IMPROVING WETLANDS FOR FORESTRY IN ALBERTA

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ABSTRACT

In Alberta, there is concern that the productive forest land base is decreasing as more forest land is withdrawn for nonforestry purposes. In 1985, a wetland drainage and improvement program was instituted under the Canada-Alberta Forest Resource Development Agreement (FRDA) to develop optimal silvicultural regimes for increasing growth of commercial tree species on drained wetlands, and to assess the effects of drainage on tree growth, ground vegetation, soils, peat, and local hydrology. Three experimental areas were chosen and surveyed. The first is a treed swamp, the second a tree bog, and the last a tread fen. The experimental design requires that: (1) on each area, a portion be designated for ditching and the remainder preserved as control; and (2) pretreatment data as well as post-treatment data be obtained from each site. Changes in groundwater table levels following drainage of the treed swamp are discussed.

RÉSUMÉ

En Alberta, on s'inquiète de plus en plus du fait que la surface de terres forestières productives est en déclin, à mesure que de plus en plus de ces terres sont utilisées à des fins non forestières. En 1985, un programme d'amélioration et d'assèchement de terres humides a été mis en oeuvre dans le cadre de l'Entente Canada-Alberta sur la mise en valeur des ressources forestières (FRDA), pour un développement optimal des régimes sylvicoles visant à intensifier la croissance d'espèces commerciales d'arbres sur les terres humides asséchées, et à évaluer les effets de l'assèchement sur la croissance des arbres, la végétation de surface, les sols, la tourbe et l'hydrologie locale. Trois zones expérimentales ont été choisies et étudiées. La première est un marécage boisé, la seconde une tourbière ombrotrophe (bog) boisée, et la troisième une tourbière minérotrophe (fen) boisée. La conception expérimentale du projet requiert ce qui suit : 1) dans chaque zone, une partie du terrain doit être prévu pour l'aménagement des fossés, le reste étant préservé pour servirr de témoin; 2) des données pré-traitement aussi bien que post-traitement doivent être obtenues pour chaque site. On évalue les variations du niveau de la nappe phréatique après l'assèchement du marécage boisé.

INTRODUCTION

In Alberta, concern about the decreasing productive forest land base as more forest land was withdrawn for other uses led foresters to consider increasing the wood-growing capability of forested wetlands. Alberta contains nearly 13 million ha of peatlands, about 11% of the peatlands in Canada (Tarnocai 1984); about 4 million of these are considered suitable for drainage and conversion to productive forests. Several drainage projects were initiated in Alberta, all but one of which are less than 5 years old (Hillman 1987). Consequently, very little information exists on the long-term effects of forest drainage in Alberta on tree growth and the environment. It is believed, however, that the potential in Alberta for increasing tree growth through peatland drainage is good (Paivanen 1980).

In 1985, in response to the concerns outlined above, the Canadian Forestry Service (CFS) and the Alberta Forest Service (AFS) prepared a research and development proposal to establish three experimental drainage areas in Alberta's boreal forest. The Wetland Drainage and Improvement Program, as it is called, is funded under category B.3 (forestry research, development, and demonstrations) of the Canada-Alberta Forest Resource Development Agreement (Anonymous 1984a). The CFS and AFS closely cooperate in all aspects of the program.

Aimed at developing cost-effective and environmentally sound technology appropriate for the boreal forest, the program's major objectives are as follows:

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1. to develop optimal silvicultural regimes for increasing the growth of commercial tree species on wetlands with lowered water tables; and

2. to assess the effects of drainage on soils, local hydrology, ground vegetation, and tree growth.

The experimental design requires that portions of each study area be designated for ditching and the remainder be preserved as control. This scheme is necessary when ditching is undertaken early in a study, and meaningful amounts of pretreatment data cannot be obtained. The main disadvantge of this approach is the difficulty in deciding if differences between control and treated sites are treatment effects or the result of differences in site characteristics.

The best method of evaluating drainage effects is by repeated measurements on the same site before and after drainage (Heikurainen 1964). In this method, the uncertainty due to site differences is reduced. The disadvantage, of course, is the long waiting period before treatment is implemented and results are available. Fortunately, pretreatment data for only 1 or 2 years are required to evaluate the effects of ditching on some variables, such as groundwater table levels. Because the ditch network construction schedule for the Canada-Alberta Wetland Drainage and Improvement Program allows for the gathering of some pretreatment data, both methods outlined above are being employed in this study.

In summer 1985, a CFS-AFS team selected three forested wetlands as experimental drainage areas. The forest vegetation on each originated after a fire. The first, Goose River, is a coniferous swamp; the second, McLennan 28, is a treed bog; and the third, Wolf Creek, is a treed fen (Fig. 1). The tree areas were surveyed, instrumented, and sampled in a similar manner. For this reason, and because of space and time constraints, only Goose River will be discussed in detail in the ensuing discussion.

RESEARCH PLAN FOR THE CANADA-ALBERTA AGREEMENT EXPERIMENTAL DRAINAGE AREAS

The division of each experimental area into drained and control sections is an essential feature of the research plan. The component investigations of the plan are outlined below:

1. Evaluation of the effects of drainage on tree growth

It is essential to establish and to measure tree growth permanent sample plots on both drained and control (undrained) areas. There must be a commitment to remeasure the plots periodically for at least another 20 years.

2. Adaptability of tree species

The suitability of different tree species for planting on drained wetlands needs to be assessed.

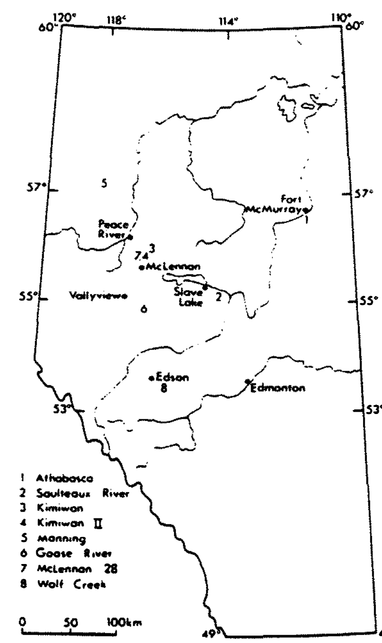

Figure 1 Locations of FRDA experimental drainage areas (6, 7, and 8) in Alberta.

3. Groundwater table levels

Groundwater table investigations are essential to confirm if the desired water levels were attained, and to determine the relationships between tree growth and water table depth. If the drop in groundwater table level is excessive, the site may become too dry.

4. Ground temperature

Ground temperature will be affected by groundwater level control operations. It is an important factor affecting the ground freeze-thaw cycle as well as tree root growth and development.

5. Nutrient level studies and fertilization trials

Existing levels of nutrients important for tree growth, such as nitrogen (N), phosphorus (P), and potassium (K), need to be determined on the experimental drainage areas. The availability of these nutrients also needs to be evaluated.

6. Ground vegetation composition

There is little or no information on the effects of drainage for forestry on ground vegetation composition in Alberta.

7. Peat subsidence

Because fibrous surface peat has a very high porosity, draining this material can result in a noticeable drop in the ground surface level. After drainage, the surface peat is no longer supported by the buoyant force of the water, and the peat volume diminishes as aeration leads to more rapid breakdown of peat material.

8. Water quality

These are three areas of water quality that need to be considered when investigating the impact of forestry drainage operations: sediment transport, changes in inorganic water chemistry, and changes in organic water chemistry.

There is scant information on the effects of forest drainage on organic chemical water quality. We do not know what components of peat have the potential to become water pollutants, nor do we know the accepted tolerable limits for such pollutants.

SITE DESCRIPTION

The Goose River experimental drainage area is located in the mixedwood boreal forest region of Alberta. It is a black spruce (Picea mariana) swamp situated about 35 km southeast of Valleyview (Fig. 1) centered on 14-68-19-W5 (54°54'N, 116°45'W; elevation 850 m). The mean annual temperature at Valleyview is 2.3°C. The average January and July temperatures are -15.9°C and 15.8°C, respectively. At the Sweathouse tower lookout adjacent to the site, the average July temperature is 14.7°C. The average annual precipitation for Valleyview is 519 mm, 302 mm of which falls during May through September. The average May-September precipitation for the Sweathouse tower lookout is 413 mm (Anonymous 1984b). The area averages 100 frost-free days annually and 2000 growing degree-days during May through September (Longley 1968).

The swamp, which covers about 320 ha, is characterized by thin (less than 1 m) peat over clay. A small creek runs westward through the site cutting through a fairly steep ravine with slopes of about 40%, near the swamp's western edge.

The swamp supports a black spruce stand 40-50 years old and a shrub understory dominated by Labrador tea (Ledum groenlandicum). The herb stratum consists primarily of three-seeded sedge (Carex trisperma), common horsetail (Equisetum arvense), woodland horsetail (E. sylvaticum), and bog cranberry (Vaccinium vitis-idaea), with lesser amounts of cloudberry (Rubus chamaemorus). Northern reed grass (Calamagrostis inexpansa) and small bog cranberry (Oxycoccus microcarpus) are constant species but have generally lower cover. Sphagnum angustifolium and S. magellanicum are the predominant mosses in the wetter areas; S. fuscum and Pleurozium schreberi predominate in the drier areas. A few patches of reindeer lichen (Cladina mitis) occur in more open, drier, and elevated areas (Johnson 1987).

METHODS

In 1985, a weather station consisting of a recording precipitation gauge and a recording hygrothermograph was installed on the Goose River site. Survey lines were cut, topographic surveys conducted, and a topographic map produced at a scale of 1:5000 with contour intervals of 0.5 m.

Preliminary peat, water, and vegetation surveys and sampling programs were completed on a rectangular grid with 200 m sampling intervals to determine wetland, vegetation, and peat types; peat depths, nutrient status, and other site characteristics. Peat cores were taken with a Macaulay-type sampler with an inside diameter of 4 cm. Core samples (6 cm long) were taken at about 15-cm intervals for chemical analyses. The pH of the wet peat was determined immediately below the sampled segment using pH paper. Saturated hydraulic conductivity was measured in the top 1 m of soil using the piezometer method (U.S. Department of the Interior 1984). Water samples were taken at each coring sites.

The core samples were oven-dried at 70°C; the moisture content (volumetric and gravimetric) and bulk density were calculated. These samples were then ashed at 480°C and the ash dissolved in 0.18 N HCl. The extract was analysed for total elements (Ca, Mg, Na, K, Al, Ti, Pb, As, Cu, Fe, Mn, Zn, Ni, S, P) by an inductively coupled plasma spectrophotometer (ICPS). Available nitrogen, phosphorus, and potassium were determined using the phenoldisulphonic acid method (Jackson 1958, p. 197), the ammonium fluoride method (Sheldrick 1984), and the ammonium acetate extraction method (Atkinson et al. 1958, p. 29), respectively.

The water samples were acidified with HNO_3 to a final concentration of 0.6 N and then analyzed by ICPS. Total nitrogen (N) for peat and water samples was determined by the modified Kjeldahl method using a technicon digestion block and Kjeltec Auto 1030 Analyzer (Tecator) (Jackson 1958, p. 183).

A drainage ditch network design was prepared using field observations, a topographic map, and enlarged aerial photos. Toth's synthetic hydraulic curve method (Toth and Gillard 1984) was used to find the optimum ditch spacings.

The drainage plan for the Goose River swamp provides for drainage of 135 ha north of the creek using mostly 40 m ditch spacings (Fig. 2). Provision was also made to evaluate different ditch spacings (30, 40, and 50 m) on a homogeneous portion of the swamp.

The ditch network was marked and 5-m rights-of-way were cleared with a D6 during winter 1985-86, when the ground was frozen. Ditch construction with a Lannen S10 excavator began in June 1986 and was completed in September 1986. About 37 km of lateral ditches and 2.73 km of main ditches were excavated, resulting in a drainage ditch density of 294 m ha^{-1}. The ditches are 0.9 m deep and about 1.4 m wide.

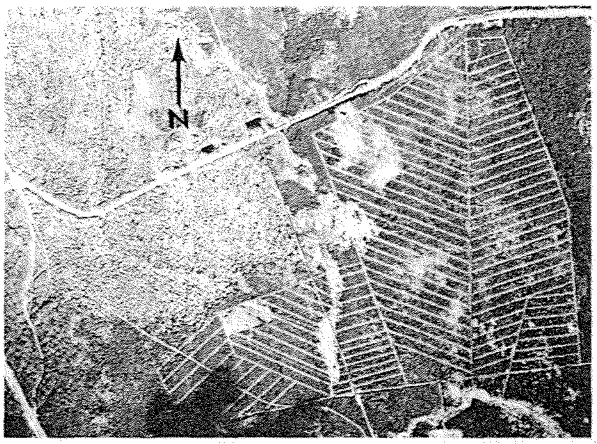

Figure 2 Aerial photograph of ditch network on Goose River experimental drainage area (scale 1:24 500).

In summer 1986, four transects were established, one on the control site south of the creek, and three at different ditch spacings, perpendicular to ditch lines on the area to be drained. Each transect was instrumented, sampled, and surveyed to measure the effects of ditching on groundwater table levels, ground temperatures, ground vegetation composition, and peat subsidence. Peat, groundwater, and foliage samples were collected from all transects to determine the existing level of nutrients important for tree growth.

1. Permanent sample plots will be established near each transect to measure tree growth. Some plots will be established along the instrument transects, perpendicular to the ditches so that tree growth can be related to distance from the ditch. Pretreatment growth data will be gathered through destructive sampling and stem analyses.

2. To determine which tree species adapt well to drained conditions, a 2-ha portion of the Goose River experimental area was cleared. It will be ditch-mounded in 1987 and later planted to lodgepole pine, white spruce, and black spruce. Ditch-mounding is an operation in which the spoil from ditches is distributed in small piles between the ditches to serve as planting mounds for tree seedlings.

3. Groundwater table configurations were monitored through a system of groundwater wells. Between 7 and 12 5-cm diameter wells were installed on each transect in 1986. Pressure transducers connected to battery-operated data loggers were inserted in 8 of the wells to provide continuous records of changes in water levels; data were recorded at 90-minute intervals. The remaining wells were measured with a carpenter's tape. One 15-cm diameter well on the 40-m spacing, and one on the 50-m spacing was equipped with a water level recorder.

4. One temperature probe, about 3 cm in diameter, was installed on each transect. Each probe, connected to a battery-driven data logger, supported sensors at the air-soil interface, and at depths of 0.075, 0.15, 0.30, 0.45, and 1.0 m. Temperature data were recorded at 90-minute intervals (3 hours in winter).

5. Peat, foliage, and groundwater samples were analyzed for the same 15 elements (including total nitrogen) tested for on the 200-m grid. The available nutrients (N, P, and K) in peat were analyzed by the methods referred to earlier.

   Thinning and fertilization permanent sample plots were established on 5.8 ha in 1987. The split plot design incorporated 3 thinning treatments, 8 fertilization treatments, and 4 replicates, for a total of 96 plots. Thinning treatments consisted of no thinning, and thinning to 1600 and 2400 stems ha^{-1}. Fertilization treatments consisted of applications of N, P, NP, PK, NK, NPK, and no fertilizer.

6. Forty-eight permanent sample plots, each 1 m^2, were established near instrumented transects in 1986 to measure the effects of drainage on ground vegetation composition. Each plot will be remeasured the first year after drainage, and then every other year subsequently.

7. To measure subsidence, three 13-mm diameter steel reinforcing rods were driven into mineral soil on each transect, so that 15 cm projected above the ground surface. The projection above ground will be measured once a year after drainage.

8. Sediment loads and inorganic chemical water quality were monitored periodically at one location upstream and two locations downstream from points where water from the drainage network's main ditch enters the creek. Sediment samples were collected in glass milk bottles using a DH-48 sediment sampler. Total suspended sediment sampler. Total suspended sediment was determined using methods described in Anonymous (1971). Inorganic chemical water quality samples were collected as 'grab' samples in 250-ml plastic bottles and analyzed for total nitrogen and the 15 elements mentioned earlier. Sampling began before ditching took place.

RESULTS AND DISCUSSION

During ditch excavation it was evident that, even though the ditches were dug to a depth of 0.9 m, most of the water running into the lateral ditches came from the interface between the organic and mineral (clay) soils. At Goose River, the average depth of this boundary is 0.6 m. It would appear, therefore, that the lateral ditches could have been shallower, and dug to a depth of, say, 0.7 m. This would have resulted in a greater machine production rate and a reduction in stress on the machine because it would have excavated less clay. The lateral ditches, in particular, do not require large cross-sections to intercept and convey water to the main ditches, and would remain functional at the shallower depth. Although ditch depth does control water table drawdown, it is believed to be less important than ditch spacing in controlling groundwater levels (Heikurainen 1964).

The Goose River site has less pretreatment data than either of the other experimental areas, but the data are sufficient to show changes in groundwater table levels resulting from drainage.

Data from the pressure transducer located 2.5 m from a ditch in the variable ditch spacing area indicated that the effect of ditching was instantaneous (Fig. 3). Between September 16 and 19, 1986 (before ditching), the water table fell at a rate of about 0.7 cm d^{-1}. On September 19, the day this particular ditch was excavated, the water table dropped sharply. Between September 19 and 25 (after ditching), it dropped 20 cm or 3.3 cm d^{-1}. During the period September 25-27, 36 mm of rain fell, causing a rise of 14 cm in the water table. In the interval between storms the water table dropped 9 cm (1.5 cm d^{-1}). A storm on October 3-4 produced 28 mm of rain and a 13-cm increase in the water table level. Thereafter, the water table level dropped at a rate of 5.5 cm d^{-1} until a small storm (6 mm) on October 6 and 7 interrupted its descent. The final portion of the hydrograph (Fig. 3) shows a drip in water level of 1.2 cm d^{-1}. On October 17, the water level was 44 cm below the ground surface, compared with 20 cm before ditching was implemented on September 19. Although the contributions from rainfall almost restored the water table to its September 16 level, the presence of the ditch prevented this level

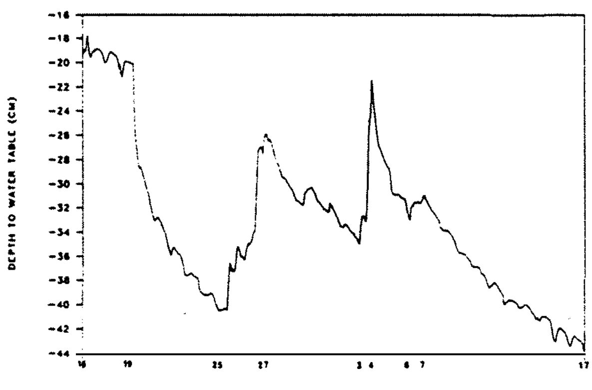

Figure 3 Groundwater table levels immediately before and after ditching, 2.5 m from the nearest ditch, Goose River site, 50-m spacing.

from being sustained, or from dropping at the original predrainage rate.

Water table profiles obtained from transects on the control area and on the area with variable ditch spacings (Figs. 4-7) show water table drawdown as a function of distance from the ditch. In each case, the precise level of the ground surface (the uppermost curve in each plot) was determined by differential leveling.

Measurements from two pressure transducers located in wells 32 m apart showed that the hydraulic gradient on the control (Fig. 4) approximated the topographic slope (1.5%), and that groundwater flow was directed north toward the creek. There was little difference between the average water table level for the before-drainage period and for the after-drainage period (Fig. 4).

Before drainage, a near-horizontal water table prevailed on the 40-m transect (Fig. 5a). The levels ranged in depth from 10 to 45 cm. After drainage, the profiles bent downward toward the ditches (Fig. 5b). The average profiles for the 40-m spacing (Fig. 5c) show that there was a drop in water levels of 10 cm at the center between ditches, and a 25- and 40-cm drop near the ditches.

The average groundwater table profile before ditching for the 30-m spacing (Fig. 6) lay parallel with the ground slope about 20 cm below the surface. The hydraulic gradient indicates that the groundwater flowed southward toward the creek. After ditching, the central portion of the profile was at least 15 cm lower than before, while near the ditches the average water table depth had dropped by 25-30 cm to 50 cm. The 30-m spacing produced a greater drop in groundwater table levels near the center between ditches than did the 40-m spacing.

On the 50-m spacing transect, the average profiles (Fig. 7) show that drainage with 50-m spacings lowered the water table less than 10 cm in the central portion of the transect. Evidently the 50-m spacing had less effect than the 40-m spacing on groundwater levels near the central portion of the transect. Near the ditches, a drop of 15 to 30 cm was achieved.

Although no statistical analyses were carried out to establish the significance of these results, it is clear from the data that drainage lowered the water table on the Goose River experimental drainage area. If the drawdown can be characterized by any one profile, it would be the "after" drainage profile in Figure 5, because Goose River was ditched mostly with 40-m spacings. The average profiles before and after drainage indicate that, regardless of ditch spacing, ditching created a drawdown of about 30 cm 2-3 m from the ditch. Ditch spacing controlled how far the influence of the ditch would extend. Evidently, as the distance between ditches increased, the drawdown at the center between ditches decreased.

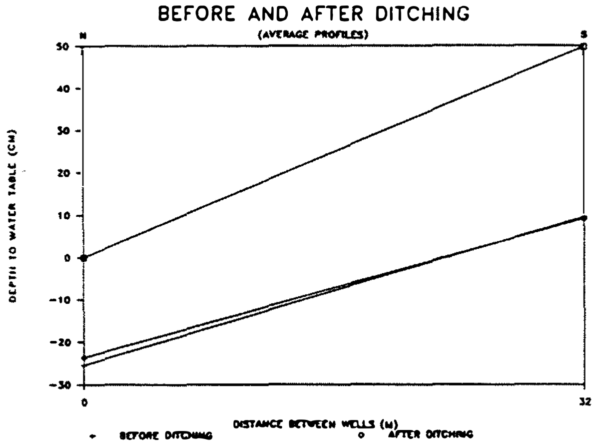

Figure 4 Goose River water table profiles, control area.

Because ditching produces a convex drawdown curve, it is important in forest drainage studies to know the relation between tree growth and depth to water table, and to identify what is meant by "optimum depth to water table" for different tree species. Trees at the center between ditches may respond differently from those located near ditches. These problems will be addressed in future studies on the Goose River site.

CONCLUSIONS

For the Goose River experimental forest drainage site, where shallow peat overlies clay, it appeared from observations of the ditching operation that the lateral ditches could have been shallower. Most of the water released by ditching issued from the interface between the organic material and the mineral soil.

Preliminary investigations of different ditch spacings (30, 40, and 50 m) on groundwater levels showed that water table profiles between ditches were roughly parabolic. Near the ditches, groundwater levels dropped about 30 cm. At the center between ditches, the water table dropped about 15 cm for the 30-m spacing, 10 cm for the 40-cm spacing, and less than 10-cm for the 50-cm spacing. Studies relating groundwater table profiles to tree growth are planned.

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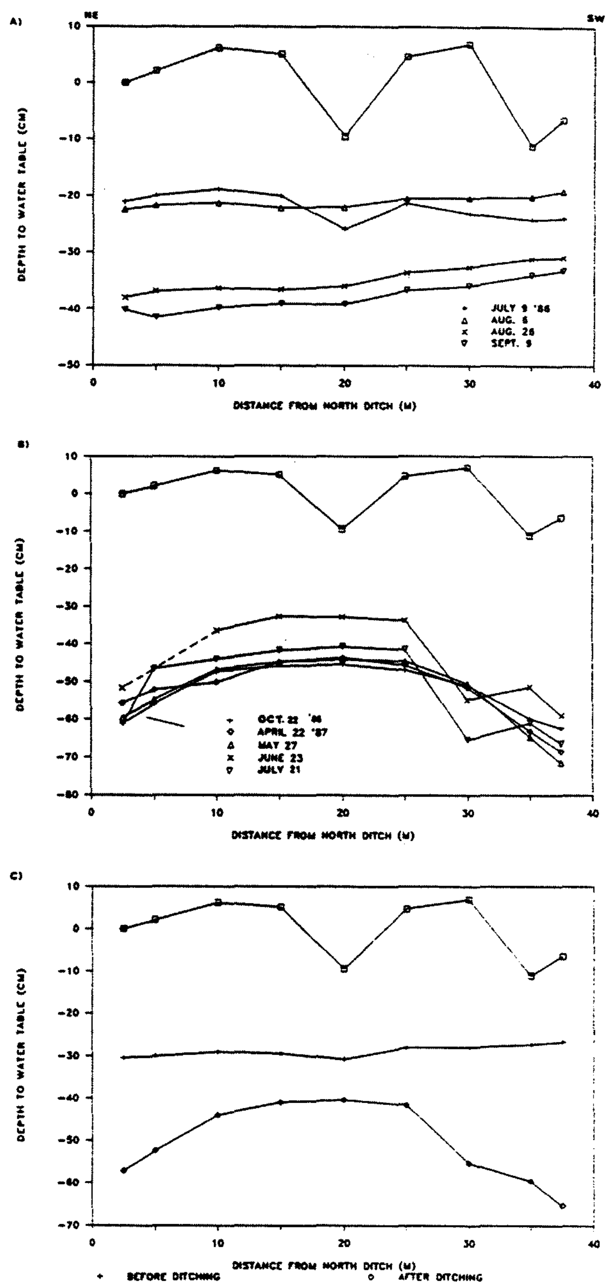

Figure 5 Goose River water table profiles, 40-m spacing; A) before ditching, B) after ditching, C) average profiles.

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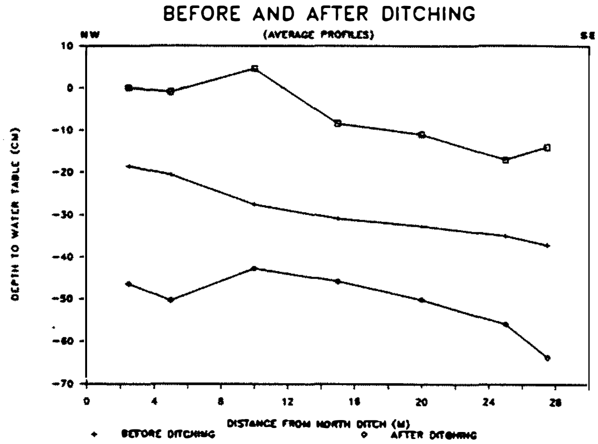

Figure 6 Goose River water table profiles, 30-m spacing.

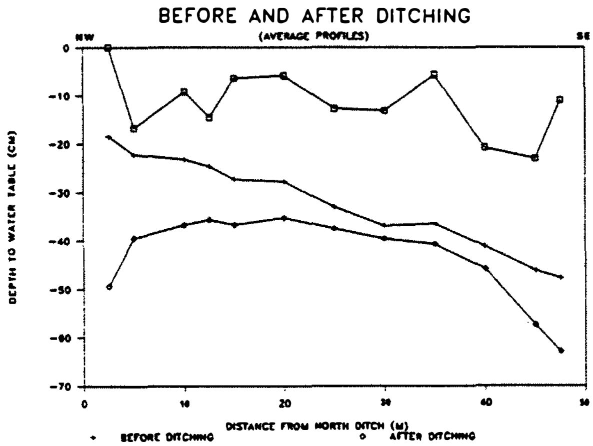

Figure 7 Goose River water table profiles, 50-m spacing.

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