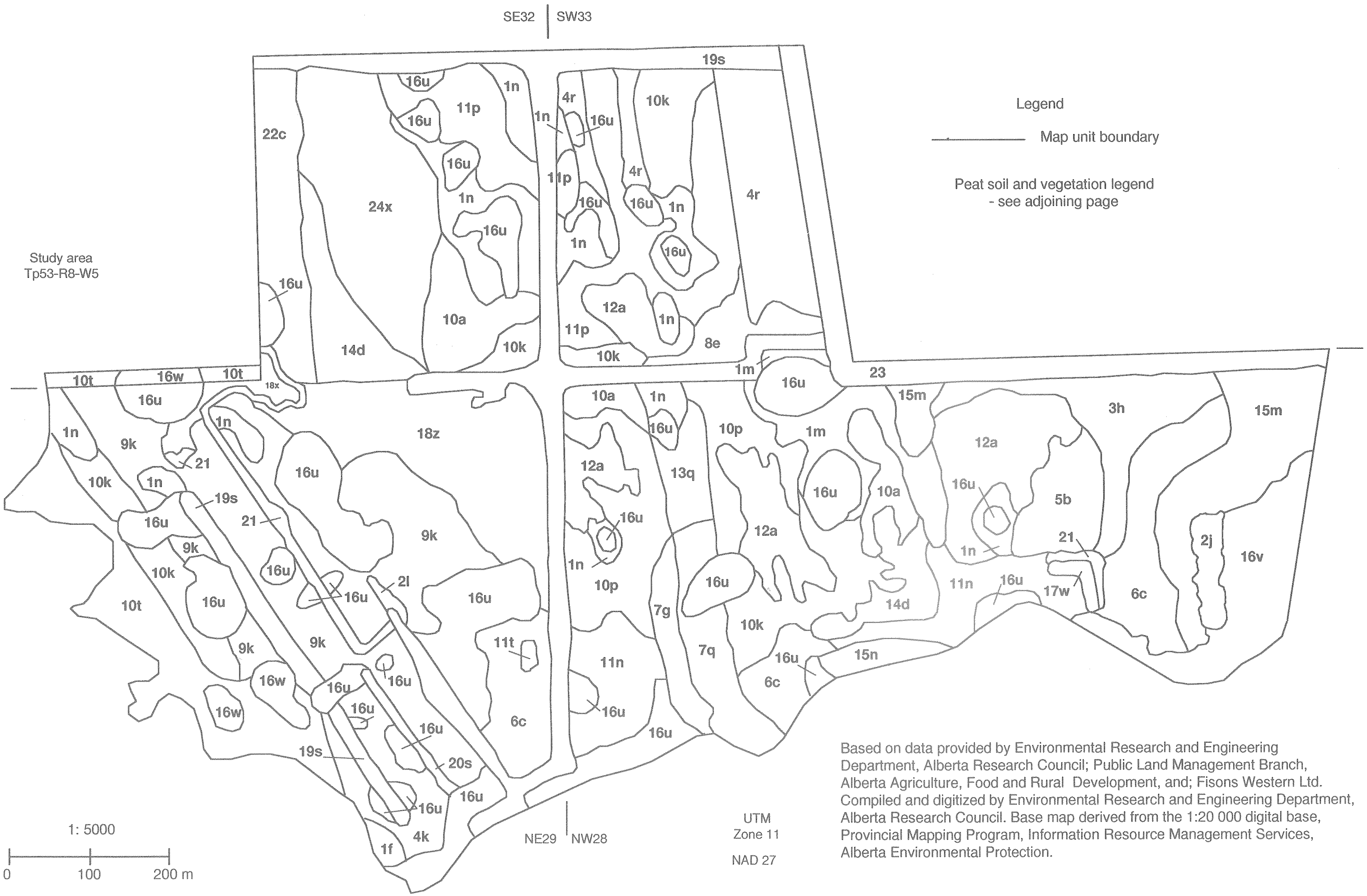
Herb and Shrub
- Very low - ≤0.2 m
- Low - >0.2 to 1 m
- Intermediate - >1 to 3 m
- Tall - >3 to 5
- Very tall - >5 m

Tree
- Dwarf, Low - ≤3 m
- Intermediate - >3 to 15 m
- Tall - >15 to 25 m
- Very tall - >25 m

Map 2. Peat Soil/Vegetation Map

Mapping and Characterization of Cutover Peatlands for Reclamation Planning

Map 2: Peat Soil/Vegetation Map



Legend

Map unit boundary

Peat soil and vegetation legend
- see adjoining page

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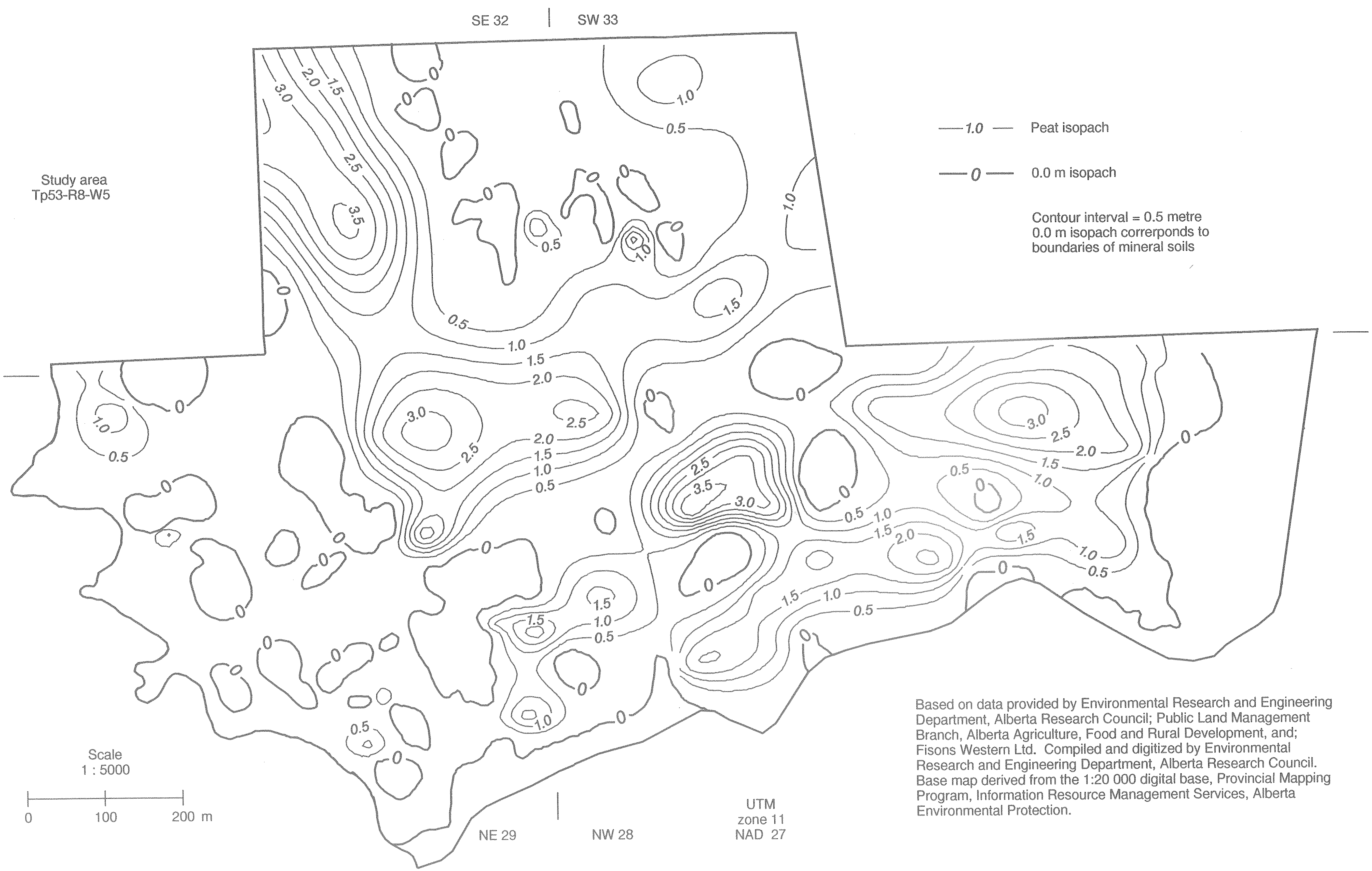
Map 3. Peat Isopach Map

Mapping and Characterization of Cutover Peatlands for Reclamation Planning
Map 3 : Peat Isopach Map



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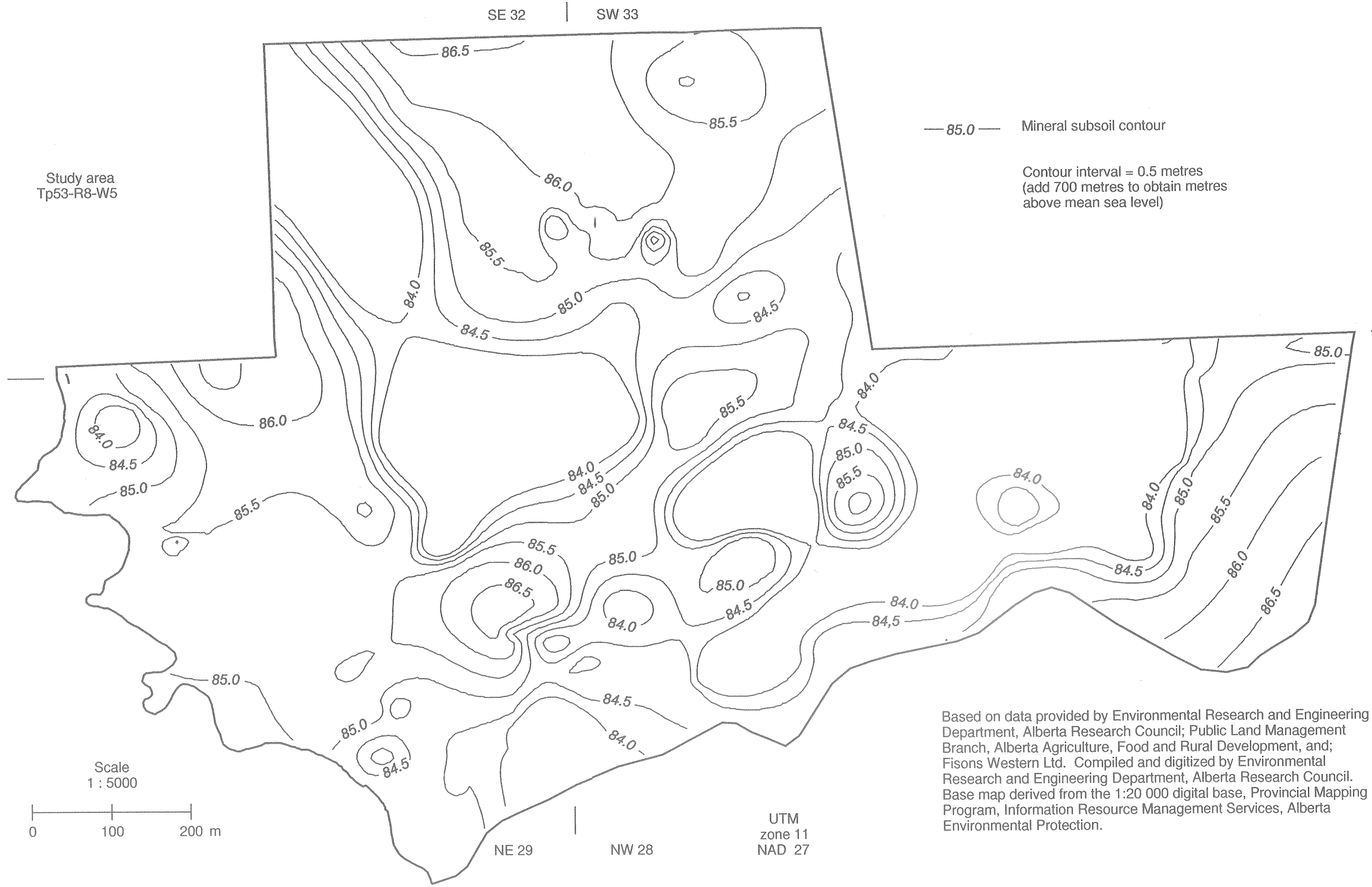
Map 4. Elevation Contour of Mineral Subsoil Map

Mapping and Characterization of Cutover Peatlands for Reclamation Planning
Map 4 : Elevation Contour Map of Mineral Subsoil



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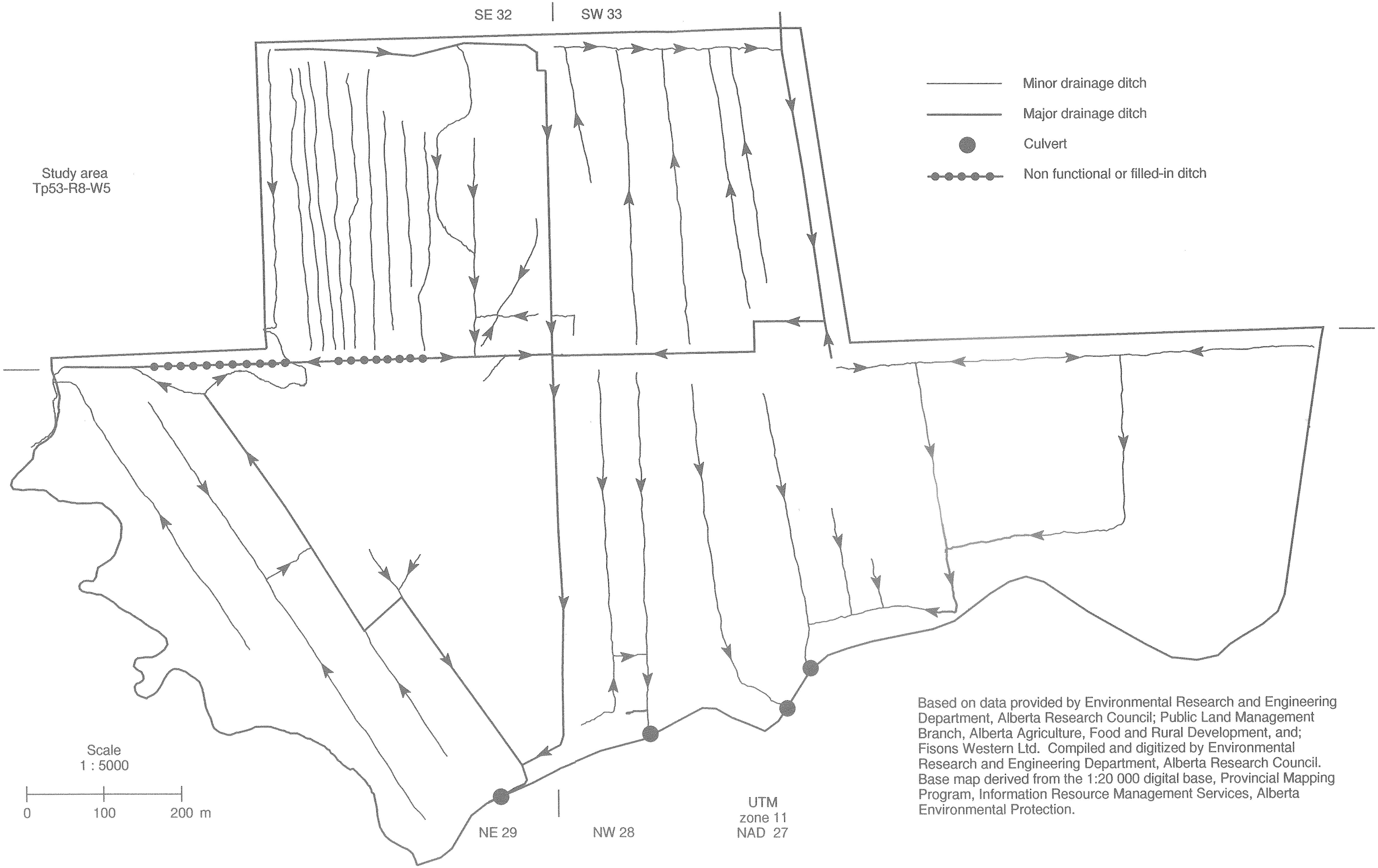
Map 5. Drainage System Map

Mapping and Characterization of Cutover Peatlands for Reclamation Planning

Map 5 : Drainage System Map



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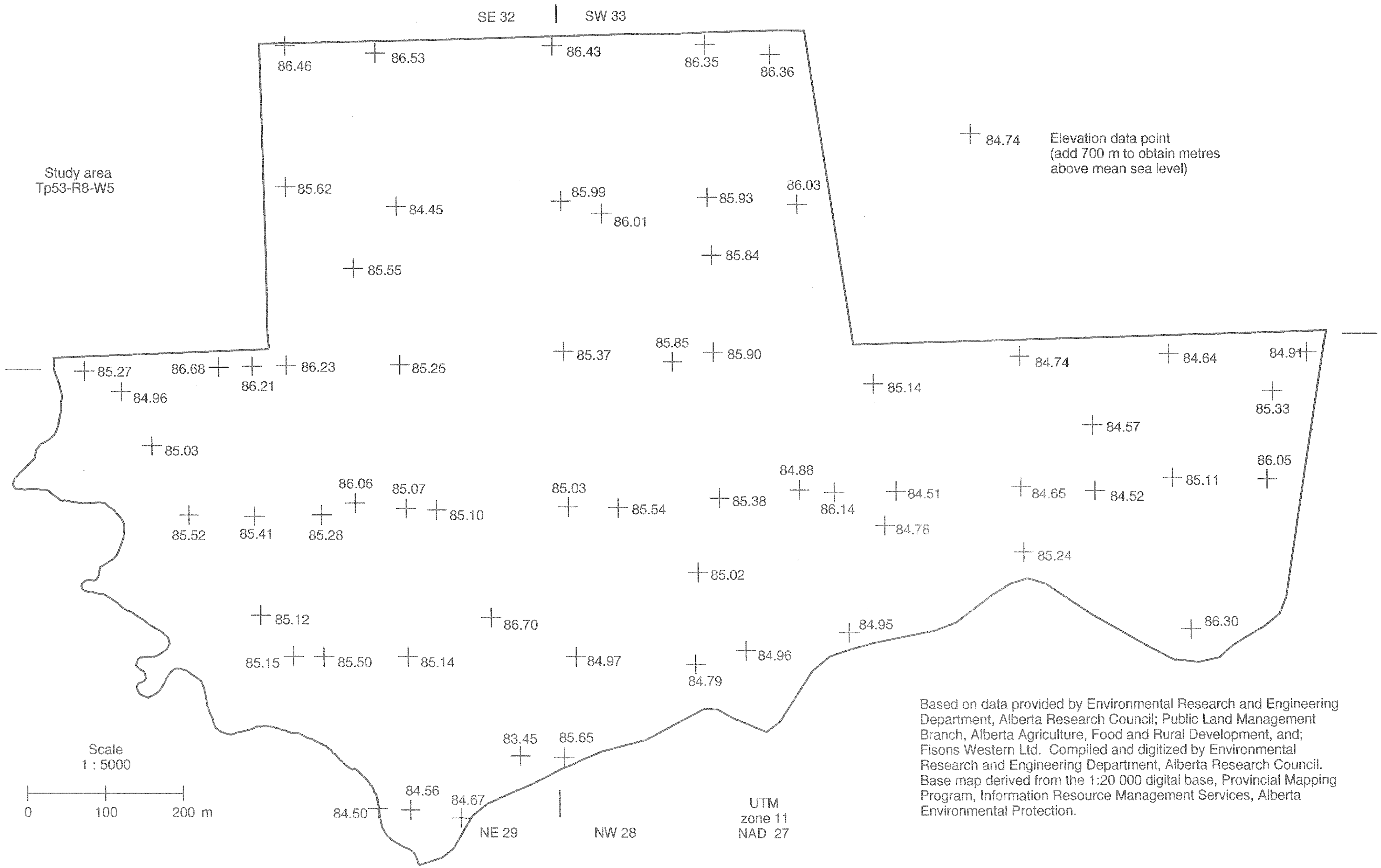
Map 6. Location of Surface Elevation Data Points

Mapping and Characterization of Cutover Peatlands for Reclamation Planning
Map 6 : Location of Surface Elevation Data Points



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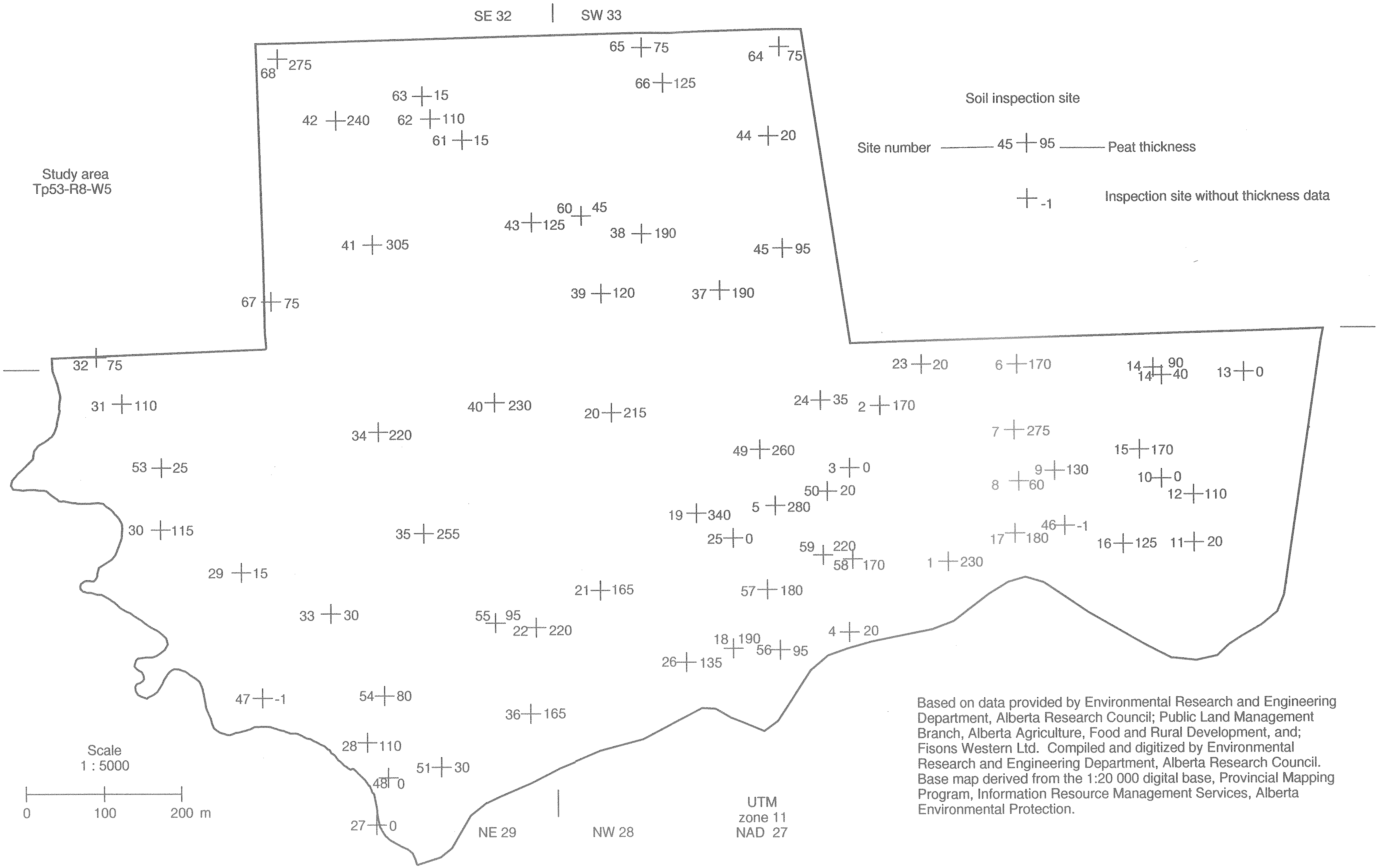
Map 7. Location of Soil Inspection Sites

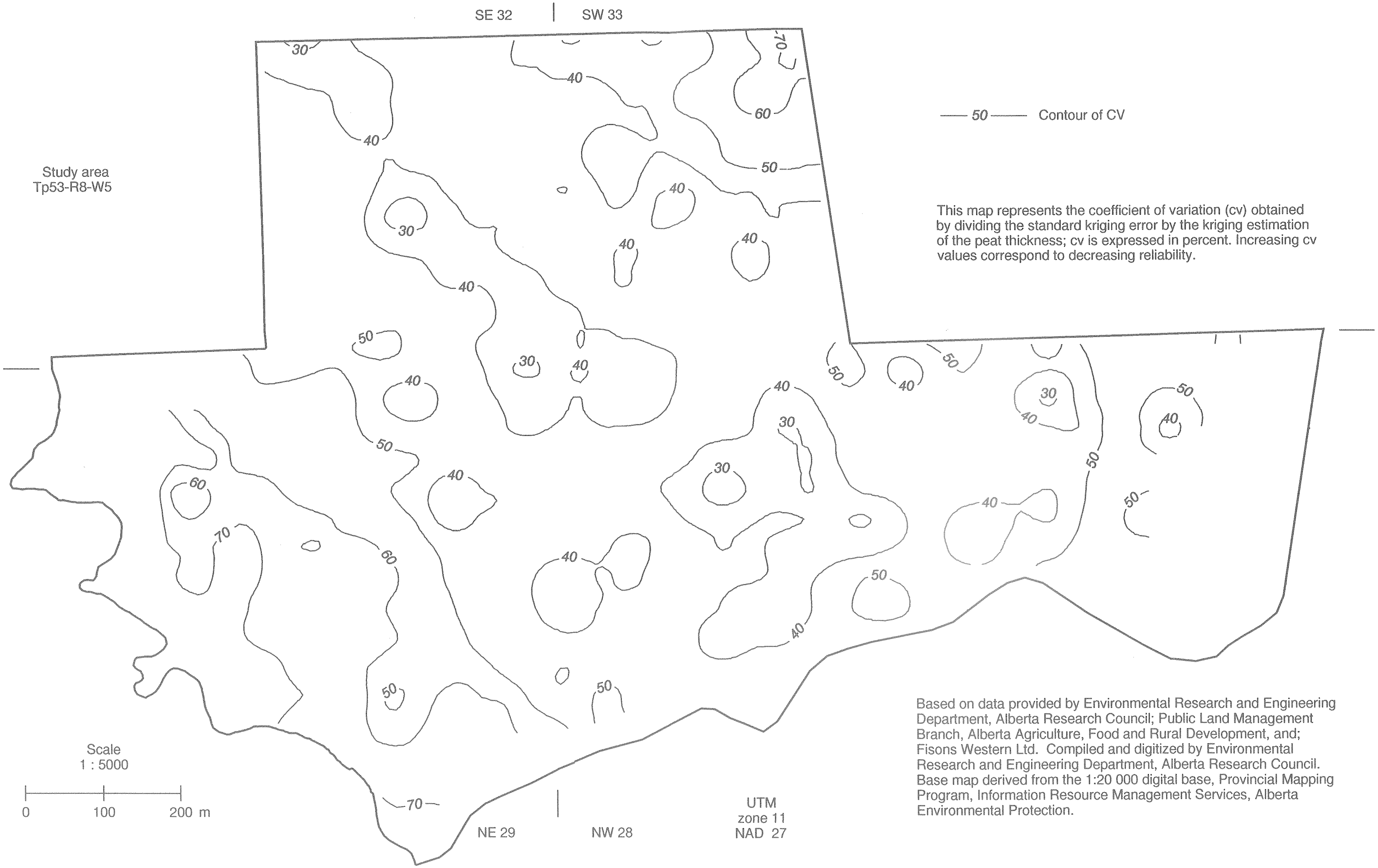
Mapping and Characterization of Cutover Peatlands for Reclamation Planning
Map 7 : Location of Soil Inspection Sites



Based on data provided by Environmental Research and Engineering Department, Alberta Research Council; Public Land Management Branch, Alberta Agriculture, Food and Rural Development, and; Fisons Western Ltd. Compiled and digitized by Environmental Research and Engineering Department, Alberta Research Council. Base map derived from the 1:20 000 digital base, Provincial Mapping Program, Information Resource Management Services, Alberta Environmental Protection.

Map 8. Coefficient of Variation for Peat Thickness

Mapping and Characterization of Cutover Peatlands for Reclamation Planning
Map 8 : Coefficient of Variation for Peat Thickness



This map represents the coefficient of variation (cv) obtained by dividing the standard kriging error by the kriging estimation of the peat thickness; cv is expressed in percent. Increasing cv values correspond to decreasing reliability.

Based on data provided by Environmental Research and Engineering Department, Alberta Research Council; Public Land Management Branch, Alberta Agriculture, Food and Rural Development, and; Fisons Western Ltd. Compiled and digitized by Environmental Research and Engineering Department, Alberta Research Council. Base map derived from the 1:20 000 digital base, Provincial Mapping Program, Information Resource Management Services, Alberta Environmental Protection.

PART III. PEAT AND PEATLAND CLASSIFICATION SYSTEMS AND GLOSSARY OF TERMS

1. CLASSIFICATION SYSTEMS

1.1 CLASSIFICATION SYSTEMS FOR PEAT SOILS AND STRATIGRAPHY

1.1.1 Peat Material Classification

A universal classification of peat material developed by the International Peat Society (Kivinen 1980) is recommended as a general framework for describing peat materials. The scheme uses three properties for classification: botanical composition, degree of decomposition, and the trophic status (nutrient richness) of the peat.

1. Botanical composition
   - Moss peat
   - Sedge peat
   - Wood peat
2. Decomposition degree
   - Weakly decomposed
   - Moderately decomposed
   - Strongly decomposed
3. Trophic status
   - Oligotrophic
   - Mesotrophic
   - Eutrophic

This system can be applied to most types of peat, but requires refinement and subdivision according to local conditions and use requirements. The subdivisions of the three main properties indicated above are guidelines only. The categories and terminology used differ in different countries. Classes commonly used in Canada, and used in this project, for the three peat properties are outlined below.

1.1.2 Botanical composition.

Categories of botanical composition used to describe peat materials have been suggested for use in Canada by Tarnocai (1984). The classes are as follows:

1. Sphagnum peat
2. Sedge peat
3. Moss-sedge peat
4. Woody sedge peat
5. Woody peat
6. Feather moss peat
7. Sedimentary peat
8. Amorphous peat

Broader categories are used in the Canadian System of Soil Classification as described by the Agriculture Canada Expert Committee on Soil Survey (1987) and by Mills et al. (1977). The categories are bog (sphagnum), fen (sedge), swamp (forest), and undifferentiated peat. The relatively more detailed Tarnocai (1984) classification above (Classes 1-8) is suggested as being appropriate for more detailed surveys.

1.1.3 Degree of decomposition

Decomposition refers to the breakdown of plant matter accomplished biochemically through the action of microorganisms as well as mechanically through the action of wetting-drying and freeze-thaw cycles in peat (Kong et al. 1980; Puustjarvi 1977). From the point of view of the structure of peat, the results of chemical decomposition and physical disintegration are similar and difficult to distinguish. Several methods of determining the degree of decomposition have been developed. Some are practical field methods, while others are for use in a laboratory.

Two systems are commonly employed in Canada. One is used in soil classification and has three categories of decomposition - weakly, medium, and strongly decomposed - corresponding to the terms fibric, mesic, and humic, respectively, as described in the Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey 1987; see Section 4 for definitions of each of the above terms).

The second commonly used system for describing peat decomposition is the 10-point system of von Post (1924). In this system, a value of H-1 represents undecomposed peat and H-10 refers to completely amorphous material. This system is applied to wet peats, and is unsuitable for dried materials or for peats with high contents of mineral materials. The method is applied by squeezing a small amount of fresh peat in the palm of the hand. The colour of the water extract and the amount and nature of fiber remaining in the hand are indicators of the degree of decomposition. The criteria for the different categories in this system are presented in Section 4.

1.1.4 Trophic status

A threefold classification of nutrient richness of peats - oligotrophic, mesotrophic, eutrophic - is widely recognized. These terms have commonly been used as descriptors of nutrient status in aquatic systems. With respect to peat materials, the terms are used in the sense of capacity of peat to supply plant nutrients to the growing vegetation, or simply as the content of nutrients as determined by analytical procedures. Parameters that could be used include total contents of nutrients, pH, base cation content, and degree of base saturation. The exact limits between the three groups (oligotrophic, mesotrophic, eutrophic) may vary

The classification of the nutrient-pH gradient of Jeglum (1971) partially corresponds to the reaction classes for peat in the Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey 1987). There are two categories- euic, having $pH(CaCl_2) > 4.5$, and dysic, with $pH(CaCl_2) < 4.5$. Determination of pH in 0.01 M $CaCl_2$ provides a value that is usually about 0.5 units lower than that determined in moist or saturated peat. Hence, $pH(CaCl_2)$ of 4.5 is equivalent to about pH 5 in Jeglum's (1971) classification and the terms oligotrophic and dysic are essentially the same. The euic category in the soil classification system is not subdivided, however, and there are no classes equivalent to mesotrophic and eutrophic.

Table 3.1. Classification of the nutrient-pH gradient.[1]

Nutrient Status	pH of Water	pH of Peat	pH of Peat ($CaCl_2$)
Very oligotrophic	<4.4	<3.9	<3.4
Oligotrophic	4.5 to 5.4	4.0 to 4.9	3.5 to 4.4
Mesotrophic	5.5 to 6.4	5.0 to 5.9	4.5 to 5.4
Eutrophic	6.5 to 7.4	6.0 to 6.9	5.5 to 6.4
Very eutrophic	>7.5	>7.0	>6.4

[1] Source: Jeglum (1971).

in different regions and according to the analytical methods used (e.g., Daniels 1979; Pyavchenko 1979).

At a broad level of characterization, pH has been found to be strongly correlated with the overall availability of plant nutrients (Jeglum et al. 1974). Both pH of groundwater and pH of surface peat layers have been used as indices relating nutrient status to types of vegetation growing in peatlands (Jeglum 1971). Jeglum's (1971) classification of the nutrient-pH gradient and ranges of pH used are shown in Table 3.1. The moist peat pH values have been found to average 0.5 units lower than water pH values and thus, the limits of the criteria differ for water and peat in Table 3.1.

Nutrient classes have more recently been based on the total calcium content of the surface 50 cm of peat (Zoltai and Johnson 1987). Calcium was the preferred index element because it is the most abundant inorganic constituent in peat and because it influences acidity and nutrient mobility in the soil. The nutrient classes and calcium ranges suggested by Zoltai and Johnson (1987) are as follows:

1. Oligotrophic < 5 000 mg kg^{-1};
2. Dystrophic 5 000 to 10 000 mg kg^{-1};
3. Mesotrophic 10 00 to 30 000 mg kg^{-1};
4. Macrotrophic >30 000 mg kg^{-1}.

These classes may be difficult to apply because laboratory analysis is required before peat samples can be allocated to a particular class. Measurement of pH on field samples is a more convenient way to estimate trophic status, while laboratory measurements of pH and total calcium on a subset of samples can be carried out to calibrate or verify field determinations.

1.2 DRAINAGE REGIME CLASSIFICATION

Classes proposed for describing water regime were adapted from the classification for the saturated soil zone as described by the Agriculture Canada Expert Committee on Soil Survey (1983). Limits to these classes were also partly derived from field observations from the study described in Part II of this report. This is a preliminary classification, and somewhat more investigation is required in order to develop a system for general application. The classes are as follows:

1. Very highly saturated - water table is just below the soil surface, generally within 20 cm. The soil may be inundated during part of the year, especially after spring thaw.
2. Highly saturated - water table is mainly in the range of 20 to 50 cm below the surface, and may be near or at the surface during the spring.
3. Moderately saturated - water table is generally in the range of 50 to 100 cm below the soil surface.
4. Relatively dry - water table is about 100 cm or more below the soil surface.

1.3 VEGETATION CLASSIFICATION SYSTEM

The Canadian Vegetation Classification System (National Vegetation Working Group 1990) is applicable to the description of peatland vegetation. The first approximation of this classification system uses a combination of physiognomic, structural dominance and floristic criteria in a seven level hierarchy. The following summary of the seven levels of the system is taken directly from the report of the National Vegetation Working Group (1990).

1. Level I distinguishes broad physiognomic types. Allocation of individual types of vegetation to a specific category is based on both stand physiognomy and dominance criteria. Preference is given to individual growth-forms for classification purposes as follows: trees > shrubs > herbs > non vascular. For example, a stand with 30% cover of trees and a 70% cover of shrubs is classified as a "Tree stand", despite the greater cover of shrubs, because trees represent the dominant growth-form in terms of overall stand structure.

2. Level II subdivides physiognomic types (Level I) on the basis of different growth-forms that commonly form plant communities. Two groups are recognized within the Tree and Shrub categories: evergreen and deciduous. Herbs are subdivided into Forbs and Graminoids while Nonvasculars are subdivided into Lichens and Bryophytes. Physiognomic types within a single growth-form without a clear dominant (>75% composition) are considered to be codominants or 'mixed' (e.g., Mixed Herb - 60% forb and 40% graminoids).

3. Level III subdivides the growth-forms of Level II on the basis of total stand ground cover. Three categories are recognized: closed (>60%), open (25 to 60%), and sparse (<25%).

4. Level IV subdivides the physiognomic classes within Level III on the basis of height. Five classes are recognized for Trees (dwarf - <3 m due to environment; low - <3 m due to age; intermediate - >3 m to 15 m; tall - >15 m to 25 m; and very tall - >25 m); five for Shrubs (very low - <0.2 m; low - >0.2 m to 1 m; intermediate - >1m to 3 m; tall - >3 m to 5 m; and very tall - >5 m); and four classes for Herbs (very low - <0.2 m; low - >0.2 m to 1m; intermediate - >1m to 3 m; and tall - >3 m to 5 m). No equivalent differentiation was made for Nonvasculars.

5. Level V subdivides Level IV on the basis of dominant (e.g., diamond willow, trembling aspen, white spruce-alpine fir, elk sedge, black spruce), and codominant species (e.g., white spruce-alpine fir). A dominant species is defined as having the greatest cover and/or biomass within a community, and is usually the tallest species. Codominants are two or more dominant species that occur in approximately equal abundance and have a similar physiognomy. Common names for species are used at this Level.

6. Level VI subdivides Level V on the basis of major understory vegetation, if present (e.g., White Spruce/ Feathermoss, Willow/Reedgrass). Differentiation is based on dominant growth-forms or species as represented by percent cover. Classes within this level represent broadly defined plant communities and are referred to as 'Types' and described using common plant names.

7. Level VII represents a subdivision of Level VI classes on the basis of one or more major understory species. This level is the most detailed level of the vegetation classification system, and generally corresponds to the association or subassociation and sociation of the Braun-Blanquet floristics and structural dominance approaches, respectively. Scientific plant names are used at this Level.

1.4 SOIL CLASSIFICATION SYSTEM

Soils of peatlands, or Organic soils, are classified according to the Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey 1987). At the highest level of classification, the Order, organic soils are defined as containing 17% or more organic carbon (30% organic matter) to certain depths. At the second level of classification, the Great Group, organic soils are differentiated mainly on the basis of the degree of decomposition of the organic material in certain tiers (layers) or combinations of tiers. There are four Organic soil Great Groups: Fibrisol, Mesisol, Humisol, and Folisol. The first three are based on predominance in the 40 to 120 cm layer of fibric, mesic, and humic peat, respectively. Folisols, which occur mainly in coastal regions, are well drained Organic soils developed from forest materials of upland origin.

At the third level of classification, the Subgroup, the soils are differentiated on the basis of the kinds and sequences of horizons. The next level in the system, the Family, is based on characteristics of the surface tier, reaction, soil climate, particle size of the terric layer, limno materials, and depth to lithic contact. At the Series level of the classification, a number of properties can be used to differentiate soils: e.g., botanical origin of parent material, abundance of logs and stumps, calcareousness, bulk density, mineralogy of terric or cumulo layers, and others.

Further details regarding definition and classification criteria for Organic soils are provided in Section 4 under the entry 'Organic soil'.

2. ELEMENTAL CONTENTS OF PEAT

Ranges and averages of percentage elemental composition for Organic soil are provided in Table 3.2. This data summary provides a basis for comparing elemental levels in peatlands for purposes such as nutrient level evaluations and environmental impact assessments.

3. WATER QUALITY GUIDELINES

The quality guidelines in Tables 3.3 and 3.4 are extracted from CCREM (1987) for uses pertinent to peatlands and associated water bodies. These provide a basis for evaluating potential impacts of activities in peatlands on quality of water in associated aquatic environments.

Table 3.2 Approximate ranges and average in percentages of some elements occurring in undeveloped organic soils.[1]

Element		Percent Range (Oven Dry Basis)	% Typical Average	
			Eutrophic Peats	Oligotrophic Peats
Aluminum	Al	0.01 - 5.0	0.5	0.1
Barium	Ba	0.0006 - 0.3	0.005	-
Boron	B	0.00001 - 0.1	0.01	0.0001
Calcium	Ca	0.01 - 6.0	2.0	0.3
Carbon	C	12.0 - 60.0	48.0	52.0
Chlorine	Cl	0.001 - 5.0	0.10	0.01
Cobalt	Co	<0.0003	0.0001	0.00003
Copper	Cu	0.0003 - 0.01	0.001	0.0005
Hydrogen	H	2.0 - 6.0	5.0	5.2
Iron	Fe	0.02 - 3.0	0.5	0.1
Lead	Pb	0.00 - 0.04	0.005	0.001
Magnesium	Mg	0.01 - 1.5	0.3	0.06
Manganese	Mn	0.0001 - 0.08	0.02	0.003
Molybdenum	Mo	0.00001 - 0.005	0.001	0.0001
Nickel	Ni	0.0001 - 0.03	0.001	0.0005
Nitrogen	N	0.3 - 4.0	2.5	1.0
Oxygen	O	30.0 - 40.0	32.0	35.0
Phosphorus	P	0.01 - 0.5	0.07	0.04
Potassium	K	0.001 - 0.8	0.1	0.04
Silicon	Si	0.1 - 30.0	5.0	0.5
Sodium	Na	0.02 - 5.0	0.05	0.01
Sulphur	S	0.004 - 4.0	0.5	0.1
Zinc	Zn	0.001 - 0.4	0.05	0.005

[1] Adapted from the original table in Lucas (1982).

Table 3.3 CCREM guidelines for freshwater aquatic life.

Parameter	Guideline	Comments
	Inorganic parameters	
Aluminum[1]	0.005 mg L^{-1}	pH<6.5;[Ca^{2+}]<4.0 mg L^{-1}; DOC<2.0 mg L^{-1}
	0.1 mg L^{-1}	pH>6.5;[Ca^{2+}]>4.0 mg L^{-1}; DOC>2.0 mg L^{-1}
Antimony	ID[2]	
Arsenic	0.05 mg L^{-1}	
Beryllium	ID	
Cadmium	0.2 mg L^{-1}	Hardness[3] 0-60 mg L^{-1}
	0.8 mg L^{-1}	Hardness 60-120 mg L^{-1}
	1.3 mg L^{-1}	Hardness 120-180 mg L^{-1}
	1.8 mg L^{-1}	Hardness >180 mg L^{-1}
Chlorine (total residual)	2.0 mg L^{-1}	Measured by amperometric or equivalent method
Chromium	0.02 mg L^{-1}	To protect fish
	2.0 mg L^{-1}	To protect aquatic life, including zooplankton and phytoplankton
Copper	2 mg L^{-1}	Hardness 0-60 mg L^{-1}
	3 mg L^{-1}	Free cyanide as CN
Dissolved oxygen	6.0 mg L^{-1}	Warm-water biota - early life stages
	5.0 mg L^{-1}	- other life stages
	9.5 mg L^{-1}	Cold-water biota - early life stages
	6.5 mg L^{-1}	- other life stages
Iron	0.3 mg L^{-1}	
Lead	1 mg L^{-1}	Hardness 0-60 mg L^{-1}
	2 mg L^{-1}	Hardness 60-120 mg L^{-1}
	4 mg L^{-1}	Hardness 120-180 mg L^{-1}
	7 mg L^{-1}	Hardness >180 mg L^{-1}
Mercury	0.1 mg L^{-1}	

continued . . .

Table 3.3 Concluded.

Parameter	Guideline	Comments
Nickel	25 mg L^{-1}	Hardness 0-60 mg L^{-1}
	65 mg L^{-1}	Hardness 60-120 mg L^{-1}
	110 mg L^{-1}	Hardness 120-180 mg L^{-1}
	150 mg L^{-1}	Hardness >180 mg L^{-1}
Nitrogen		
Ammonia (total)	2.2 mg L^{-1}	pH 6.5; temperature 10°C
	1.37 mg L^{-1}	pH 8.0; temperature 10°C
Nitrite	0.06 mg L^{-1}	
Nitrate		Concentrations that stimulate prolific weed growth should be avoided.
Nitrosamines	ID	
pH	6.5-9.0	
Selenium	1 mg L^{-1}	
Silver	0.1 mg L^{-1}	
Thallium	ID	
Zinc[4]	0.03 mg L^{-1}	
	Physical parameters	
Temperature		Thermal additions should not alter thermal stratification or turnover rates, exceed maximum weekly mean temperatures, and exceed maximum short-term temperatures.
Total suspended solids	increase of 10.0 mg L^{-1}	Background suspended solids<100.0 mg L^{-1}
	increase of 10% above background	Background suspended solids >100.0 mg L^{-1}

1 Concentrations of heavy metals reported as total metal in an unfiltered sample.
2 ID = insufficient data to recommend a guideline.
3 Hardness expressed as $CaCO_3$.
4 Tentative guideline.

Table 3.4 CCREM guidelines for livestock drinking water quality.

Parameter	Guideline (mg L^{-1})
	Major Ions and Nutrients
Calcium	1000
Nitrate plus nitrite	100
Nitrite alone	10.0
Sulphate	1000
Total dissolved solids (salinity)	3000
	Heavy Metals and Trace Ions[1]
Aluminum	5.0
Arsenic	0.5 (5.0 when not added to feed)
Beryllium[2]	0.1
Boron	5.0
Cadmium	0.02
Chromium	1.0
Cobalt	1.0
Copper	1.0 (cattle) 5.0 (swine and poultry) 0.5 (sheep)
Fluoride	2.0 (1.0 if feed contains fluoride)
Iron[2]	0.1
Manganese[3]	-
Mercury	0.003
Molybdenum	0.5
Nickel	1.0
Selenium	0.05
Uranium	0.2
Vanadium	0.1
Zinc	50.0
	Biological Parameters
Blue-green algae	Avoid heavy growths of blue-green algae
Pathogens and parasites	Water of high quality should be used

[1] Guidelines expressed as total concentrations.
[2] Tentative guideline.
[3] No guideline recommended at this time.

4. TERMINOLOGY FOR DESCRIBING PEAT AND PEATLANDS

This glossary provides definitions of terms used in this report as well as of some additional commonly used terms. Sources for the definitions, given in the list of references, are as follows:

Agriculture Canada Expert Committee on Soil Survey (1987); Aiken et al. (1985); Bates and Jackson (1987); Canadian Society of Soil Science (1976); Cole (1983); Crum (1988); Gore (1983); Morris (1992); National Wetlands Working Group (1988); Puustjarvi (1977); Stanek and Worley (1983).

acidity, active - the activity of hydrogen ion in water or in the aqueous phase of a soil, measured and expressed as a pH value.

acidity of water - amount of acid, given as millimoles of a strong base per litre of water, necessary to titrate a sample to a certain pH value.

aerobic - (1) having molecular oxygen as a part of the environment; (2) growing only in the presence of molecular oxygen, such as aerobic organisms; (3) occurring only in the presence of molecular oxygen, as applied to certain chemical or biochemical processes such as aerobic decomposition.

afforestation - conversion of previously unforested, bare land into forest land by planting of forest trees.

alkalinity - the buffering system or titratable base in water; the milliequivalents of hydrogen ions neutralized by a liter of water; often expressed as $CaCO_3$ in mg L^{-1}.

amorphous peat - the structureless portion of an organic deposit in which the plant remains are decomposed beyond recognition.

anaerobic - (1) having no molecular oxygen in the environment; (2) growing in the absence of molecular oxygen, such as anaerobic bacteria; (3) occurring in the absence of molecular oxygen, as in a biochemical process.

anion - an ion carrying a negative charge of electricity. The common peat soil and water anions are bicarbonate, carbonate, sulphate, chloride, and hydroxyl.

ash - the loss on ignition of a peat sample; the percent of original material remaining as residue after heating at 450°C for 16 hours in an electric muffle furnace.

available nutrient - that portion of any element or compound in the soil that can readily be absorbed and assimilated by growing plants.

base saturation percentage - the extent to which the adsorption complex of a soil is saturated with exchangeable cations other than hydrogen and aluminum.

bog - a peat-covered area or peat-filled wetland, generally with a high water table. The water table is at or near the surface. The surface is often raised or level with the surrounding wetlands, and is virtually unaffected by the nutrient-rich groundwaters from the surrounding mineral soils. Hence, the groundwater of the bog is generally acid and low in nutrients. The dominant peat materials are Sphagnum and forest peat underlain, at times, by fen peat. The associated soils are Fibrisols, Mesisols and Organic Cryosols. The bogs may be treed or treeless and they are usually covered with *Sphagnum* mosses, feathermosses, and ericaceous shrubs.

brown moss peat - peat composed of various proportions of mosses of Amblystegiaceae (*Scorpidium, Drepanocladus, Calliergon, Campylium*), *Hypnum*, and *Tomenthypnum*.

calcium carbonate equivalent - the total inorganic carbon content of soil material expressed in terms of percent calcium carbonate ($CaCO_3$).

cation - an ion carrying a positive charge of electricity. The common soil cations are calcium, magnesium, sodium, potassium, and hydrogen.

cation exchange - the interchange between a cation in solution and another on the surface of any surface-active material in the soil such as clay or organic matter.

cation exchange capacity (total exchange capacity) - the total amount of exchangeable cations that a soil can adsorb. In SI units, it is expressed in centimoles positive charge per kg of soil (cmol(+)kg^{-1}).

conductance, electrical; conductivity, electrical - ability of water to conduct an electric current per unit area divided by the voltage drop per unit length; specific conductance (conductivity) refers to the electron flow between two 1-cm^2 electrodes, set 1 cm apart.

density, bulk - mass of an oven-dry soil sample per unit gross volume (including pore space) expressed as Mg m^{-3}.

drainage - the removal of excess surface water or groundwater from land by natural runoff and percolation, or by means of surface or subsurface drains.

dysic - a soil term referring to pH <4.5 ($CaCl_2$) in all parts of the control section of an organic soil.

dystrophy - the condition in water in which decay is hindered and recycling of nutrients is slowed; there is a high loading of allochthonous organic matter, but a low level of autochthonous input; dystrophic waters are heavily stained (brown water) and have a high content of humic substances.

ecosystem - a local biological community and its pattern of interaction with its environment.

edaphic - referring to the ground or soil, especially with reference to materials derived from them or their influence.

eluviation - the transportation of soil material in suspension or in solution within the soil by the downward or lateral movement of water.

ericaceous - of or relating to the heath family.

euic - a soil term referring to pH >4.5 ($CaCl_2$) in all parts of the control section of an organic soil.

eutrophic - term referring to peatlands that are relatively nutrient-rich; also refers to soils and waters with high nutrient content and high biological activity.

evapotranspiration - the combined loss of water from a given area and during a specific period of time, by evaporation from the soil surface and by transpiration from plants.

exchangeable cation - a cation that is held by the adsorption complex of the soil and is easily exchanged with other cations of neutral salt solutions.

fen - a peat-covered or peat-filled wetland with a high water table that is usually at or above the surface. The waters are mainly nutrient-rich, minerotrophic waters from mineral soils. The dominant peat materials are shallow to deep, well to moderately decomposed fen peat. The associated soils are Mesisols, Humisols, and Organic Cryosols. The vegetation consists dominantly of sedges, grasses, reeds, and brown mosses, with some shrub cover and, at times, a scanty tree layer.

fertility, peat - the status of a soil in relation to the amount and availability to plants of elements necessary for plant growth.

fiber, rubbed or unrubbed - the organic material retained on a 100-mesh sieve (0.15 mm) either with or without rubbing, except for wood fragments that cannot be crushed in the hand and are larger than 2 mm in the smallest dimension. Rubbed fiber refers to materials rubbed between the fingers ten times or processed in a blender.

fibric - organic materials containing large amounts of weakly decomposed fibers whose botanical origins are readily identifiable; fibric material has 40% or more of rubbed fiber by volume (or weight of rubbed fibre retained on a 100 mesh sieve) and is classified in the von Post scale of decomposition as class 1 to class 4.

Fibrisol - see Organic soil.

forb - a herbaceous plant which is not a grass, sedge, or rush.

forest peat - peat materials derived mainly from trees such as black spruce, and from ericaceous shrubs and feathermosses.

Great Group - a category in the Canadian system of soil classification. It is a taxonomic grouping of soils having certain morphological features in common and a similar pedogenic environment.

groundwater - water that is passing through or standing in the soil and the underlying strata in the zone of saturation. It is free to move by gravity.

growing season - period with soil temperatures over 5°C at a depth of 50 cm.

herb - any flowering plant except those developing persistent woody bases and stems above ground.

horizon, soil - a layer of soil or soil material approximately parallel to the land surface; it differs from adjacent genetically related layers in properties such as colour, structure, texture, consistence, and chemical, biological, and mineralogical composition. More detailed descriptions of horizons and layers may be found in Agriculture Canada Expert Committee on Soil Survey (1987).

humic - organic material that is at an advanced stage of decomposition. It has the lowest amount of fiber, the highest bulk density, and the lowest saturated water-holding capacity of the organic materials; it is physically and chemically stable over time, unless it is drained; the rubbed fiber content is <10% by volume and the material usually is classified in the von Post scale of decomposition as class 7 or higher.

humic substances - a general category of naturally occurring, biogenic heterogeneous organic materials that can generally be characterized as being yellow to black in colour, of high molecular weight, and refractory.

humification - the processes by which organic matter decomposes to form humus.

Humisol - see Organic soil.

humus - (1) the high-molecular-weight, polymeric fraction of organic matter that remains after most of the plant and animal residues have decomposed (it is usually dark coloured); (2) humus is also used in a broader sense to designate the humus forms referred to as forest humus; (3) all the dead organic material on and in the soil that undergoes continuous breakdown, change, and synthesis.

hydromorphic - developed under conditions of excess moisture; hydromorphic soils are found in areas of poor drainage.

hydrophyte, hydrophytic - a plant that grows in water, or in wet or saturated soils; water-loving.

infiltration - the downward entry of water into the soil.

lacustrine - originating in, or derived from, a lake.

landforms - the various shapes of the land surface resulting from a variety of actions such as deposition or sedimentation (eskers, lacustrine basins), erosion (gullies, canyons), and earth crust movements (mountains).

leaching - the downward movement within the soil of materials in solution.

lime (in soil) - a soil constituent consisting principally of calcium carbonate, and including magnesium carbonate, and perhaps the oxide and hydroxide of calcium and magnesium.

limnic - peat formation occurring on or in deep water by free-floating or deeply rooted plants.

marsh - a class in the Canadian wetland classification system; a marsh is a mineral or a peat-filled wetland which is periodically inundated by standing or slowly moving water. Surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats. The waters are nutrient-rich. The substratum usually consists dominantly of mineral material, although some marshes are associated with peat deposits. The associated soils are dominantly

Gleysols with some Humisols and Mesisols. Marshes characteristically show a zonal or mosaic surface pattern of vegetation consisting of unconsolidated grass and sedge sods, frequently interspersed with channels or pools of open water. Marshes may be bordered by peripheral bands of trees and shrubs, but the predominant vegetation consists of a variety of emergent non-woody plants such as rushes, reeds, reed-grasses, and sedges. Where open water areas occur, a variety of submerged and floating aquatic plants flourish.

mesic - organic materials at a stage of decomposition between that of fibric and humic materials; peat soil material with >10% and <40% rubbed fibers; mesic material usually is classified in the von Post scale of decomposition as class 5 or 6.

Mesisol - see Organic soil

mesophyte - a plant that grows under intermediate moisture conditions.

mesotrophic - containing a moderate amount of plant nutrients.

microrelief - small-scale, local differences in relief, including mounds, swales, or hollows.

millisiemen (ms) - one one-thousandth of a siemen; a unit of electrical conductance, the reciprocal ohm; the decisiemen, one-hundredth of a siemen, is the preferred term in soil sciences.

minerotrophic - a supply of water to vegetation originally derived from mineral soils or rocks but sometimes via lakes or rivers as intermediates; it may be eutrophic, mesotrophic, or oligotrophic.

mire - (1) an English word which is, in the general sense, a term embracing all kinds of peatlands and peatland vegetation (bog and fen); (2) a section of wet, swampy ground; bog; marsh; wet, slimy soil of some depth; deep mud, etc.

morphology, soil - the physical constitution, particularly the structural properties, of a soil profile as exhibited by the kinds, thickness and arrangement of the horizons in the profile, and by the texture, structure, consistence and porosity of each horizon.

mottling - spotting and blotching of different colour or shades of colour interspersed with the dominant colour.

muck - fairly well decomposed organic soil material relatively high in mineral content, dark in colour, and accumulated under conditions of imperfect drainage.

muskeg - a North American term frequently employed for peatland. The word is of Algonquin Indian origin and is applied in ordinary speech to natural and undisturbed areas covered more or less with *Sphagnum* mosses, tussocky sedges, and an open growth of scrubby trees.

oligotrophic - (1) designation for peatlands that are poor to extremely poor in nutrients and with low biological activity; (2) containing a small amount of plant nutrients; refers to waters low in nutrient loading with low primary production of organic material by algae and/or macrophytes. Growth in an oligotrophic water is often limited by low levels of phosphorus and nitrogen.

ombrotrophic - a supply of nutrients exclusively from rain water (including snow and atmospheric fallout), therefore making nutrition extremely oligotrophic often in an unbalanced way.

order, soil - a category in the Canadian System of Soil Classification. All the soils within an order have one or more characteristics in common.

organic carbon, soil - the percent by weight of carbon in organic forms in soil materials, determined by the difference between total carbon (determined by dry combustion) and inorganic carbon (determined by acid dissolution).

organic matter, soil - the organic fraction of the soil; includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. It is estimated by multiplying the soil organic carbon content by 1.724.

Organic soil - an order of soils in the Canadian System of Soil Classification, that have developed predominantly from organic deposits. The majority of organic soils are saturated for most of the year, unless artificially drained, but some of them are not usually saturated for more than a few days. They contain 17% or more organic carbon, and: (1) if the surface layer consists of fibric organic material and the bulk density is less than 0.1 Mg m^{-3} (with or without a mesic or humic Op less than 15 cm thick), the layer must extend to a depth of at least 60 cm; or (2) if the surface layer consists of organic material with a bulk density of 0.1 Mg m^{-3} or more, the organic material must extend to a depth of at least 40 cm; or (3) if a lithic contact occurs at a depth shallower than stated in (1) or (2) above, the organic material must extend to a depth of at least 10 cm.

Peat soils that have permanently frozen layers are classed as soils of the Cryosolic order in the Canadian System of Soil Classification. Classification of Organic soils is based on a vertical section of the soil called a control section. The control section extends to a depth of 1.60 m or to a lithic or terric contact, and is further subdivided into tiers, or layers, as follows:

Surface tier - the upper 0.40 m of peat.
Middle tier - the tier below the surface tier, having a thickness of 0.80 m or extending to a lithic, terric or hydric contact.
Bottom tier - the tier below the middle tier, having a thickness of 0.40 m or extending to a lithic, terric or hydric contact.

Classification of Organic soils into Great Groups and Subgroups is based on the degree on decomposition of the material in the various tiers. The classes describing materials on the basis of decomposition degree are fibric, mesic and humic (q.v.). The Great Groups within the Organic soil order are described below. Descriptions of the numerous Subgroups can be found in 'The Canadian System of Soil Classification' (Agriculture Canada Expert Committee on Soil Survey 1987; citation in Chapter 2).

Fibrisols - Organic soils with dominantly fibric middle tiers, or middle and surface tiers if a terric, lithic, or hydric contact occurs in the middle tier.

Mesisols - Organic soils with dominantly mesic middle tiers, or middle and surface tiers if a terric, lithic, or hydric contact occurs in the middle tier.

Humisols - Organic soils with dominantly humic middle tiers, or middle and surface tiers if a terric, lithic, or hydric contact occurs in the middle tier.

Folisols - Organic soils with dominantly upland organic (folic) materials of forest origin

parent material - the unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil has developed by pedogenic processes.

particle size distribution - the amounts of the various soil separates (different size ranges of particles) in a soil or peat sample, usually expressed as weight percentages and determined by sedimentation, sieving, micrometry, or combinations of these methods.

peat - material constituting peatlands, exclusive of the live plant cover, consisting largely of organic residues accumulated as a result of incomplete decomposition of dead plant constituents under conditions of excessive moisture (submergence in water and/or waterlogging).

peatland - a generic term including all types of peat-covered terrain.

pedogenic - pertaining to the mode of origin of the soil, especially the processes or soil-forming factors responsible for the development of the solum.

percolation - the downward movement of water through saturated or nearly saturated soil.

permeability, soil - the ease with which gases and liquids penetrate or pass through a bulk mass of, or a layer of soil or peat. Because different soil horizons vary in permeability, the specific horizon should be designated.

pH - the negative logarithm of the hydrogen-ion activity of a solution or of soil or peat. The degree of acidity or alkalinity of a soil or peat sample is determined by means of a glass, quinhydrone, or other suitable electrode or indicator at a specified moisture content or soil-water ratio, and expressed in terms of the pH scale.

porosity, soil - the volume percentage of the total bulk not occupied by solid particles.

profile, soil - a vertical section of the soil through all its horizons and extending into the parent material.

reaction, soil - the degree of acidity or alkalinity of a soil, usually expressed as a pH value. Descriptive terms commonly associated with certain ranges in pH are: extremely acid, less than 4.5; very strongly acid, 4.5 to 5.0; strongly acid, 5.1 to 5.5; moderately acid, 5.6 to 6.0; slightly acid, 6.1 to 6.5; neutral, 6.6 to 7.3; slightly alkaline, 7.4 to 7.8; moderately alkaline, 7.9 to 8.4; strongly alkaline, 8.5 to 9.0; and very strongly alkaline, greater than 9.0.

relief - the difference in elevation between the high and low points of a land surface.

runoff - that part of precipitation that flows towards the stream on the ground surface (surface runoff) or within the soil (subsurface runoff or interflow).

sedge peat - peat composed mostly of the stalks, leaves, rhizomes, and roots of sedges (*Carex* spp.).

sedimentary peat - a material composed of plant debris and faecal pellets less than a few tenths of a millimetre in diameter and having brown or gray-brown colours when dry. It has slightly viscous water suspensions, is slightly plastic but not sticky, and shrinks upon drying to form clods that are difficult to rewet. It has few or no plant fragments recognizable to the naked eye.

shallow water - a class in the Canadian wetland classification system; semipermanent to permanent standing or flowing water with relatively large and stable expanses of open water, which are locally known as ponds, pools, sloughs, shallow lakes, bays, lagoons, oxbows, impoundments, reaches, or channels. Shallow waters are distinguished from deep waters by the upper 2 m limit, although depths may occasionally exceed this during periods of abnormal flooding. During droughts, low water, or intertidal periods, drawdown flats may be temporarily exposed. Included in this class are all basins in which summer open water zones exceed 8 ha in size, regardless of the extent of bordering wetlands. These shallow water units are delineated from wetland complexes by the outer border of floating vegetation mats or by midsummer surface water levels, usually expressed by peripheral deep marsh emergents or shrubs. All other wetland basins less than 8 ha in area, with summer open water zones occupying 75% or more of the basin diameter, are classed as shallow water. The margins may be unvegetated, or may have rooted emergent vegetation including trees if confined to a narrow margin occupying no more than 25% of the basin diameter. Vegetation, if present in the open water zone, consists only of submerged and floating aquatic plant forms.

shrub - a woody perennial plant differing from a tree by its low stature and by generally producing several basal shoots instead of a single trunk.

silvic - pertaining to organic soils developed in forest peat; used in describing organic soil families.

solum - upper horizons of a soil in which parent material has been modified and in which most plant roots are contained; usually consists of the A and B horizons.

solution, soil - the aqueous liquid phase of the soil and its solutes consisting of ions dissociated from the surfaces of the soil particles and of other soluble materials.

sphagnic - pertaining to Organic soils developed in peat derived mainly from Sphagnum spp.; used in describing organic soil families.

Sphagnum peat - peat consisting mainly of *Sphagnum* spp.; usually poorly decomposed and raw; may also contain *Eriophorum* spp., *Carex* spp., and ericaceous species.

stratigraphy, peat - a vertical sequence of layers of different materials within a peat deposit. Differences may be due to floristic composition, state of decomposition, or incidence of extraneous materials.

Subgroup, soil - a category in the Canadian System of Soil Classification. It is a subdivision of the Great Group, and therefore is defined more specifically.

subsidence - lowering in elevation of a considerable area of a peatland surface due to loss of organic matter by biological oxidation, compaction and, shrinkage due to water removal.

swamp - a peat-filled area or a mineral wetland with standing or gently flowing waters occurring in pools and channels. The water table is usually at or near the surface. There is strong water movement from margin or other sources, hence the waters are nutrient-rich. If peat is present, it is mainly well decomposed forest peat underlain at times by fen peat. The associated soils are Mesisols, Humisols, and Gleysols. The vegetation is characterized by a dense cover of coniferous or deciduous trees, tall shrubs, herbs, and some mosses.

terric - unconsolidated mineral soil.

terric layer - an unconsolidated mineral substratum underlying organic soil material.

texture, soil - the relative proportions of the soil separates (sand, silt, and clay) in a soil.

topography - the surface features of a region, especially the relief and contours of the land.

topsoil (or surface soil) - the uppermost part of the soil that is ordinarily moved in tillage, or its equivalent in uncultivated soils. It ranges in depth from 7.5 to 25 cm and is frequently designated as the plow layer, or the Ap layer or horizon, where Ap refers to a soil horizon disturbed by cultivation.

trace element - chemical element present in a minor amount in water or soil.

transpiration - process by which water from vegetation is transferred into the atmosphere in the form of vapour.

trophic level - the relative nutritional position of organisms or populations within a food web; for example, all organisms that feed on algae are at the same trophic level.

trophic status - nutrient status; availability of nutrients to plants. See oligotrophic, mesotrophic, and eutrophic.

unsaturated zone - the zone above the water table in an aquifer; the vadose zone.

von Post humification scale - scale describing peat moss in varying stages of decomposition ranging from H1, which is completely unconverted, to H10, which is completely converted (Table 3.5).

water capacity - the percentage of water remaining in organic soil material (peat) after having been saturated and after drainage of free water has practically ceased.

water content - volume of water per unit volume of peat. Maximum content is reached when all pore spaces are filled with water and peat is saturated.

water table - the upper surface of groundwater or that level below which the soil is saturated with water.

waterlogged - saturated with water.

wetland - land having the water table at, near, or above the land surface or which is saturated for long enough periods to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment. Wetlands include peatlands and areas that are influenced by excess water but which, for climatic, edaphic or biotic reasons, produce little or no peat. Shallow open water, generally less than 2 m deep, is also included in wetlands.

Table 3.5. The von Post scale of decomposition for peats.[1]

Decomposition Degree, H	Nature of Squeezed Water	Amount of Peat Extruded Between Fingers	Nature of Residue After Squeezing
1	clear, colourless	none	unaltered, fibrous
2	clear, yellow brown	none	almost unaltered
3	turbid, slight brown	none	slightly altered, plant remains distinct
4	turbid, brown	almost none	somewhat mushy, plant remains easily identifiable
5	very turbid, dark	very little	very mushy, plant remains difficult to identify
6	muddy, dark	about 1/3	strongly mushy, plant remains indistinct, scarcely identifiable
7	very muddy, dark	about 1/2	very soupy, plant remains scarcely identifiable
8	little free water, very dark and muddy	about 2/3	very soupy, very few identifiable plant remains
9	no free water	almost all	homogeneous, little or no plant remains
10	no free water	all	completely amorphous, no plant remains

[1] Adapted from Agriculture Canada Expert Committee on Soil Survey (1987), Crum (1988) and Puustjarvi (1977).

5. PEATLAND INVENTORY REQUIREMENTS FOR SURFACE MATERIAL LEASE (SML) APPLICATIONS

(REVISED March 2, 1993)

(These requirements are reproduced from documentation developed by the Industrial Land Management Section, Public Lands Division, Department of Agriculture and Rural Development (Tedder 1993). These requirements were undergoing revision during the time of completion of this report. Moreover, jurisdiction over peatland development applications may change with reorganization in government departments during the time of completion of this report.)

Soil and terrain inventory data is essential information for public land managers in evaluating peatland development proposals. Public land managers have the responsibility to obtain sufficient information concerning the resource and development proposal to identify potential environmental concerns, make informed land use decisions on land use allocation, and specify operational and reclamation requirements.

Information requirements include the type and quantity of peat, the composition of the underlying mineral soil, and topography of the original and final landscape.

These inventory requirements are in addition to any other information required by the department to evaluate a lease application. <u>Any changes in inventory requirements, in particular as they apply to small operations, are to have prior approval from the land management agency.</u>

Section A outlines the minimum information requirements for large commercial operations while Section B covers small operations. Small operations are defined as those having less than 40 acres of peatland disturbance.

A. INFORMATION REQUIREMENTS FOR LARGE OPERATIONS (> 40 ACRES)

1. Elevation Survey

Essential for planning initial drainage. Contour intervals of 05. m with an accuracy of plus or minus 0.1 m are generally sufficient. Elevations can be determined using a level and stadia rod. Hand clearing of sight lines may be necessary in heavy bush. A 100 metre line spacing is recommended for the survey.

2. Site Data for the Peat and Mineral Soil

Using an auger or corer, examine representative peat profiles at a minimum 15 sites per quarter section (approximately one inspection per 10 acres of peatland). Inventory all peatland within the lease area that will be affected by drainage or disturbance. Select data sites to ensure the full range of peatland types present are inventoried.

Peat profile sampling along the elevation survey lines is suggested after the elevation survey is completed to assist in site location accuracy. Sample the underlying mineral soil (below the muck layer) to a minimum depth of 10 cm.

The following information will help determine development areas, final land use options and reclamation requirements.

a) For each inspection site record the following data:
   i) vegetative cover (see Section 3)
   ii) total thickness of peat
   iii) thickness of each peat type in the soil profile
   iv) for each peat layer in the profile, identify:
      - the dominant botanical composition (e.g. sphagnum moss, sedge, reed, wood, sedimentary, or combinations thereof).
      - the state of decomposition (von Post scale)
   v) thickness of any marl, wood, mineral

or muck layers

b) For 4 of the 15 sites per quarter section record the following in addition to the requirements in a):
   i) pH of all major peat layers
   ii) pH of surface water
   iii) texture of the underlying mineral soil (using the Canadian system of Soil Classification categories). Hand texturing in the field is acceptable.
   iv) per cent stoniness for gravel size stones and larger.
   v) color of the mineral soil (use a Munsell colour chart).

The use of litmus paper for pH measurement is acceptable.

3. Vegetative Cover

For each inspection site:

a) describe the dominant tree or shrub species and ground cover vegetation to characterize the site in general (e.g. stunted black spruce/moss, willow/sedge, sedge, tamarack/sedge, moss/Labrador tea, etc.).

b) identify any rare or unusual plant species.

4. Mapping of Data

a) Plot the data on a 1:5 000 (1 inch to 420 foot) map (preferably an airphoto mosaic) to show:
   i) legal description (Township, Range, Meridian, Section, Quarter section boundaries)
   ii) peatland deposit boundary
   iii) lease area
   iv) location of data sites
   v) topography of peat surface (0.5 metre contours, or 0.1 metres on nearly level peatlands)
   vi) elevation of mineral soil surface (0.5 m contours)
   vii) isopach map of peat thickness
   viii) extent of mineable peat reserves
   ix) topography of reclaimed surface (0.5 m contours)
   x) location of road allowances
   xi) location of survey pins

b) Include on the map the location of existing and proposed developments such as:
   i) main ditches and field ditches with direction of flow
   ii) drainage outlets
   iii) access roads
   iv) peat storage sites
   v) plant site
   vi) sedimentation ponds
   vii) fuel tank site
   viii) areas of non-development (a 40 metre buffer zone of non-development is generally required around the perimeter of the lease).

5. Cross-Sections

Provide a sufficient number of cross-sections of the peatland profile at a scale of 1:5 000 to adequately show topographic, peat profile and mineral surface variations along the long axis and short axis of each deposit. On the cross-sections, also include soil profile variations and identify peat horizons to be harvested.

B. Inventory Requirements for Small Operations (Less than 40 acres)

For operations that will disturb or drain less than 40 acres of peatland, the following information requirements can be used as a guide. Small operations may not be required to supply all of the following data, as it will depend on the site characteristics. Additional or reduced inventory requirements may be approved on a site specific basis by the land management agency.

a) Elevation Survey - not required if the surface slope and drainage direction are obvious.

b) Site Data - see Section 2

d) Vegetative Cover - see Section 3

e) Mapping of data - on a 1:5 000 (1 inch = 420 feet) or larger scale map, plot:

   i) legal description
   ii) peatland boundary
   iii) data site locations

iv) proposed drainage ditches and outlets
v) access roads
vi) peat storage locations
vii) plant site
viii) fuel tank site
ix) buffer zone of no clearing or drainage

f) Cross Sections - see Section 5

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RECLAMATION RESEARCH REPORTS

1. **RRTAC 79-2: Proceedings: Workshop on Native Shrubs in Reclamation. P.F. Ziemkiewicz, C.A. Dermott and H.P. Sims (Editors). 104 pp. No longer available.**

The Workshop was organized as the first step in developing a Native Shrub reclamation research program. The Workshop provided a forum for the exchange of information and experiences on three topics: propagation; outplanting; and, species selection.

2. **RRTAC 80-1: Test Plot Establishment: Native Grasses for Reclamation. R.S. Sadasivaiah and J. Weijer. 19 pp. No longer available.**

The report details the species used at three test plots in Alberta's Eastern Slopes. Site preparation, experimental design, and planting method are also described.

3. **RRTAC 80-2: Alberta's Reclamation Research Program - 1979. Reclamation Research Technical Advisory Committee. 22 pp. No longer available.**

This report describes the expenditure of $1,190,006 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.

4. **RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites. N.S.C. Cameron et al. 46 pp. No longer available.**

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

5. **RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. P.F. Ziemkiewicz, S.K. Takyi and H.F. Regier (Editors). 160 pp. $10.00**

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.

6. **RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta. L.E. Watson, R.W. Parker and D.F. Polster. 2 vols, 541 pp. No longer available; replaced by RRTAC 89-4.**

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

7. **RRTAC 81-1: The Alberta Government's Reclamation Research Program - 1980. Reclamation Research Technical Advisory Committee. 25 pp. No longer available.**

This report describes the expenditure of $1,455,680 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.

8. **RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta. D.G. Walker and R.L. Rothwell. 76 pp. $10.00**

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.

9. **RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation. P.F. Ziemkiewicz, R. Stein, R. Leitch and G. Lutwick (Editors). 253 pp. $10.00**

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.

10. **RRTAC 82-1: Land Surface Reclamation: An International Bibliography. H.P. Sims and C.B. Powter. 2 vols, 292 pp. $10.00**

Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system (in a SPIRES database called RECLAIM). Vol. 2 comprises the keyword index and computer access manual.

11. **RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. C.B. Powter and H.P. Sims. 97 pp. $5.00**

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 in the Alberta Environment Library.

12. **RRTAC 82-3: The Alberta Government's Reclamation Research Program - 1981. Reclamation Research Technical Advisory Committee. 22 pp. No longer available.**

This report describes the expenditure of $1,499,525 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.

13. **RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings. Monenco Consultants Ltd. 185 pp. No longer available**

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 (See RRTAC 92-4).

14. **RRTAC 83-2: The Alberta Government's Reclamation Research Program - 1982. Reclamation Research Technical Advisory Committee. 25 pp. No longer available.**

This report describes the expenditure of $1,536,142 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.

15. **RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta. Hardy Associates (1978) Ltd. 205 pp. No longer available.**

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.

16. **RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology. P.F. Ziemkiewicz (Editor). 123 pp. $10.00**

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.

17. **RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation. Techman Engineering Ltd. 124 pp. No longer available.**

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

18. **RRTAC 84-1: Land Surface Reclamation: A Review of the International Literature. H.P. Sims, C.B. Powter and J.A. Campbell. 2 vols, 1549 pp. $20.00**

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

19. **RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation. Techman Engineering Ltd. 58 pp. $10.00**

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.

20. **RRTAC 84-3: Reclamation Research Annual Report - 1983. P.F. Ziemkiewicz. 42 pp. $5.00**

This report describes the expenditure of $1,529,483 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.

21. **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. $10.00**

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

22. **RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills. P.F. Ziemkiewicz (Editor). 416 pp. $10.00.**

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

23. **RRTAC 85-2: Reclamation Research Annual Report - 1984. P.F. Ziemkiewicz. 29 pp. No longer available.**

This report describes the expenditure of $1,320,516 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.

24. **RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies. A. Somani. 372 pp. $10.00**

The report examines the critical issue of settling pond design, and sizing and alternative technologies. The study was co-funded with The Coal Association of Canada.

25. **RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta. T.M. Macyk. 146 pp. No longer available.**

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.

26. **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. $5.00**

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.

27. **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. $10.00**

This report summarizes 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.

28. **RRTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 71 pp. $10.00**

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.

29. **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. $5.00**

The report deals with 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 in the Battle River Mining area in east-central Alberta.

30. **RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project. M.R. Trudell. 25 pp. $5.00**

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.

31. **RRTAC 86-8: Reclamation Research Annual Report - 1985. P.F. Ziemkiewicz. 54 pp. $5.00**

This report describes the expenditure of $1,168,436 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.

32. **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. No longer available.**

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. The study was co-funded with The Coal Association of Canada.

33. **RRTAC 87-1: Disposal of Drilling Wastes. L.A. Leskiw, E. Reinl-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp. No longer available.**

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 provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

34. **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. No longer available.**

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. The study was co-funded with The Coal Association of Canada.

35. **RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings. D.A. Lloyd (Compiler). 218 pp. No longer available.**

Technical papers were presented which describe: 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.

36. **RRTAC 87-4: Reclamation Research Annual Report - 1986. 50 pp. No longer available.**

This report describes the expenditure of $1,186,000 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.

37. **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. $10.00**

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. The study was co-funded with The Coal Association of Canada.

38. **RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes. Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp. $10.00**

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. The study was co-funded with The Coal Association of Canada.

39. **RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil. S. Fullerton. 83 pp. No longer available.**

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 a 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.

40. **RRTAC 87-8: Waste Dump Design for Erosion Control. R.G. Chopiuk and S.E. Thornton. 45 pp. $5.00**

This report describes a study to evaluate the potential 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.

41. **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. No longer available.**

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.

42. **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 8 maps. $10.00**

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. Eight maps supplement the report.

43. **RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project.**
A. Maslowski-Schutze. 78 pp. $10.00

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.

44. **RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site. M.R. Trudell and R. Faught. 83 pp. No longer available.**

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.

45. **RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils. T.M. Macyk. 27 pp. $5.00**

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.

46. **RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook. T.R. Eccles, R.E. Salter and J.E. Green. 101 pp. plus appendix. $10.00**

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. The study was co-funded with The Coal Association of Canada.

47. **RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and its Impacts on Surface Water. M.R. Trudell (Compiler). 135 pp. No longer available.**

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.

48. **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. $10.00**

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 Canada Limited oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their un-inoculated counterparts.

49. **RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill. D.R. Pauls (compiler). 135 pp. $10.00**

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 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.

50. **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.M. Danielson and S. Visser. 177 pp. No longer available.**

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.

51. **RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee. 67 pp. No longer available.**

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.

52. **RRTAC 88-7: Baseline Growth Performance Levels and Assessment Procedure for Commercial Tree Species in Alberta's Mountains and Foothills. W.R. Dempster and Associates Ltd. 66 pp. $5.00**

Data on juvenile height development of lodgepole pine and white spruce from cut-over or burned sites in the Eastern Slopes of Alberta were used to define reasonable expectations of early growth performance 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 performance against these expectations. The study was co-funded with The Coal Association of Canada.

53. **RRTAC 88-8: Alberta Forest Service Watershed Management Field and Laboratory Methods. A.M.K. Nip and R.A. Hursey. 4 Sections, various pagings. $10.00**

Disturbances such as coal mines in the Eastern Slopes of Alberta have the potential for affecting watershed quality during and following mining. The collection of hydrometric, water quality and hydrometeorologic information is a complex task. A variety of instruments and measurement methods are required to produce a record of hydrologic inputs and outputs for a watershed basin. There is a growing awareness and recognition that standardization of data acquisition methods is required to ensure data comparability, and to allow comparison of data analyses. The purpose of this manual is to assist those involved in the field of data acquisition by outlining methods, practices and instruments which are reliable and recognized by the International Organization for Standardization.

54. **RRTAC 88-9: Computer Analysis of the Factors Influencing Groundwater Flow and Mass Transport in a System Disturbed by Strip Mining. F.W. Schwartz and A.S. Crowe. 78 pp. No longer available.**

Work presented in this report demonstrates how a groundwater flow model can be used to study a variety of mining-related problems such as declining water levels in areas around the mine as a result of dewatering, and the development of high water tables in spoil once resaturation is complete. This report investigates the role of various hydrogeological parameters that influence the magnitude, timing, and extent of water level changes during and following mining at the regional scale. The modelling approach described here represents a major advance on existing work.

55. **RRTAC 88-10: Review of Literature Related to Clay Liners for Sump Disposal of Drilling Wastes. D.R. Pauls, S.R. Moran and T. Macyk. 61 pp. No longer available.**

The report reviews and analyses the effectiveness of geological containment of drilling waste in sumps. Of particular importance was the determination of changes in properties of clay materials as a result of contact with highly saline brines containing various organic chemicals.

56. **RRTAC 88-11: Highvale Soil Reconstruction Project: Five Year Summary. D.N. Graveland, T.A. Oddie, A.E. Osborne and L.A. Panek. 104 pp. $10.00**

This report provides details of a five year study to determine a suitable thickness of subsoil to replace over minespoil in the Highvale plains coal mine area to ensure return of agricultural capability. The study also examined the effect of slope and aspect on agricultural capability. This study was funded and managed with industry assistance.

57. **RRTAC 88-12: A Review of the International Literature on Mine Spoil Subsidence. J.D. Scott, G. Zinter, D.R. Pauls and M.B. Dusseault. 36 pp. $10.00**

The report reviews available engineering literature relative to subsidence of reclaimed mine spoil. The report covers methods for site investigation, field monitoring programs and lab programs, mechanisms of settlement, and remedial measures.

58. **RRTAC 89-1: Reclamation Research Annual Report - 1988. 74 pp. $5.00**

This annual report describes the expenditure of $280,000.00 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.

59. **RRTAC 89-2: Proceedings of the Conference: Reclamation, A Global Perspective. D.G. Walker, C.B. Powter and M.W. Pole (Compilers). 2 Vols., 854 pp. No longer available.**

Over 250 delegates from all over the world attended this conference held in Calgary in August, 1989. The proceedings contains over 85 peer-reviewed papers under the following headings: A Global Perspective; Northern and High Altitude Reclamation; Fish & Wildlife and Rangeland Reclamation; Water; Herbaceous Revegetation; Woody Plant Revegetation and Succession; Industrial and Urban Sites; Problems and Solutions; Sodic and Saline Materials; Soils and Overburden; Acid Generating Materials; and, Mine Tailings.

60. **RRTAC 89-3: Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil. M.P. Sharma. 38 pp. ISBN 0-7732-0878-X. $5.00**

Bromacil and Tebuthiuron were commonly used soil sterilants on well sites, battery sites and other industrial sites in Alberta where total vegetation control was desired. Activated charcoal was found to be effective in binding the sterilants in greenhouse trials. The influence of factors such as herbicide:charcoal concentration ratio, soil texture, organic matter content, soil moisture, and the time interval between charcoal incorporation and plant establishment were evaluated in the greenhouse.

61. **RRTAC 89-4: Manual of Plant Species Suitability for Reclamation in Alberta - 2nd Edition. Hardy BBT Limited. 436 pp. ISBN 0-7732-0882-8. $10.00.**

This is an updated version of RRTAC Report 80-5 which describes the characteristics of 43 grass, 14 forb and 34 shrub and tree species which make them suitable for reclamation in Alberta. The report has been updated in several important ways: a line drawing of each species has been added; the range maps for each species have been redrawn based on an ecosystem classification of the province; new information (to 1990) has been added, particularly in the sections on reclamation use; and the material has been reorganized to facilitate information retrieval. Of greatest interest is the performance chart that precedes each species and the combined performance charts for the grass, forb, and shrub/tree groups. These allow the reader to pick out at a glance species that may suit their particular needs. The report was produced with the assistance of a grant from the Recreation, Parks and Wildlife Foundation.

62. **RRTAC 89-5: Battle River Soil Reconstruction Project Five Year Summary. L.A. Leskiw. 188 pp. No longer available.**

This report summarizes the results of a five year study to investigate methods required to return capability to land surface mined for coal in the Battle River area of central Alberta. Studies were conducted on: the amounts of subsoil required, the potential of gypsum and bottom ash to amend adverse soil properties, and the effects of slope angle and aspect. Forage and cereal crop growth was evaluated, as were changes in soil chemistry, density and moisture holding characteristics.

63. **RRTAC 89-6: Detailed Sampling, Characterization and Greenhouse Pot Trials Relative to Drilling Wastes in Alberta. T.M. Macyk, F.I. Nikiforuk, S.A. Abboud and Z.W. Widtman. 228 pp. No longer available.**

This report summarizes a three-year study of the chemistry of freshwater gel, KCl, NaCl, DAP, and invert drilling wastes, both solids and liquids, from three regions in Alberta: Cold Lake, Eastern Slopes, and Peace River/Grande Prairie. A greenhouse study also examined the effects of adding various amounts of waste to soil on grass growth and soil chemistry. Methods for sampling drilling wastes are recommended.

64. **RRTAC 89-7: A User's Guide for the Prediction of Post-Mining Groundwater Chemistry from Overburden Characteristics. M.R. Trudell and D.C. Cheel. 55 pp. $5.00**

This report provides the detailed procedure and methodology that is required to produce a prediction of post-mining groundwater chemistry for plains coal mines, based on the soluble salt characteristics of overburden materials. The fundamental component of the prediction procedure is the geochemical model PHREEQE, developed by the U.S. Geological Survey, which is in the public domain and has been adapted for use on personal computers.

65. **RRTAC 90-1: Reclamation Research Annual Report - 1989. 62 pp. No longer available.**

This annual report describes the expenditure of $480,000.00 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.

66. **RRTAC 90-2: Initial Selection for Salt Tolerance in Rocky Mountain Accessions of Slender Wheatgrass and Alpine Bluegrass. R. Hermesh, J. Woosaree, B.A. Darroch, S.N. Acharya and A. Smreciu. 40 pp. $5.00**

Selected lines of slender wheatgrass and alpine bluegrass collected from alpine and subalpine regions of Alberta as part of another native grass project were evaluated for their ability to emerge in a saline medium. Eleven slender wheatgrass and 72 alpine bluegrass lines had a higher percentage emergence than the Orbit Tall Wheatgrass control (a commonly available commercial grass). This means that as well as an ability to grow in high elevation areas, these lines may also be suitable for use in areas where saline soil conditions are present. Thus, their usefulness for reclamation has expanded.

67. **RRTAC 90-3: Natural Plant Invasion into Reclaimed Oil Sands Mine Sites. Hardy BBT Limited. 65 pp. $5.00**

Vegetation data from reclaimed sites on the Syncrude and Suncor oil sands mines have been summarized and related to site and factors and reclamation methods. Natural invasion into sites seeded to agronomic grasses and legumes was minimal even after 15 years. Invasion was slightly greater in sites seeded to native species, but was greatest on sites that were not seeded. Invasion was mostly from agronomic species and native forbs; native shrub and tree invasion was minimal.

68. **RRTAC 90-4: Physical and Hydrological Characteristics of Ponds in Reclaimed Upland Landscape Settings and their Impact on Agricultural Capability. S.R. Moran, T.M. Macyk, M.R. Trudell and M.E. Pigot, Alberta Research Council. 76 pp. $5.00**

The report details the results and conclusions from studying a pond in a reclaimed upland site in Vesta Mine. The pond formed as a result of two factors: (1) a berm which channelled meltwater into a series of subsidence depressions, forming a closed basin; and (2) low hydraulic conductivity in the lower subsoil and upper spoil as a result of compaction during placement and grading which did not allow for rapid drainage of ponded water. Ponds such as this in the reclaimed landscape can affect agricultural capability by: (1) reducing the amount of farmable land (however, the area covered by these ponds in this region is less than half of that found in unmined areas); and, (2) creating the conditions necessary for the progressive development of saline and potentially sodic soils in the area adjacent to the pond.

69. **RRTAC 90-5: Review of the Effects of Storage on Topsoil Quality. Thurber Consultants Ltd., Land Resources Network Ltd., and Norwest Soil Research Ltd. 116 pp. $10.00**

The international literature was reviewed to determine the potential effects of storage on topsoil quality. Conclusions from the review indicated that storage does not appear to have any severe and longterm effects on topsoil quality. Chemical changes may be rectified with the use of fertilizers or manure. Physical changes appear to be potentially less serious than changes in soil quality associated with the stripping and respreading operations. Soil biotic populations appear to revert to pre-disturbance levels of activity within acceptable timeframes. Broad, shallow storage piles that are seeded to acceptable grass and legume species are recommended; agrochemical use should be carefully controlled to ensure soil biota are not destroyed.

70. **RRTAC 90-6: Proceedings of the Industry/Government Three-Lift Soils Handling Workshop. Deloitte & Touche. 168 pp. $10.00**

This report documents the results of a two-day workshop on the issue of three-lift soils handling for pipelines. The workshop was organized and funded by RRTAC, the Canadian Petroleum Association and the Independent Petroleum Association of Canada. Day one focused on presentation of government and industry views on the criteria for three-lift, the rationale and field data in support of three- and two-lift procedures, and an examination of the various soil handling methods in use. During day two, five working groups discussed four issues: alternatives to three-lift; interim criteria and suggested revisions; research needs; definitions of terms. The results of the workshop are being used by a government/industry committee to revise soils handling criteria for pipelines.

71. **RRTAC 90-7: Reclamation of Disturbed Alpine Lands: A Literature Review. Hardy BBT Limited. 209 pp. $10.00**

This review covers current information from North American sources on measures needed to reclaim alpine disturbances. The review provides information on pertinent Acts and regulations with respect to development and environmental protection of alpine areas. It also discusses: alpine environmental conditions; current disturbances to alpine areas; reclamation planning; site and surface preparation; revegetation; and, fertilization. The report also provides a list of research and information needs for alpine reclamation in Alberta.

72. **RRTAC 90-8: Plains Hydrology and Reclamation Project: Summary Report. S.R. Moran, M.R. Trudell, T.M. Macyk and D.B. Cheel. 105 pp. $10.00**

This report summarizes a 10-year study on the interactions of groundwater, soils and geology as they affect successful reclamation of surface coal mines in the plains of Alberta. The report covers: Characterization of the Battle River and Wabamun study areas; Properties of reclaimed materials and landscapes; Impacts of mining and reclamation on post-mining land use; and, Implications for reclamation practice and regulation. This project has led to the publication of 18 RRTAC reports and 22 papers in conference proceedings and referred journals.

73. **RRTAC 90-9: Literature Review on the Disposal of Drilling Waste Solids. Monenco Consultants Limited. 83 pp. $5.00**

This report reviews the literature on, and government and industry experience with, burial of drilling waste solids in an Alberta context. The review covers current regulations in Alberta, other provinces, various states in the US and other countries. Definitions of various types of burial are provided, as well as brief summaries of other possible disposal methods. Environmental concerns with the various options are presented as well as limited information on costs and monitoring of burial sites. The main conclusion of the work is that burial is still a viable option for some waste types but that each site and waste type must be evaluated on its own merits.

74. **RRTAC 90-10: Potential Contamination of Shallow Aquifers by Surface Mining of Coal. M.R. Trudell, S.R. Moran and T.M. Macyk. 75 pp. $5.00**

This report presents the results of a field investigation of the movement of salinized groundwater from a mined and reclaimed coal mine near Forestburg into an adjacent unmined area. The movement is considered to be an unusual occurrence resulting from a combination of a hydraulic head that is higher in the mined area than in the adjacent coal aquifer, and the presence of a thin surficial sand aquifer adjacent to the mine. The high hydraulic head results from deep ponds in the reclaimed landscape that recharge the base of the spoil.

75. **RRTAC 91-1: Reclamation Research Annual Report - 1990. Reclamation Research Technical Advisory Committee. 69 pp. No longer available.**

This annual report describes the expenditure of $499 612 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 lists the 70 research reports published under the program.

76. **RRTAC 91-2: Winter Soil Evaluation and Mapping for Regulated Pipelines. A.G. Twardy. 43 pp. ISBN 0-7732-0874-7. $5.00**

Where possible, summer soil evaluations are preferred for pipelines. However, when winter soil evaluations must be done, this report lays out the constraints and requirements for obtaining the best possible information. Specific recommendations include: restricting evaluations to the time of day with the best light conditions; use of core- or auger-equipped drill-trucks; increased frequency of site inspections and soil analyses; and, hiring a well-qualified pedologist. The province's soils are divided into four classes, based on their difficulty of evaluation in winter: slight (most soils); moderate; high; and, severe (salt-affected soils in the Brown and Dark Brown Soil Zones).

77. **RRTAC 91-3: A User Guide to Pit and Quarry Reclamation in Alberta. J.E. Green, T.D. Van Egmond, C. Wylie, I. Jones, L. Knapik and L.R. Paterson. 151 pp. ISBN 0-7732-0876-3. $10.00**

Sand and gravel pits or quarries are usually reclaimed to the original land use, especially if that was better quality agricultural or forested land. However, there are times when alternative land uses are possible. This report outlines some of the alternate land uses for reclaimed sand and gravel pits or quarries, including: agriculture, forestry, wildlife habitat, fish habitat, recreation, and residential and industrial use. The report provides a general introduction to the industry and to the reclamation process, and then outlines some of the factors to consider in selecting a land use and the methods for reclamation. The report is not a detailed guide to reclamation; it is intended to help an operator determine if a land use would be suitable and to guide him or her to other sources of information.

78. **RRTAC 91-4: Soil Physical Properties in Reclamation. M.A. Naeth, D.J. White, D.S. Chanasyk, T.M. Macyk, C.B. Powter and D.J. Thacker. 204 pp. ISBN 0-7732-0880-1. $10.00**

This report provides information from the literature and Alberta sources on a variety of soil physical properties that can be measured on reclaimed sites. Each property is explained, measurement methods, problems, level of accuracy and common soil values are presented, and methods of dealing with the property (prevention, alleviation) are discussed. The report also contains the results of a workshop held to discuss soil physical properties and the state-of-the-art in Alberta.

79. **RRTAC 92-1: Reclamation of Sterilant Affected Sites: A Review of the Issue in Alberta. M. Cotton and M.P. Sharma. 64 pp. ISBN 0-7732-0884-4. No longer available**

This report assesses the extent of sterilant use on oil and gas leases in Alberta, identifies some of the concerns related to reclamation of sterilant affected sites and the common methods for reclaiming these sites, and outlines the methods for sampling and analyzing soils from sterilant affected sites. The report also provides an outline of a research program to address issues raised by government and industry staff.

80. **RRTAC 92-2: Reclamation Research Annual Report - 1991. Reclamation Research Technical Advisory Committee. 55 pp. ISBN 0-7732-0888-7. No longer available.**

This report describes the expenditure of $485,065 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the five program areas, and describes the projects funded under each program. It also lists the 75 research reports that have been published to date.

81. **RRTAC 92-3: Proceedings of the Industry/Government Pipeline Reclamation Success Measurement Workshop. R.J. Mahnic and J.A. Toogood. 62 pp. ISBN 0-7732-0886-0. $5.00.**

This report presents the results of a workshop to identify the soil and vegetation parameters that should be used to assess reclamation success on pipelines in Alberta. Six soil parameters (topsoil admixing; topsoil replacement thickness; compaction; soil loss by erosion; texture; and salinity) and six vegetation parameters (plant density; species composition; ground cover; vigour; weeds/undesirable species; and rooting characteristics) were selected as most important. Working groups discussed these parameters and presented suggested methods for assessing them in the field.

82. **RRTAC 92-4: Oil Sands Soil Reconstruction Project Five Year Summary. HBT AGRA Limited. 109 pp. ISBN 0-7732-0875-5. $10.00**

This report documents a five year study of the effects of clay and peat amendments to oil sand tailings sand on survival and growth of trees and shrubs. Ten species (jack pine, white spruce, serviceberry, silverberry, buffaloberry, pin cherry, prickly/woods rose, Northwest poplar, green alder, and Bebb willow) were planted into tailings sand amended with three levels of peat and three levels of clay. The treatments were incorporated to a depth of 20 cm or 40 cm. Data are provided on plant survival and growth, root size and distribution, disease and small mammal damage, herbaceous cover, soil moisture, soil chemistry, and bulk density.

83. **RRTAC 92-5: A Computer Program to Simulate Groundwater Flow and Contaminant Transport in the Vicinity of Active and Reclaimed Strip Mines: A User's Guide. A.S. Crowe and F.W. Schwartz, SIMCO Groundwater Research Ltd. 104 pp. plus appendix. ISBN 0-7732-0877-1. NOTE: This report is only available from the Alberta Research Council, Publications Centre, 250 Karl Clark Road, P.O. Box 8330, Station F, EDMONTON, Alberta T6H 5R7 as ARC Information Series 119. The cost is $20.00 and the cheque must be made out to the Alberta Research Council.**

The manual describes a computer program that was developed to study the influence of coal strip mining on groundwater flow systems and to simulate the transport of generated contaminants, both spatially and in time, in the vicinity of a mine. All three phases of a strip mine can be simulated: the pre-mining regional groundwater flow system; the mining and reclamation phase; and, the post-mining water level readjustment phase. The model is sufficiently general to enable the user to specify virtually any type of geological conditions, mining scenario, and boundary conditions.

84. **RRTAC 92-6: Alberta Drilling Waste Sump Chemistry Study. Volume I: Report (Volume II: Appendices is only available through the Alberta Research Council, Publications Centre, 250 Karl Clark Road, P.O. Box 8330, Station F, EDMONTON, Alberta T6H 5R7. The cost is $15.00 and the cheque must be made out to the Alberta Research Council.). T.M. Macyk, S.A. Abboud and F.I. Nikiforuk, Alberta Research Council. 217 pp. ISBN 0-7732-0879-8. $10.00.**

This study synthesizes the data from sampling and analysis of the solids and liquids found in 128 drilling waste sumps across Alberta. Drilling waste types sampled included: 72 freshwater gel, 19 invert, 27 KCl, 2 NaCl, and 8 others. Data and statistics are tabulated by waste type, depth of the drill hole, and ERCB administrative region for both the solids and the liquids. Using preliminary loading limits developed by the government/industry Drilling Waste Review Committee, the report presents information on the volume and depth of waste that could be landspread, and the area required for landspreading. The oil and gas industry provided approximately $585,000 for the sampling and analysis phase of this study.

85. **RRTAC 93-1: Reclamation of Native Grasslands in Alberta: A Review of the Literature. D.S. Kerr, L.J. Morrison and K.E. Wilkinson, Environmental Management Associates. 205 pp. plus appendices. ISBN 0-7732-0881-X. $10.00.**

A review of the literature on native grassland reclamation was conducted to summarize the current state of knowledge on reclamation and restoration efforts within Alberta. The review is comprehensive, including an overview of the regulations and guidelines governing land use on native prairie; a description of the dominant grassland ecoregions in Alberta; a review of the common disturbance types, extent and biophysical effects of disturbance on native prairie within Alberta; a description of the factors which influence the degree of disturbance and reclamation; and examples of both natural and enhanced recovery of disturbed sites through the examination of selected case studies.

86. **RRTAC 93-2: Reclamation Research Annual Report - 1992. Reclamation Research Technical Advisory Committee. 56 pp. ISBN 0-7732-0883-6. $5.00.**

This report describes the expenditure of $474,705 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and the research strategies of the five programs, and describes the projects funded under each program. It also lists the 85 research reports that have been published to date.

87. **RRTAC 93-3: Catalogue of Technologies for Reducing the Environmental Impact of Fine Tailings from Oil Sand Processing. B.J. Fuhr, Alberta Research Council, D.E. Rose, Dereng Enterprises Ltd., and D. Taplin, Komex International Ltd. 63 pp. ISBN 0-7732-0885-2. $5.00.**

A catalogue containing 22 technologies for reducing the environmental impact of fine tailings derived from oil sands has been assembled. The report consists of an introduction to oil sand processing and fine tailings generation, a simple spreadsheet for comparing the technologies, and a process summary for each technology. The technologies were not evaluated for effectiveness. Rather, a detailed set of questions was prepared that highlights the environmentally-related information a proponent should have. These questions will help to form a basis for comparisons among the technologies.

88. **RRTAC 93-4: Organic Materials as Soil Amendments in Reclamation: A Review of the Literature. Land Resources Network Ltd. 228 pp. ISBN 0-7732-0887-9. $10.00**

A review of the literature was conducted to examine the effect of various organic materials when used as amendments to disturbed soil. Organic amendments reviewed included animal manures, crop residues, peat, wood wastes, sewage sludge, municipal yard waste, humates, vermicomposts, and spent mushroom composts. Their effects on soil chemistry, physical properties, and biology were examined. Application methods, costs, longevity of effects, and use in reclamation were also reviewed. Benefits and drawbacks of each were discussed.

89. **RRTAC 93-5: Drilling Waste Disposal. T.M. Macyk and S.A. Abboud, Alberta Research Council. 125 pp. ISBN 0-7732-0889-5. $10.00**

An overall perspective and description of the steps involved in the management and land-based disposal of drilling wastes in Alberta. A computer program, available from the Alberta Research Council, has been written to support the data management required for proper disposal. A field manual is in preparation. These three information sources provide technical support for the Energy Resources Conservation Board's Guide G-50: Drilling Waste Management.