BENCHMARK SITE DOCUMENTATION

05-AB (PROVOST, ALBERTA)

SOIL QUALITY EVALUATION PROGRAM

Site Description Report

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SOIL QUALITY BENCHMARK SITES - THE STUDY

INTRODUCTION

Questions about trends in soil quality and means of measuring those trends, if detectable, arose in the late 80's in response to the sustainable agriculture issue (Mathur and Wang 1991). The popular opinion was that the value of agricultural soil resources has deteriorated, and may continue to be declining under conventional farming practices. The rate of decline is only speculative. Baseline data sets with which to make such evaluations aren't available for many regions. Information about problem soils tends to be plentiful; much less is known about the "medium to good quality" farmlands that dominate many agricultural regions.

In 1988 Agriculture Canada's Land Resource Research Centre (now Centre for Land and Biological Resources Research, CLBRR) started a pilot project in eastern Canada to establish benchmark sites for collecting baseline data to monitor trends in soil quality. This study was adopted nationally, in 1990, by the National Soil Conservation Program (NSCP) as part of the Soil Quality Evaluation Program (SQEP) managed by CLBRR. The study was labelled Soil Quality Benchmark Sites (SQUBS).

A network of 23 benchmark monitoring sites were established across Canada by late 1992. Various land, soil and air characteristics are to be monitored for at least 10 years. The Provost site, coded 05-AB, was established in September, 1990. It represents the northern belt of Dark Brown soils that occur in the Prairie - Parkland Transition, also called Aspen Groveland. The landscape is representative of the relatively rough, hummocky to undulating, morainal terrain that is common through east-central Alberta and west-central Saskatchewan.

OBJECTIVES

The benchmark site study was envisaged as a "case study" approach for monitoring the trends in soil quality change. Two basic assumptions underlie this approach. 1) Landscapes representative of major agro-ecosystems and managed under typical farm production systems could be characterized in detail to create baseline data sets with which to make soil quality assessments. 2) Monitoring selected soil variables within these landscapes (benchmark sites) for 10 or more years would facilitate the evaluation of trends in soil quality change. To complete the picture, it was anticipated that benchmark site information could be used to support expert systems for making general statements on soil quality trends regionally and nationally.

To implement this vision, three national objectives for establishing benchmark sites were developed. In order of priority, these were:

1. to provide a baseline data set for assessment of change in soil quality and biological productivity of representative agro-ecosystems,

2. to provide a means of testing and validating predictive models of soil degradation and productivity, and

3. to provide a network of benchmark sites at which integrated research projects can be developed.

In keeping with the national objectives, several major agro-ecosystems and agricultural landscapes were identified by a group of federal-provincial agrologists from across Canada. One such grouping - Dark Brown soils of the Prairie - Parkland Transition occurring on medium textured till or shallow fluviolacustrine materials with undulating to hummocky terrain - was designated for east-central Alberta. Characterization of complex segmented terrain, and the prospect of monitoring organic matter loss, wind and water erosion, and perhaps salinity, were viewed as objectives for this benchmark site. Comparison with other Great Plains sites of similar terrain in the thin and thick Black soil belts was also anticipated.

SITE SELECTION CRITERIA

Criteria were developed to guide the selection of benchmark sites, the main goal being to represent the dominant landscape within major agro-ecological regions. Based on the specific objectives above, the east-central Alberta site was to:

1. represent the northern Dark Brown soil zone under the Prairie - Parkland Transition Ecoregion;

2. represent undulating to hummocky glacial terrain comprised of medium textured till, preferably with a shallow fluviolacustrine or glaciolacustrine veneer;

3. represent a wheat - oilseed or barley - fallow crop rotation managed under conventional tillage (i.e. mutiple-pass cultivation);

4. be about 5-10 ha in size, and of sufficient size to adequately represent all segments of the complex landscape;

5. show potential for change in soil organic matter, and for impact by wind and/or water erosion and salinity; and

6. complement or provide information for Alberta Agriculture's on-farm conservation planning activities and rainfall simulation studies.

The search for a site, based on the guidelines above, began in September 1990, mainly in the Neutral and Provost uplands within the Municipal District of Provost (M.D. No. 52). Alberta Agriculture's local District Agriculturalist, Agnes Whiting, provided valuable guidance on the landscapes and farm operators throughout the area. The final selection was made in early October from among several potential candidates. The M.D. of Provost's Agricultural Fieldman, Bert Forbes, assisted with the final decision, and especially farm cooperator negotiations. A site about 16 km (10 mi) NE of Provost, on land owned and managed by Dennis Carter, was selected. Several factors affected the final decision.

1. The soils, terrain and farm management system were representative of an extensive area in the targeted region.

2. All landscape segments, from hilltops to depressions, could be adequately sampled with several short transects (50-100 m) within an area of 5-10 ha.

3. The farm operator, Dennis Carter, was fully cooperative and supportive, belonged to a family with a long history and good standing in the community, and offered a stable farm operation.

4. Potential for comparing the cultivated site to similar natural terrain, located within 1 km and owned by the Carter family, was a bonus attraction.

BENCHMARK SITE 05-AB (PROVOST)

SITE LOCATION

The Provost Benchmark Site is situated in east-central Alberta, about 300 km (185 mi) southeast of Edmonton and only 8 km (5 mi) from the Saskatchewan border. It is located within Legal Survey Division (LSD) 8 and the SE quarter of Section 7, Township 40, Range 1, west of the 4th Meridian. The NE corner of the site occurs at approximately 52º25'35" N latitude and 110º07'35" W longitude; UTM coordinates Zone 12, Easting 559464.69 m and Northing 5808583.24 m. From Provost townsite, the site can be reached by traveling 10 km (6 mi) east along Highway No. 13, to the village of Hayter, and about 8 km (5 mi) north along a gravel road (Fig. 1).

SAMPLING DESIGN AND METHODOLOGY

Field Sampling Design

Terrain at the Provost site is hummocky to undulating with distinct internal relief. An area 250 m east-west by 350 m north-south, totalling 8.8 ha (21.7 ac) in size, was selected to represent this landscape. Nine transects, labelled T1 to T9, were laid out within this area. Orientation of each transect was perpendicular to the contour, or nearly so, stretching from the top of a "hill" to the bottom of an adjacent depression. Transect length ranged from 40 m (T1) to 120 m (T8). Sampling points were chained out at 10 m intervals along each transect, starting at T*x*.0 on the hilltop. The nine transects encompassed a total of 67 sampling points. Points T9.06-T9.08 were located on uncultivated land, a wetland depression and its margin. Figures 2 and 3 show transect and sampling point locations relative to topographic and soil features of the area.

Each transect point was described, during sampling activities, in terms of slope position, slope shape, soil taxonomy, and other pertinent landscape features. Slope position was reported as one of five classes: 1) crest, 2) upper slope (i.e. shoulder), 3) mid slope, 4) lower slope, and 5) depression. Slope shape was identified as one of three classes: 1) convex, 2) concave, and 3) straight (or "level").

Two pedons were selected to characterize and sample, in detail, 2 of the major soils of the area. Pedon 1 (P1, Fig. 2) represented Rego Dark Brown soils of the hilltop positions; Pedon 2 (P2, Fig. 2) represented Orthic Dark Browns of mid-slopes. They are described in Appendix B.

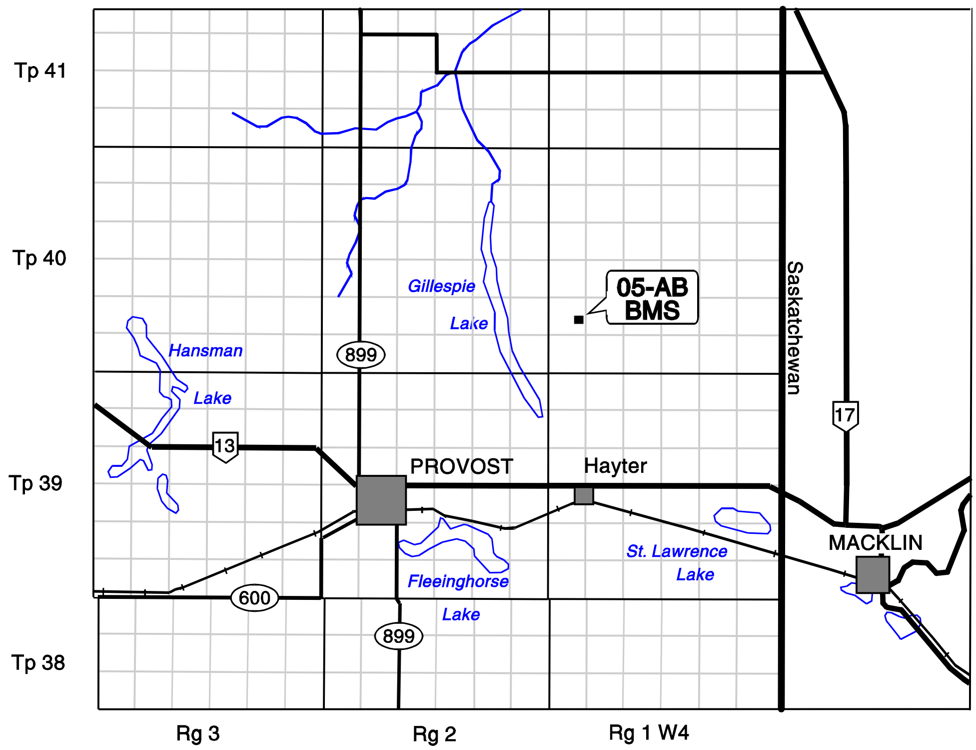

Figure 1. Location of the 05-AB (Provost) Benchmark Site in east-central Alberta.

Soil and Topographic Characterization

Topographic Data and Contour Map: A detailed contour map, with a 0.5 m interval, was created for the site (Fig. 2). Two independent data sources were related to create the X-Y-Z digital database for the contour mapping. The initial dataset was derived photogrammetrically, by contract with Stewart Weir Land Data Inc. of Edmonton. X (easting), Y (northing) and Z (elevation) co-ordinates, all in meters, were based on Universal Transverse Mercator (UTM) co-ordinates and elevation, estimated from 1:50,000 series NTS maps. The "real-world" accuracy of this estimation method was gauged at 15-30 m horizontally (X-Y) and 4-8 m vertically (Z). Follow-up field data was collected, using a total station instrument and Alberta Agriculture expertise, to correct some problem areas. In addition, the coordinates for all transect points, both pedon sampling sites, two topographic benchmarks, and the NE site corner were measured. The field survey coordinates were initially set to arbitrary values, but later merged to the photogrammetric UTM dataset.

Detailed Soil Map: The soils of the site were mapped at a scale of about 1:2000 (Fig. 3). The complex landscape was subdivided into repeating unit areas with similar patterns of terrain and soils. These repeating landscape units are identified by mapping units based on the series (or variant) and phase levels of classification (E.C.S.S. 1987a, 1987b). Delineation and mapping unit decisions were based on sampling point inspections, additional random soil and terrain inspections, traverses of the site, aerial photo interpretation, and topographic characteristics.

Sampling Activities

Four types of sampling activities were conducted to establish the baseline field and pedological characteristics of the Provost Benchmark Site. The first three activities were conducted in the late fall of 1990, the fourth, for aggregates, in the spring of 1991. Sampling followed the final fall cultivation in the fallow year of a wheat-fallow rotation.

Transect Point Sampling for Baseline Data: A loose sample of the contemporary Ap, Apk or Ah horizon was taken at every sampling point. For comparison purposes, loose sample of an "older" Ap2 or Ap3 horizon was collected at 15 transect points. In addition, loose sample at approximately 50-60 cm depth (usually B or C horizon) was collected at every 4^{th} sampling point. Horizon type and depth, color, structure, field texture, consistence, landscape position, classification, and other morphological and site information were recorded for each sampling point and sample.

Pedon Sampling: Pits about 1 m by 2 m by 1.5 m deep were opened by backhoe at the P1 and P2 locations (Fig. 2). The soil horizons of the exposed pedon were identified and described according to Day (1982). About 1 kg of loose soil was collected from each horizon. Cores (7.5 x 7.5 cm) were taken from 3 or 4 main horizons by hand operated Uhland sampler as per procedure 2.211 in McKeague (1978). Five cores were taken from each of the upper two horizons, four cores from other horizons.

Transect Point Sampling for ^{137}Cs Analysis: Surface soil redistribution, including water erosion, is part of monitoring activities at the Provost Benchmark Site. A volume loose sample (1-2 kg) of the contemporary Ap, Apk or Ah horizon was taken at every transect sampling point. For comparison purposes, a volume sample of an "older" Ap2 or Ap3 horizon was also collected at 15 transect points. A bulk density sample, collected in a 7.5 x 5.0 cm Kubiena box, was taken from the middle of each A horizon. The thickness of each A horizon was recorded.

Sampling for Dry Aggregate Size Distribution: The size distribution of dry aggregates was considered a means of quantifying surface soil structure at the Provost Benchmark Site. Representative transect points, a minimum of 2 per slope position, were selected for sampling. A volume loose sample (about 2 kg) of the soil surface to 5 cm depth was collected at each of the selected points. Timing was judged critical to provide some standardization for temporal comparisons. Thus sampling was done after spring thaw, before the first cultivation, when the soil was reasonably dry.

Field Measurements

The baseline set of *in situ* field measurements were begun prior to spring tillage in 1991. Yield and root and pore counts were first measured in late summer, 1991; yield information will be collected annually. Climatological data collection was initiated in May, 1991; climate parameters will be measured continuously for the duration of the project.

Hydraulic Conductivity (KSAT): Saturated hydraulic conductivity was measured by Guelph Permeameter at three depth ranges (5-10, 15-25 and 30-40 cm) using 5 and 10 cm heads per procedure 56.2.1 by Reynolds (1993). Measurements were made at 23 transect points, selected in a stratified random manner with a minimum of 3 per landscape position. Results were calculated and recorded in cm/hr and placed in classes as defined by McKeague *et al.* (1986). Results from the 5-10 cm depth range (Ap) were highly variable and changed with tillage; hence measurements at this depth were discontinued at most sites.

Penetration Resistance and Soil Moisture: Resistance to penetration was measured for 3 depths (0-10, 10-20 and 20-30 cm) using the Centre-Cone Penetrometer, operated manually per the user's manual (Star Quality Samplers 1990). Reported results, in bars, are the averages of 5 readings per depth per sampling point. Measurements were made at 34 transect points, selected in a stratified random manner, with a minimum of 3 per landscape position. Small samples, one from each depth at each sampling point, were collected in moisture tins for gravimetric determination of soil moisture. Results from the 0-10 cm depth (Ap) were highly variable and changed with tillage; thus measurements at this depth were discontinued at most sites.

Electromagnetic Ground Conductivity (EM38) Measurements: Electromagnetic inductance readings can be converted to electrical conductivity values that provide an estimate of soil salinity. Measurements were made at over 50% of the transect sampling points using a Geonics EM38 Ground Conductivity Unit. Readings were made in the horizontal (0-60 cm) and vertical (0-120 cm) modes at the selected points. Results can be converted to saturated paste EC equivalents (dS m^{-1}), based on estimated soil temperature and moisture conditions and soil texture (McKenzie *et al.* 1989).

Root and Biopore Counts: A root and pore counting procedure was tested at 5 transect sampling points. Counts were made at the bottom of the Ap/Apk (10- 15 cm), at about 25 cm, and at about 50 cm. The procedure was found to be time consuming and destructive. Large countable roots and pores were almost non-existent; tiny, nearly microscopic roots and pores were too numerous to count. There was virtually no difference between results at this cultivated site and those from a nearby natural site where the procedure was also tested. Based on these experiences, root and biopore measurements were not recommended for the prairie benchmark sites.

Crop Yield Sampling, Grains Group: The first two crops grown since site establishment - canola in 1991 and wheat in 1992 - were sampled at the time of maximum growth, just prior to harvesting by the producer. Sampling points were selected (at least 3 per slope position as circumstances permitted) by stratified random means. At the selected points, all above-ground crop material within a 1 m^2 area was clipped at about 1-3 cm above the soil surface. The samples are collected in large porous bags and transported to a threshing facility operated by Alberta Agriculture, Food and Rural Development (AAFRD) near Edmonton. After air drying, the crop samples were threshed to separate grain and residue (straw). Weights of both, in kg ha^{-1}, harvest index (grain weight as % of total dry matter weight) and residue - grain ratio are reported.

Climate: A climate monitoring station, using the Campbell Scientific CR10 measurement and control module, was installed along the fenceline about 70 m north of the site, on an east-facing, mid-slope position. Sensors for measuring air temperature and relative humidity (inside a gill radiation shield), global solar radiation, and wind speed were attached to a galvanized-steel radio tower at about 2 m above the ground. Other measuring devices were installed to collect soil temperature at 20, 50 and 100 cm; total rainfall and 15-minute rainfall intensity; and snow depth. Measurements were initiated in mid May, 1991. A major programming change, which added some new measurements and daily summaries, was instituted in mid November, 1991. Corrections and other minor changes followed until late May, 1992, when the current program functioned smoothly. Hourly, daily and monthly output are available for selected parameters.

Analytical (Laboratory) Methods

Sample Handling and Preparation: Loose samples for chemical, physical and ^{137}Cs analyses were air-dried and roller-ground to separate the fine earth fraction (<2mm) from coarse fragments as per procedure 1.2 (McKeague, 1978). The prepared cesium^{137} samples were shipped to the Univ. of Guelph's Dept. of Land Resource Sci. for analysis. Pedon and field samples prepared for detailed laboratory characterization were split into two equal parts, one part for analysis and the other for future use. Core samples from the pedons were stored at low temperatures (about 4^{o}C) until processing. Samples for aggregate analysis were very carefully collected and transported in pizza-style cardboard boxes to minimize aggregate breakage. After air drying, the samples were shipped to the SK Land Resource Unit, Saskatoon, for rotary sieve analysis.

Soil Reaction (pH): pH in $CaCl_2$ measured with a pH meter using a 1:2 soil to 0.01 M $CaCl_2$ solution, per procedure 84-001 in Sheldrick (1984).

Total Carbon: LECO induction furnace, as per procedure 84-013 in Sheldrick (1984).

Organic Carbon: Calculated as the difference between total carbon and inorganic carbon determined in the $CaCO_3$ procedure.
Total Nitrogen: Samples were digested using a semi-micro version of the Kjeldahl- Wilforth-Gunning method (A.O.A.C. 1955) using Se-K_2SO_4 (Keltabs) as the catalyst. Ammonium-N in the distillate was detected colorimetrically with a Kjeltec nitrogen analyzer.

$CaCO_3$ Carbonate Equivalent: Carbonates were determined by the inorganic carbon manometric (calcimeter) method of Bascombe (1961), similar to procedure 84-008 of Sheldrick (1984), on samples with $CaCl_2$ pH of 6.5 and greater.

Cation Exchange Capacity and Exchangeable Cations: Cation exchange capacity (CEC) and exchangeable cations (Ca, Mg, Na, K, and in a few cases Al) were measured by one of three methods, depending on $CaCl_2$ pH of the sample. Except as noted, extracted cations were determined by inductively-coupled, plasma spectrophotometry (ICPS); displaced ammonium by nitrogen analyzer.

- pH less than 5.5 - 2M NaCl method, as per procedure 84-004 in Sheldrick (1984). Cation replacement is by Na, hence Na cation and CEC are not determined. Exchangeable Al and permanent charge CEC (the sum of Ca, Mg, K and Al) were determined on a few samples, as per procedure 84-004 in Sheldrick (1984), including detection by atomic absorption spectrophotometry.
- pH 5.5 to 6.4 - 1M, buffered (pH 7), NH_4OAc steam distillation method (USDA Soil Conservation Service 1984).
- pH 6.5 and greater (calcareous soils) - 1M, buffered (pH 7), NH_4Cl steam distillation method (USDA Soil Conservation Service 1984).

Available N: "Plant-available" nitrogen was not measured at the benchmark sites. The sampling intensity required to track the variability of available N was considered impractical for the study. Further, chemical fertilizer inputs would significantly affect the results, increase the variability, and compensate for less than adequate amounts.

Available P: "Plant-available" or extractable phosphorus was measured by one of two methods, depending on the predominance of calcareous versus acidic, non-calcareous soils at a site.

- Mainly neutral to alkaline and calcareous samples - sodium bicarbonate ($NaHCO_3$) extraction with P determined by using ammonium molybdate solution, as per procedure 84-017 in Sheldrick (1984).
- Mainly acid to neutral samples - Bray method (0.03M HN_4F + 0.025 M HCl), extractable P determined by using ammonium molybdate solution, as per procedure 84-018 by Sheldrick (1984).

Available K: "Plant-available" or extractable potassium was measured by one of two methods, depending on calcareousness of the samples. Extracted K was determined by ICPS.

- Calcareous samples (pH 6.5 or greater) - 1M, buffered (pH 7), NH_4OAc extraction, as per procedure 84-005 in Sheldrick (1984).
- Non-calcareous samples - cold, 0.05M, H_2SO_4 extraction (Knudsen *et al.* 1982).

Total Elemental Analysis: Total amounts of selected elements (Al, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb and Zn) were determined using the perchloric acid digestion method (84-023 in Sheldrick 1984) on all pedon and 10% of field samples.

Electrical Conductivity and Soluble Salts: Subsets of the pedon and selected field samples were submitted to AAFRD's Soil and Animal Nutrition Testing Laboratory for EC and soluble salt analyses. Electrical conductivity (EC) and soluble salts (cations) were determined on saturation extracts (method 3.21 in McKeague 1978); EC by a conductivity bridge, cations by ICPS. Sodium adsorption ratios (SAR, ratio of soluble Na to Ca + Mg) were also calculated.

Cesium^{137} Analysis: Samples collected for ^{137}Cs determinations were analyzed using high resolution Gamma-spectroscopy methods described by deJong *et al.* (1982).

Particle Size Distribution Analysis: The fine earth fraction of all pedon and 10% of field samples was separated into particle size groups using a pipette or filter candle system, per procedure 84-026 in Sheldrick (1984). Samples were pretreated to remove soluble salts, carbonates, and organic matter as required. Clays were collected for mineralogical analysis; sands were fractionated by sieve analysis, per procedure 47.2.3.2 in Sheldrick and Wang (1993).

Mineralogical (XRD) Analysis: Minerals present in clay fractions, collected during the particle size analysis procedure, were identified by X-ray diffraction (XRD) analysis. Mineral identification was based on a composite of diffraction data from air-dry, glycerolated and thermally treated specimens of each clay sample. Mineral content was estimated from diffraction intensities using procedures like those described by Kodama *et al.* (1977). Semi-quantitative results were recorded.

Soil Moisture Retention: Undisturbed 7.5 cm diameter x 7.5 cm length cores were used for determining moisture retention at tensions equivalent to 0, 10, 30, 60 and 100 cm of water on a glass bead tension table; at $^1/_3$ and 1 bar tensions (333 and 1000 cm of water) on an aluminum oxide tension table. Moisture retention at 4 and 15 bars were determined on ground samples with pressure plate extraction similar to procedure 53.4 by Topp *et al.* (1993).

Surface Area: Total surface area of all pedon samples and about 10% of field point samples was determined by the ethylene glycol monoethyl ether (EGME) method of Cihacek and Bremner (1979).

Bulk Density: Two sets of bulk density values were obtained. 1) Oven-dry bulk density values, uncorrected for coarse fragment content, were determined on the core samples from the pedons, per procedure 2.211 in McKeague (1978). 2) Oven-dry bulk density values, uncorrected for coarse fragment content, were determined on the Kubiena box samples, which were collected in conjunction with sampling for cesium^{137} analysis.

Dry Aggregate Size Distribution: Samples were air dried and shipped in pizza-style boxes, with minimum disturbance, to Agriculture and Agri-Food Canada's Saskatchewan Land Resource Unit for rotary sieve analysis. Aggregate distribution was determined, per the procedure of White (1993), using a rotary sieve with screen openings of 53.53, 34.58, 17.51, 7.20, 2.58, 1.30, and 0.50 mm.

AGRONOMICS

Information on the agronomic history and current farming practices was obtained through an interview process using a standard questionnaire. The owner/operator, Dennis Carter, and his father, Bill Carter, who is still actively involved in the farming operation, were interviewed about the Provost site. The following is a summary of the interview data.

Farm History

The quarter section that contains the Provost Benchmark Site was purchased from a neighbor in 1984. Fortunately, the early farming history has been passed on.

The Early Years: The land was first broken and cropped in 1912. The cropping rotation was usually cereal (wheat) - fallow (clover grown in 1935). The plow was the principal tillage tool, drawn by horses until 1940. Fertilization methods, including manuring, and pest control measures were not used until 1950. Harvesting, until 1947, was mainly by stationary threshing machine, which required removal of the crop material, bound in sheaves, to a threshing site.

Major Changes: Tractor power was introduced in 1940. Deep-tillage cultivators replaced the plow as the main tillage implement in about 1950. Use of chemical fertilizers (11-48-0) and herbicides (2-4-D ester) also began *circa* 1950. Use of fertilizers high in nitrogen (e.g. 34-0-0) began in 1977. Fertilizer use has decreased slightly in recent years due to soil testing. Pre-emergent herbicide usage (e.g. Treflan and Avadex) began in 1980. In recent years herbicides have replaced some tillage operations. Harvesting changed in 1947 with the introduction of a combine. Most of the time since then, crop residue has been left on the field and tilled into the soil. In 1991 the crop rotation was extended to include canola.

Co-operator Assessment: The interviewees noted that yields and crop quality have increased over the 80^+ years of cultivation. They felt that yields in the immediate vicinity were usually higher than most in the area. Comments were that they farm "in a good area", that crop "quality has always been good" but has increased because of "better wheat varieties now". No degradation problems were observed.

Current Management Practices

Crop Rotation System: A canola - cereal - fallow rotation, common throughout the area, has been used since the introduction of canola in 1991. The system has some flexibility in that cereals may be grown for a second consecutive year if moisture reserves are favorable. This was also a common practice in the past. The cereal grain is usually wheat, occasionally barley. When sampled and characterized in 1990-91, the site was in fallow. The 1991 crop was canola, the 1992 crop wheat, and 1993 in fallow.

Equipment: Current farm equipment for tillage and seeding include one large 4-wheel drive tractor (Versatile 875), two 2-wheel drive tractors (John Deere 4440 and 4020), a deep-tillage cultivator, a hoe-type press drill, and a harrow-packer. A pull-type field sprayer is used for spraying some herbicides. Harvesting equipment includes a 25-foot pull-type swather, a self-propelled combine (John Deere 7720), and two grain trucks (3-ton and 2-ton).

Management Procedures: Table 1 presents a year by year account of "typical" farm management activities used throughout the rotation, including an optional second year of cereals. For the presentation, canola was arbitrarily chosen as the first year of the rotation. An annual diary of actual operational activities will be kept by the farm operator for the duration of the monitoring study.

Table 1. Typical tillage, crop management and harvesting procedures.

Crop Year	Main Activity	Time Frame	Operational Procedures
1. Canola:	Spring cultivation	Mid April start	Deep tillage cultivator, usually 2 passes
	Planting	Early May	Drill followed by harrow-packer
	Fertilizer application	Early May	12-51-0 (30 lbs/ac) starter with seed
	Cutting/harvesting	Mid-late August	Swathed; combined about 2 weeks later
	Fall cultivation	Late September	Deep tillage cultivator with spikes (anhydrous)
	Fall fertilization	Late September	Anhydrous-N spiked in if moisture adequate (one pass with fall cultivation)
2. Cereal: (wheat)	Spring cultivation	Mid April start	Deep tillage cultivator, usually 2 passes
	Spring fertilizer (optional)	(Mid April)	Broadcast 34-0-0 if too dry for anhydrous-N the previous fall
	Planting	Early May	Drill followed by harrow-packer
	Fertilizer application	Early May	12-51-0 starter with seed
	Spraying	Early May	2-4-D amine herbicide
	Cutting/harvesting	Early-mid June	Swathed; combined about 2 weeks later
	Fall cultivation	Late August N/A	Usually no cultivation with normal to low moisture reserves
		(Late September)	Spiked (with anhydrous-N) if moisture reserves considered good
	Fall fertilizer	N/A	Usually none with normal to low moisture
		(Late September)	Anhydrous-N spiked in if moisture is good
3. Optional Cereal:	If moisture conditions are favorable, a cereal crop (wheat or barley) is planted and harvested (see 2. above) for the second consecutive year.		
	Fall cultivation	N/A	None; stubble left standing
	Fall fertilization	N/A	None
4. Fallow:	Spring cultivation	Late May start	Deep tillage cultivator, depending on types of weeds - might be sprayed instead
	Spraying (optional)	(Late May)	Broadleaf herbicide may replace cultivation depending on types of weeds present
	Summer cultivation	Mid June & on	Cultivator; total summer & fall passes = 3 to 5
	Fall cultivation	Late September	Cultivator; last pass to incorporate pre-emergent herbicide for canola crop next year

SOIL AND LANDSCAPE DESCRIPTION

Ecology and Climate

The Provost Benchmark Site occurs in the Grassland Ecoclimatic Province (Ecoregions Working Group 1989) or Ecoprovince (Strong 1992). This broad region has a continental macroclimate with cold winters, short summers, and low precipitation. Large yearly and daily temperature ranges plus maximum precipitation in summer (June or July) attest to the continental conditions (Table 2).

Ecoclimatic provinces are further subdivided into ecoclimatic regions (Ecoregions Working Group 1989) or ecoregions (Strong 1992). Sources disagree on which ecoclimatic region fits the Provost area although descriptions of the area are comparable. It is situated in the north-central part of the Arid Grassland Ecoclimatic Region (Ecoregions Working Group 1989) in one perspective, the southern part of the Aspen Parkland Ecoregion (Strong 1992) in another. This disparity clearly demonstrates that the area, once aptly termed aspen groveland (Strong and Leggat 1981), is transitional between the drier treeless grassland to the south and aspen-dominated parkland to the north. The Dark Brown soil group is characteristic of the area (Alberta Soil Survey 1993); Black and Gleysolic soils are also common.

The vast majority of the area has been cultivated for several decades; native vegetation has been replaced with cereal and oilseed crops. Remnant natural landscape is rare; a small parcel of about 35 ha exists less than 1 km north of the benchmark site. It is typical of the groveland area as described by Strong (1992). Grassland plant communities are dominant and associated with the driest segments of the land-scape. Groves of aspen (*Populus tremuloides*) occur in moister sites such as shallow depressions, north-facing slopes, creek banks, and seepage sites, and account for about 15% of the land cover. Upland shrub communities, developed in localities where snow commonly accumulates, account for another 10-15% cover. Slough-like depressions, usually ringed with willows and dominated by wetland vegetation such as sedges, account for about 15% of the hummocky to undulating terrain in this vicinity. Even though they rarely contain permanent water, many of the largest and wettest depressions remain uncultivated in surrounding fields.

The Site is located in Agroecological Resource Area (ARA) I1, Provost (Pettapiece 1989). Its agro-climate is classed as 2AH which signifies slight moisture and heat limitations for arable crop production (ASAC. 1987). Selected climate indices, computed from climate normals (AES N.d.) and generalized for the ARA (No. 34 in the prairie region, Kirkwood *et al.* 1993), are:

- Seasonal growing degree days >5 ^{o}C: 1419.
- Growing season start (date that mean daily air temp. is ≥5 ^{o}C in spring): Apr. 21.
- Growing season end (date that mean daily air temperature is ≤5 ^{o}C in fall): Oct. 14.

Wind is likely an important part of the regional climate, based on data from AES climate stations at Coronation A, AB, and Scott CDA, SK (AES 1993). Mean yearly wind speeds are 16 and 14 km/h respectively, with very little variation month to month. The most frequent direction is clearly NW. Maximum hourly wind speeds are often in the 60 to 80 km/h range with no clear seasonal patterns. Maximum gust speeds over 100 km/h were recorded in several months at Coronation A.

Terrain

The Provost Benchmark Site is located on the Provost Upland District, one of several upland areas found in eastern Alberta and western Saskatchewan (Acton *et al.* 1960, Pettapiece 1986). As with most of these uplands, the terrain is characterized by undulating to hummocky moraine dotted with small wetland depressions. The Provost Upland is situated within the Neutral Hills Uplands Section of the Eastern Alberta Plains Region (Pettapiece 1986).

The undulating to hummocky moraine of the Provost Benchmark Site has distinct internal relief. The contour map (Fig. 2) shows this complex terrain in plan view. The hillier parts have complex slope patterns, mostly of class 3 and 4 topography with minor class 5 to 6 on the steepest slopes and some class 2 slopes across broad hilltops. Lower lying localities have level to very gentle slopes, mostly of class 2 topography. Uncultivated patches are mainly bowl-shaped wetland depressions with surprisingly sharp steep margins.

The moraine is comprised of moderately calcareous, CL-L textured, continental till. Underlying and principal source bedrock is the nonmarine Belly River Formation which consists of sandstone, siltstone and mudstone (Green 1972). Salinity in upper till layers is minimal (E.C. <1 dS m^{-1}). Weakly saline subsoil (E.C. about 4 dS m^{-1}) was found at a few sampling points. A thin discontinuous capping (<1 m) of local slopewash or glaciolacustrine sediment covers the till. It is nearly continuous in the level to gently sloping, low lying segments of the landscape., less extensive on the hillier parts. Where mainly unaltered, the veneer material is SiL-L textured and moderately calcareous.

Table 2. Selected temperature and precipitation data (climate normals) for Macklin, SK (52º20'N 109º57'W, 667m ASL) (AES N.d.) .

Month/ Year	Mean Temp. (ºC)	Mean Max. Temp. (ºC)	Mean Min. Temp. (ºC)	Total Precip. (mm)	Rain-fall (mm)	Snow-fall (cm)	Max. 24-hour Rainfall[1] (mm)	PE[2] (mm)
Jan.	-17.9	-12.7	-22.9	20.5	0.6	19.9	7.6	0
Feb.	-13.0	-7.4	-18.4	16.0	0.4	15.7	6.4	0
Mar.	-7.7	-2.0	-13.4	19.3	0.9	18.4	10.2	0
Apr.	3.1	9.4	-3.2	21.8	13.9	7.9	52.1	41
May	10.7	18.0	3.3	34.6	33.6	0.5	41.7	112
Jun.	15.0	21.9	7.9	70.7	70.7	0.0	78.7	132
Jul.	17.6	24.7	10.4	72.5	72.5	0.0	71.1	145
Aug.	16.5	23.8	9.1	58.6	58.6	0.0	83.8	122
Sep.	10.6	17.4	3.7	30.4	29.4	0.9	52.1	63
Oct.	4.6	11.3	-2.2	14.7	8.2	6.5	25.4	15
Nov.	-5.7	-0.5	-10.7	14.3	3.0	11.4	12.7	0
Dec.	-13.2	-8.3	-18.0	20.9	0.7	20.2	6.4	0
Year	1.7	8.0	-4.5	394.3	292.5	101.4	83.8	630

[1]Greatest rainfall in 24 hours (Aug., 59 years of record), based on 33 (Dec.) to 61 (Jul.) years of record.
[2]Potential Evapotranspiration, derived for the ARA from daily temperature normals interpolated from monthly values (Kirkwood *et al.* 1993).

Soil Patterns

Figure 3 shows the complex soil patterns of the Provost Benchmark Site, indicated by mapping units that are described in an adjoining legend. A generalized, terrain-oriented description of the soil patterns follows. The sampling points are listed, with landscape and soil features, in Appendix A.

The hillier, well drained, "upland" parts of the landscape have the most exposed till soils, and exhibit the most visible signs of erosion. Slopes are dominated by Orthic Dark Brown soils on till (Hughenden series, HND), some with thin Ap horizons. Soils developed on veneer overlying till (Provost series, PRO) are also common. Most prominent hilltops are clearly dominated by Rego Dark Browns on till (Neutral series, NUT). Small, very gently sloping basins within the "upland" contain a variety of mainly imperfectly and some poorly drained soils. These range from Gleyed Solonetzic Dark Brown (Hansman series, HAS) to Humic Gleysols. Appendix B contains pedon descriptions and selected data for the HND and NUT soils.

A large lower-lying area with very gentle to nearly level slopes cuts the site from southwest to northeast. Moderately well drained Orthic Dark Brown soils developed on veneer over till (Provost series, PRO) dominate. A variety of imperfectly to poorly drained soils, including gleyed Blacks and Dark Browns (e.g. HAS) and Humic Gleysols, are significant.

Depressional localities contain some form of wetland and are poorly to imperfectly drained. The dominant soils are Gleysols, mainly Humic Luvic Gleysols. A variety of related gleyed soils also occur. The parent materials, whether slopewash, lacustrine or till deposits, tend to be slightly finer textured than on surrounding parts of the terrain.

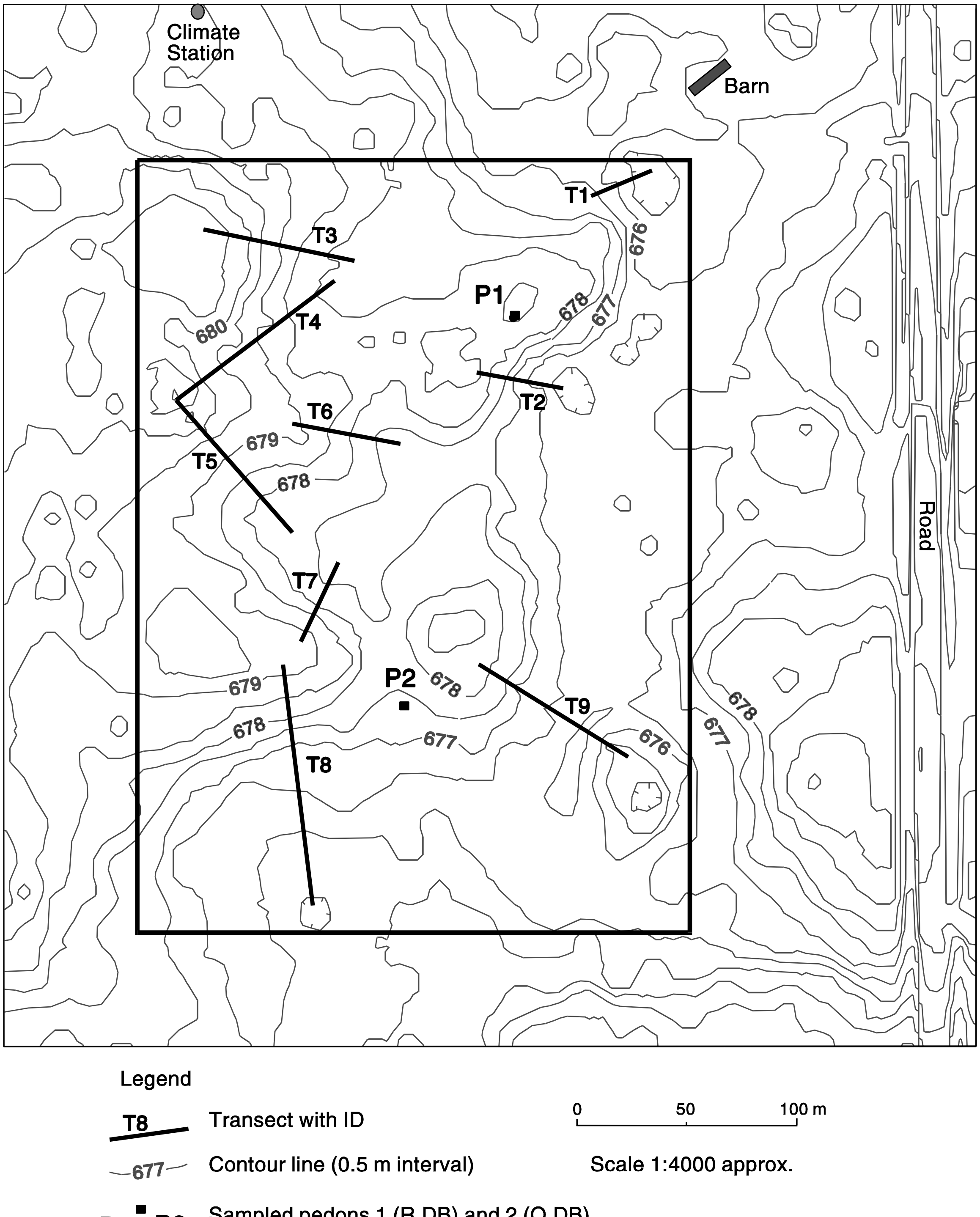

Figure 2. Contour map of the northeast part of SE7-40-1-W4 with 05-AB Benchmark Site.

05-AB (PROVOST) SOIL MAP LEGEND

MAP UNIT[1]	DESCRIPTION
HAS1/2-3	**Landscape**: Small basins within the "upland" that consist of nearly level to very gentle lower slopes. **Soils**: Mainly imperfectly drained GLSZ.DB (Hansman. HAS) and GLE.DB (HASze) on SiL-L slopewash or lacustrine veneer overlying CL-L till. Veneer extends to over 1m thick in places. Other soils include several gleyed Blacks (e.g. GLSZ.BL) and some Gleysols, mostly HU.LG.
HND4/3	**Landscape**: Very gentle broad hilltop on the "upland". **Soils**: Mainly well drained O.DB on CL-L till (Hughenden, HND), commonly with a thin (10 cm or less) Ap horizon. CA.DB and R.DB (Hughenden-ca & Neutral, HNDca & NUT) "eroded" soils are significant.
HNPR4/3-4	**Landscape**: Majority of the undulating to hummocky "upland" areas; consists of very gentle to gentle mid slopes and small hilltops. **Soils**: Well drained. Mainly O.DB on CL-L till (Hughenden, HND) with significant O.DB on SiL-L slopewash or lacustrine veneer overlying till (Provost, PRO). Also, most small hilltops and other exposed sites have CA.DB and R.DB (Hughenden-ca & Neutral, HNDca & NUT) soils. In places hummock foreslopes are moderate to strong (>9% slope).
NUT1/3-4	**Landscape**: Prominent, very gently to gently sloping, "eroded" hilltops within the "upland" areas. **Soils**: Mainly well to rapidly drained R.DB (Neutral, NUT) developed on CL-L till; some CA.DB (Hughenden-ca, HNDca). Calcareous to the surface. In places hummock foreslopes are moderate to strong (>9% slope).
PRO2/3-2	**Landscape**: Large lower-lying area with very gentle to nearly level slopes. **Soils**: Mainly moderately well drained O.DB developed on SiL-L slopewash or lacustrine veneer overlying CL-L till (Provost, PRO). Significant imperfectly drained, gleyed Dark Browns and Blacks; e.g. GL.DB (PROgl), GLSZ.DB (HAS) and GLE.DB (HASze) on the same parent material sequence. Profiles with carbonated B horizons are common. The slopewash / lacustrine veneer extends to over 1m thick in places. Small shallow depressions with Gleysols, mostly HU.LG, are also common.
ZGL	**Landscape**: Nearly level to gentle depressions (wetlands). **Soils**: Mainly poorly to imperfectly drained HU.LG developed on SiL slopewash or lacustrine veneer overlying CL till (Fleet-zlxt variant, FLTzlxt). Veneer extends to over 1m thick occasionally. Other Gleysols, e.g. O.HG and SZ.LG, can be found. Various gleyed Dark Browns, e.g. HAS and HASze, and Blacks occupy margins and better drained sites.

[1]Numerator consists of series code(s) plus number signifying typical for series (1), significant wet soils (2), or significant "eroded" profiles (4). Denominator signifies slope classes per E.C.S.S. (1987b) with slope gradients, in percent slope (%), as follows: 2 = 0-2%, 3 = 2-5%, 4 = 6-9%, 5 = 9-15%, 6 = 15-30%, etc.

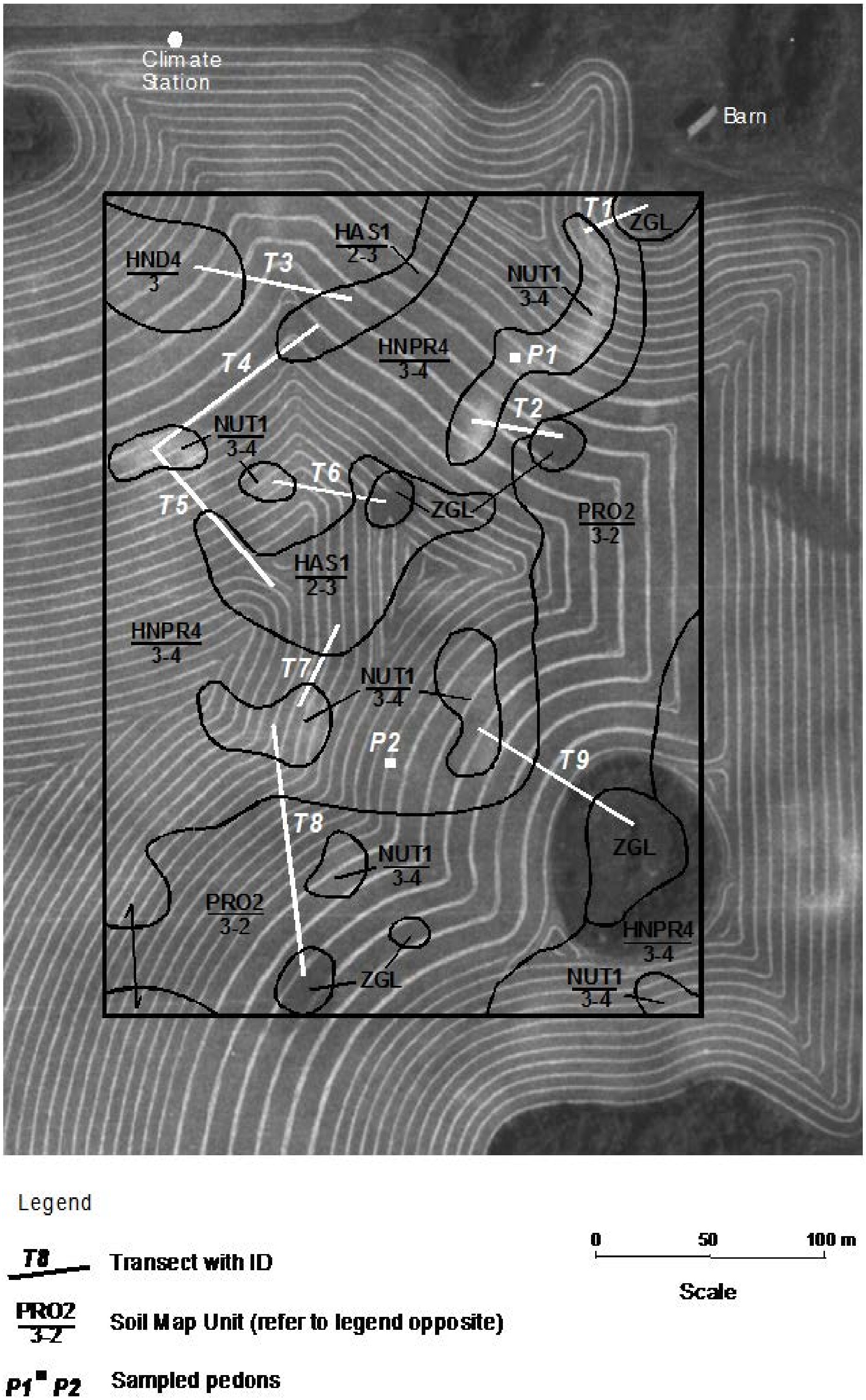

Figure 3. Detailed soil map of the 05-AB Benchmark Site.

Most of the smaller depressions are wet early in the season but dry out sufficiently in most years to raise good crops. The largest and wettest remains uncultivated even though it does not contain permanent or semi-permanent water. The lower end of Transect 9, which includes sampling points T9.06, T9.07 and T9.08, extends into this aspen-ringed depression located in the southeastern part of the Benchmark Site.

EXAMPLES OF BENCHMARK SITE BASELINE DATA ANALYSIS

Copious amounts of baseline data have been collected on the benchmark sites. Most of this data has been refined and arranged into a national benchmark site database. Further, on-going measurements on yield and climate are being attached to the database. Repeat measurements will be added as completed. A listing and brief explanation of files that make up the database is provided in Appendix C. Data on a particular site or several sites can be extracted from the database. Requests should be channeled through the authors or any unit of CLBRR.

Besides the large amount of data, there are a number of ways to analyze the data when looking for meaningful relationships, especially where the terrain is complex. At the Provost Site for example, data can be examined according to different landscape positions, slope shapes, map units, soil series/variants, soil subgroups, horizon types, or other factors and combinations of factors.

When the Provost Site was established, it was anticipated that soil attributes connected with degradation would be examined, mainly on a landscape position basis. By way of example, Table 3 summarizes organic carbon, total nitrogen, C/N ratios, carbonate content and pH data for each of the five slope position classes (see methods). Definite trends are evident The currently cultivated topsoil is uniformly thick regardless of slope position. On hilltops (crests and upper slopes) the topsoil is low in organic carbon and contains appreciable carbonates incorporated from subsoil horizons. On lower slopes and depressions, organic carbon content is much higher, carbonates are absent, and pH's are quite low. Mid slope soils are quite variable, exhibiting features of both hilltop and lower slope areas.

Table 3. Selected data on "modern" Ap/Apk (topsoil) horizons, organized by slope position.

SLOPE POSITION & STAT.		THICK-NESS (cm)	pH[1] $CaCl_2$	ORG. C (%)	TOTAL N (%)	C/N RATIO	$CaCO_3$ EQUIV. (%)
Crest,	**Average:**	11	7.5	1.80	0.18	10.1	4.24
	Std. Dev.[1]:	2	6.5-7.8	0.30	0.03	0.7	3.69
Upper,	**Average:**	10	7.4	1.79	0.18	9.9	2.05
	Std. Dev.:	2	6.9-7.7	0.27	0.03	0.3	1.59
Mid,	**Average:**	11	6.2	2.62	0.23	11.1	0.70
	Std. Dev.:	1	4.8-7.7	0.56	0.04	0.8	1.77
Lower,	**Average:**	11	5.2	3.49	0.31	11.4	--
	Std. Dev.:	2	4.6-6.2	0.36	0.04	1.3	--
Depression,	**Average:**	11	5.1	3.56	0.33	10.8	--
	Std. Dev.:	2	4.9-5.4	0.19	0.01	0.4	--

[1]Std. Dev. = standard deviation; listed for all parameters except pH where the full range of pH values are reported.

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APPENDIX A: SELECTED SOIL AND LANDSCAPE FEATURES OF SAMPLING POINTS

Selected physical soil features and landscape position information is presented in the following tables. The data is sorted by slope shape (3 classes) within slope position (5 classes; see methods). Soil subgroup codes are standard (E.C.S.S. 1987b). Soil series and variant codes are from the recently developed Generation 2 Alberta Soil Names File (Alberta Soil Series Working Group 1992). The last column lists total depth of humus-rich topsoil. The current Ap or Apk plus any underlying older Ap or uncultivated Ah or AB horizon were summed; strongly eluviated (Ae) horizons were excluded. For comparison, soils in "upland" landscape positions at the nearby natural site commonly have Ah horizons <10 cm thick (Finlayson 1992).

SLOPE POSITON	SAMPLING POINT ID	SLOPE SHAPE	SOIL SUBGROUP	SOIL SERIES	TOTAL Ap/Ah DEPTH (cm)
Crest:	05T4.00	Convex	R.DB	NUT	12
	05T1.00	Convex	R.DB	NUT	8
	05T6.00	Convex	R.DB	NUT	16
	05T7.00	Convex	R.DB	NUT	11
	05T2.00	Convex	R.DB	NUT	11
	05T9.00	Convex	R.DB	NUT	10
	05T8.00	Convex	R.DB	NUT	20
	05P1	Convex	R.DB	NUT	11
	05T3.00	Straight	O.DB	HND	18
	Average:				13
	Std. Dev.:				4
Upper Slope:	05T9.01	Convex	R.DB	NUT	9
	05T5.01	Convex	CA.DB	HNDca	12
	05T3.02	Convex	O.DB	HND	10
	05T8.01	Convex	R.DB	NUT	17
	05T4.01	Convex	CA.DB	HNDca	9
	05T3.01	Convex	O.DB	PRO	10
	05T6.01	Convex	CA.DB	HNDca	13
	Average:				11
	Std. Dev.:				3
Depression:	05T6.05		HU.LG	FLTzlxt	45
	05T7.04		GLE.DB	CNNfigl	27
	05T8.11		HU.LG	FLTzlxt	19
	05T2.04		HU.LG	FLTzlxt	38
	05T1.03		GL.DB?	HNDgl	8
	05T9.07[1]		HU.LG	FLTzlxt	30
	05T3.07		O.HG	FLTxt	25
	05T9.08[1]		SZ.LG	FLTzlzt	25
	05T4.09		GLSZ.DB	HAS	16
	Average:				26
	Std. Dev.:				11

[1]Sampling points never cultivated.

SLOPE POSITON	SAMPLING POINT ID	SLOPE SHAPE	SOIL SUBGROUP	SOIL SERIES	TOTAL Ap/Ah DEPTH (cm)
Mid Slope:	05T4.04	Concave	O.DB	PRO	16
	05T4.03	Concave	O.DB	HND	15
	05T3.04	Concave	O.DB	PRO	20
	05T4.05	Concave	O.DB	PRO	16
	05T8.02	Convex	CA.DB	PROca	12
	05T5.02	Convex	CA.DB	HNDca	11
	05T7.02	Straight	O.DB	HND	13
	05T6.03	Straight	E.DB	LFE	15
	05T3.03	Straight	O.DB	HND	11
	05T4.06	Straight	O.DB	HND	18
	05T1.01	Straight	O.DB	HNDca	20
	05T5.03	Straight	O.DB	HND	20
	05T2.01	Straight	O.DB	HNDca	30
	05T5.04	Straight	O.DB	PRO	20
	05T8.03	Straight	O.DB	HND	22
	05T6.02	Straight	O.DB	PRO	20
	05T2.02	Straight	O.DB	PRO	35
	05T8.07	Straight	O.DB	HND	14
	05T7.01	Straight	O.DB	HND	11
	05T4.02	Straight	O.DB	PRO	11
	05T8.06	Straight	O.DB	HND	12
	05P2	Straight	O.DB	HND	11
	05T9.02	Straight	O.DB	HND	33
	05T9.04	Straight	O.DB	PRO	20
	05T9.05	Straight	O.BL	BLL?	17
	Average:				18
	Std. Dev.:				7
Lower Slope:	05T2.03	Concave	GLSZ.DB	HAS	45
	05T5.08	Concave	GLSZ.DB	HAS	17
	05T9.03	Concave	GLE.DB	HASze	30
	05T8.08	Concave	GLSZ.BL?	BLLztgl	30
	05T8.04	Concave	O.DB	PRO	19
	05T4.07	Concave	O.DB	HND	23
	05T4.08	Concave	GL.DB	PROgl	23
	05T5.06	Concave	SZ.BL	BLLzt	13
	05T8.09	Convex	GLE.BL?	BLLzegl	23
	05T7.03	Straight	GLE.DB	CNNglze	17
	05T5.07	Straight	GL.DB	PROgl	16
	05T1.02	Straight	GLE.DB	HNDglze	18
	05T9.06[1]	Straight	GLSZ.BL	BLLztgl	20
	05T5.05	Straight	O.DB	PRO	15
	05T8.10	Straight	GLSZ.DB	HAS	30
	05T3.05	Straight	O.DB	PRO	18
	05T3.06	Straight	GLE.DB	HASze	15
	05T8.05	Straight	O.DB	PRO	14
	05T6.04	Straight	HU.LG	FLTzlxt	22
	Average:				21
	Std. Dev.:				8

[1]Sampling point likely never cultivated but topsoil includes substantial drift from the cultivated field only meters away.

APPENDIX B: PEDON DESCRIPTIONS

Pedons representing two of the five major soils of the site were described and sampled in detail when the site was established. Locations of these pedons are shown in Fig. 2. The descriptions and selected analytical data follow. Other available data for some or all horizons include cation exchange capacity, exchangeable cations (Na, Ca, Mg, K), available P and K, electrical conductivity and soluble salts, mineralogical analysis, and soil moisture retention and bulk density from core samples.

PEDON 1: NEUTRAL SERIES (NUT)

Identification:	05-AB, Pedon 1 (P1); Rego Dark Brown
Location:	SE7-40-1-W4; north central part of benchmark site (see Fig. 2)
Described by:	B.D. Walker; October 15, 1990
Parent material:	Moderately fine textured (fine loamy), moderately calcareous till
Landscape:	Crest (1.5% convex slope) of an eroded knoll in undulating to hummocky terrain
Drainage:	Well drained
Land use:	Cropland; canola - wheat - fallow rotation

Horizon	Depth cm	Description
Apk	0-11	Very dark brown to very dark grayish brown (10YR 2.5/2 m), dark grayish brown (10YR 4/2 d); loam; very weak, very fine, subangular blocky; loose; plentiful, micro to very fine, random roots; weakly calcareous; 2% gravels & cobbles; abrupt, smooth boundary; 7-12 cm thick; alkaline.
Cca	11-31	Light olive brown (2.5Y 5/4 m); clay loam; weak to moderate, medium to coarse, subangular blocky; friable; plentiful, micro to very fine, vertical roots; many, micro to very fine, random pores; moderately calcareous; many, medium, friable, light yellowish brown (2.5Y 6/3), horizontal carbonate streaks; 2% gravels & cobbles; gradual, wavy boundary; 15-30 cm thick; alkaline.
Ck1	31-51	Dark grayish brown (2.5Y 4/2 m) & light olive brown (2.5Y 5/4 m); clay loam; weak to moderate, medium to coarse, subangular blocky; friable; plentiful, micro to very fine, random roots; many, micro to very fine, random pores; moderately calcareous; common, fine, friable, light brownish gray (2.5Y 6/3), horizontal carbonate streaks; 5% gravels & cobbles; abrupt, smooth boundary; 12-25 cm thick; alkaline.
Ck2	51-150	Very dark grayish brown to dark grayish brown (2.5Y 3.5/2 m); loam; massive breaking to weak, coarse, subangular blocky; friable; plentiful, micro to very fine, random roots; common, very fine, vertical pores; moderately calcareous; 10% gravels, cobbles & stones; alkaline.

Selected chemical and physical characteristics of Pedon 1 are listed in the table below.

Horizon	pH $CaCl_2$	Organic C %	Total N %	$CaCO_3$ Equiv. %	Sand %	Silt %	Clay %
Apk	7.6	1.89	0.18	3.48	36	38	26
Cca	7.9	1.02	0.07	14.22	24	38	38
Ck1	8.0	0.35	0.04	11.28	33	36	31
Ck2	8.2	0.23	0.02	8.26	41	32	27

PEDON 2: HUGHENDEN SERIES (HND)

Identification:	05-AB, Pedon 2 (P2); Orthic Dark Brown with thin Ap
Location:	SE7-40-1-W4; south central part of benchmark site (see Fig. 2)
Described by:	B.D. Walker; October 15, 1990
Parent material:	Moderately fine textured (fine loamy), moderately calcareous till
Landscape:	Southwest facing mid slope (6% slope) in undulating to hummocky terrain
Drainage:	Well drained
Land use:	Cropland; canola - wheat - fallow rotation

Horizon	Depth cm	Description
Ap	0-11	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d); loam; very weak, very fine, granular; loose; plentiful, micro to very fine, random roots; 2% gravels & cobbles; abrupt, smooth boundary; 7-13 cm thick; acid.
Bt	11-30	Dark brown to brown (7.5YR 4/4 matrix m) & dark brown (10YR 3/3 exped m); clay loam; strong, medium to coarse, subangular blocky; friable; plentiful, micro to very fine, vertical roots; many, micro to very fine, vertical & horizontal pores; continuous, very thin, dark brown (10YR 3/3) clay films in many voids & channels and on some ped faces; 2% gravels & cobbles; clear, wavy boundary; 13-24 cm thick; neutral.
BC	30-50	Dark brown (10YR 3.5/3 matrix m, 10YR 3/3 exped m); clay loam; very weak, coarse prismatic breaking to weak, medium to coarse, subangular blocky; friable; plentiful, micro to very fine, random roots; many, micro to very fine, vertical & horizontal pores; common, thin, dark brown (10YR 3/3) clay films in many voids & channels and on some ped faces; moderately calcareous; many, fine, friable, light yellowish brown (2.5Y 6/4), random & irregular, carbonate streaks and spots; 5% gravels & cobbles; gradual, wavy boundary; 15-25 cm thick; alkaline.
Ck1	50-75	Olive brown to light olive brown (2.5Y 4.5/4 m) & grayish brown (2.5Y 5/2 m); clay loam; massive breaking to very weak, medium to coarse, subangular blocky; friable; few, micro to very fine, random roots; many, micro to very fine, vertical pores; moderately calcareous; many, medium, friable, light yellowish brown (2.5Y 6/4), horizontal streaks and irregular spots of secondary carbonate; 15% gravels, cobbles & stones; abrupt, wavy boundary; 23-45 cm thick; alkaline.
Ck2	75-150	Very dark grayish brown to dark grayish brown (2.5Y 3.5/2 m); clay loam; massive; firm; few, micro to very fine, random roots; common, very fine, vertical pores; moderately calcareous; 10% gravels, cobbles & stones; alkaline

Selected chemical and physical characteristics of Pedon 2 are listed in the table below.

Horizon	pH $CaCl_2$	Organic C %	Total N %	$CaCO_3$ Equiv. %	Sand %	Silt %	Clay %
Ap	5.2	2.35	0.21	--	32	42	26
Bt	6.8	1.01	0.11	0.59	32	34	34
BC	7.9	0.70	0.06	10.59	27	37	36
Ck1	8.1	0.39	0.04	10.82	27	44	29
Ck2	8.1	0.41	0.03	7.28	30	36	34

APPENDIX C: CLBRR BENCHMARK SITE DATABASE

A relational database was designed for the Soil Quality Evaluation Program, Benchmark Site Study. With a host of data types on a variety of measured entities, the main goal was to attain efficient data storage that would support reasonably simple manipulation and retrieval. The Benchmark Site Database achieved this goal by using many small files, developed in dBASE IV (Ver. 1.5). Each file contains similar types of data on similar kinds of soil and landscape entities. Most files can be linked to perform analyses across data types and landscape entities, as demonstrated in Table 3 above.

Currently the files contain baseline, reference or on-going data. Results of repeat measurements will be entered in files like those containing baseline data so that temporal comparisons can be made. As yet only a few sites have a complete set of baseline data. New data is checked and refined before being appended to the database; occasionally old data is updated if corrections or calculated values need to be added.

The dBASE files that comprise the database system are listed and briefly described below. File name extensions, always .DBF but sometimes including .DBT and others, are omitted. File names that begin with BS indicate baseline data. Most files contain data on all benchmark sites, if appropriate and available. Extracting data by site (and other filters) can be done quite easily.

SITEINFO Reference file. General information about each benchmark site including identification, location, agroecological region, major soils and landform, potential degradation problem(s), type of management, site manager, farm co-operator, and so on.

BSPTINFO Baseline and reference data. Landscape information about the field sampling points, e.g. slope position and shape, soil series/variant, map unit, etc.

BSTOPO Baseline and reference data. Spatial data for creating contour maps and locating field sampling points; relative or “real world” coordinates, including elevation, in meters.

BSDESCR Baseline and reference data. Descriptions (color, texture, structure, etc.) of the soil horizons that were sampled.

BSSLCHEM Baseline data. "Routine" chemical data (pH, total C, total N, $CaCO_3$ equivalent, CEC and exchangeable cations, available P, and available K) on all samples.

BSPTSIZ Baseline data. Particle size and surface area on selected samples.

BSEALFE Baseline data. Extractable aluminum and iron, analyzed by various methods, on selected samples. (Analysis done mainly on humid region soils, i.e. Podzols)

BSECSEL Baseline data. Electrical conductivity, soluble cations and SAR for selected samples.

BSTTLELM Baseline data. Total analysis, for at least 14 elements (Al, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, and Zn), on selected samples.

BSNO3_N Baseline data. Nitrate-N data on selected deep samples from selected sites.

BSCS137 Baseline data. $Cesium^{137}$ counts expressed per unit weight and unit area for selected samples and sites. Includes bulk density by the Kubiena box method.

BSSLMINE Baseline or reference data. Mineralogical analysis (semi-quantitative results) of clays from selected samples.

BSEM38 Baseline data. Electrical conductivity values (0-60 & 0-120 cm ranges) derived from electromagnetic inductance readings at selected points and selected sites.

BSMSTRN Baseline or reference data. Moisture retention at 0, 10, 30, 60, 100, 333, and 1500 cm water column equivalent, determined on cores from pedons, and at 4 and 15 bars determined on ground sample. Includes bulk density determined by the core method.

BSAGREG Baseline data. Dry aggregate analysis (rotary sieve) results from selected sites.

BSKSAT Baseline data. Saturated hydraulic conductivity, measured by Guelph Permeameter, for 2 or 3 depths at selected field points

BSPTRMST Baseline data. Penetrometer resistance and moisture content (dated) for 3 or 4 depths at selected field points. Spring and fall results are included at some sites to compare moist and dry seasons.

BSTHWRM Baseline data. Earthworm counts and weights for selected horizons at selected sites (mainly humid region sites).

BSBIOPRT Baseline data. Biopore and root counts for selected depths at selected sites (mainly humid region sites).

YLDINFO On-going reference data. Yearly information on crop type, harvest notes and the file that contains the yield data for each site.

GRAINYLD On-going data. Grain and residue yield (kg ha^{-1}), harvest index (%) and residue - grain ratio for grain crops (i.e. seed-bearing crops such as cereals, oilseeds, etc. where the seed is separated from the rest of the above-ground dry matter) by site, sampled field point, year and crop type.

FORAGYLD On-going data. Dry matter yield (kg ha^{-1}) of forage crops by site, sampled field point, year and type of forage crop.

Note 1: Yields of other types of crops (e.g. sugar beets, sweet corn, potatoes) will be reported in different yield files than the grain crops because harvesting methods and yield parameters differ.

Note 2: Climate data from the Campbell Scientific monitoring stations (installed at a few sites) will likely be added to the database in the near future. Hourly, daily and monthly summary files are envisaged.