EFFECTIVENESS OF SOIL CONSERVATION PROCEDURES EMPLOYED ON RECENT MAJOR PIPELINE CONSTRUCTION IN WESTERN CANADA[1]

Donald M. Wishart[2] and John W. Hayes[3]

ABSTRACT

The effectiveness of a soil conservation method employed on recent major pipeline construction in Western Canada was investigated. Prior to any major construction activities, topsoil was salvaged over the full right-of-way. Following pipeline lowering and backfilling, subsoils were ripped and debris was removed from the subsoil. The topsoil then was replaced, cultivated and fertilizer applied. Near the end of the first growing season after construction, vegetation, and soil characteristics were monitored. Data collected indicate that efforts to conserve soil quality were successful. Construction did not result in impairment of topsoil or soil compaction. Depressed crop production was observed on the right-of-way in drier regions during the first growing season after construction. The depressed crop production was determined to be related to the very dry soil conditions on the right-of-way which resulted from the extensive working of soil. Effects of dry soil conditions along the right-of-way did not persist in the second growing season.

INTRODUCTION

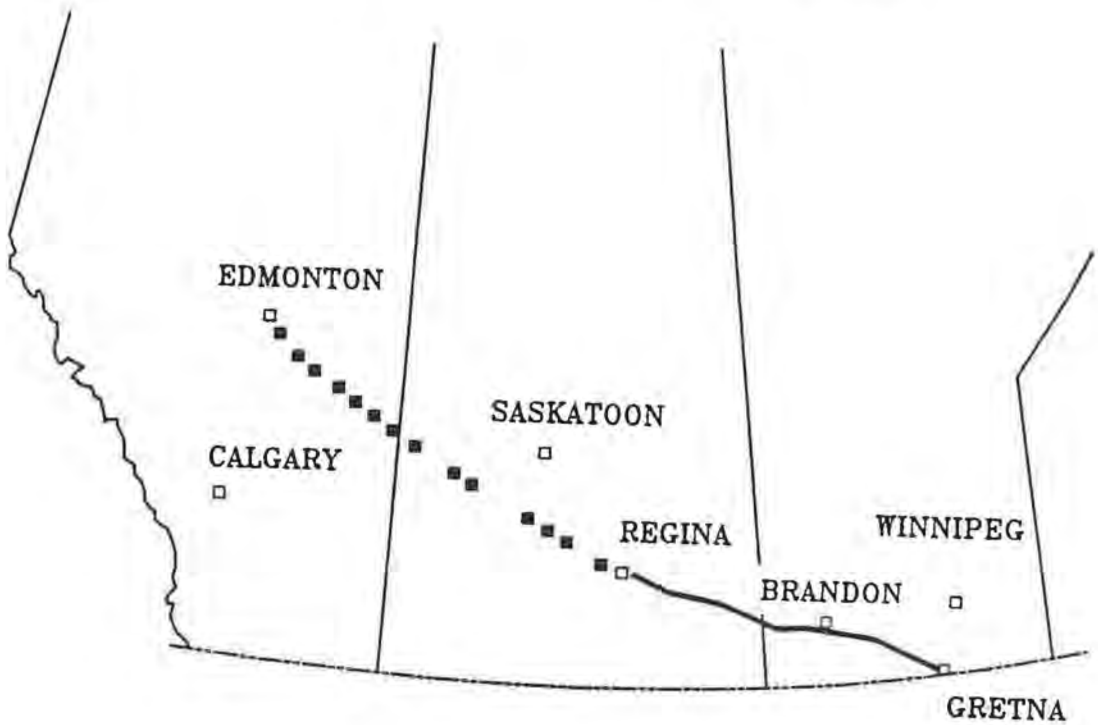
Interprovincial Pipe Line Company (IPL) undertook extensive capacity expansion and operational improvements to its crude oil pipeline system in Western Canada (Figure 1). In 1986, IPL constructed 540 km of 508 mm O.D. pipeline continuously from Regina, Saskatchewan to Gretna, Manitoba. Approximately 87 km of 508 mm O.D. pipeline were constructed in 15 segments between Edmonton, Alberta and Regina, Saskatchewan in the summer of 1987.

[1] Paper presented at the 1988 AC/CLRA Conference, Kananaskis, Alberta, September 22-23, 1988.

[2] Donald M. Wishart, Manager, Environmental Services, Interprovincial Pipe Line Company, P.O. Box 398, Edmonton, Alberta, Canada T5J 2J9.

[3] John W. Hayes, Environmental Coordinator, Environmental Services, Interprovincial Pipe Line Company, P.O. Box 398, Edmonton, Alberta, Canada T5J 2J9.

Figure 1: 1986 AND 1987 PIPE LINE CONSTRUCTION PROGRAM



Prior to construction, IPL conducted environmental impact assessments of the projects and contacted each landowner. Since nearly all of the construction right-of-way was located on agricultural lands, soil conservation was identified as the most significant environmental issue. Pipeline construction can affect soil quality in largely two ways.

Mixing of topsoils and subsoils during pipeline construction has been observed to impair agricultural capability (Button and de Jong 1970, Shields 1980, Hardy Associates Ltd. 1983, Culley and Dow 1988). Dilution of organic matter and changes in texture can affect moisture and nutrient holding capacities of the soil, as well as structural and drainage characteristics. The introduction of salts or sodium from subsoils can alter ionic balance, pH, nutrient availability and structure.

Repeated travel of heavy equipment along the right-of-way during pipeline construction can produce compacted layers (pans) within normal rooting depths (Mackintosh et al. 1984). These compacted layers posses vastly different chemical (Kemper et al. 1971) and physical (Raney 1971) properties than bulk soil. The compacted layers can result in poor internal drainage and restricted root penetration. The effects on crop production apparently varies among species, moisture and fertility regimes (Tomar et al. 1981) and depth to compacted layer (Wilhelm and Mielke 1988).

This paper describes both the approach, used during the recent pipeline construction programs to minimize the impact of construction on soil quality, and the effectiveness of this approach.

CONSTRUCTION PROGRAM

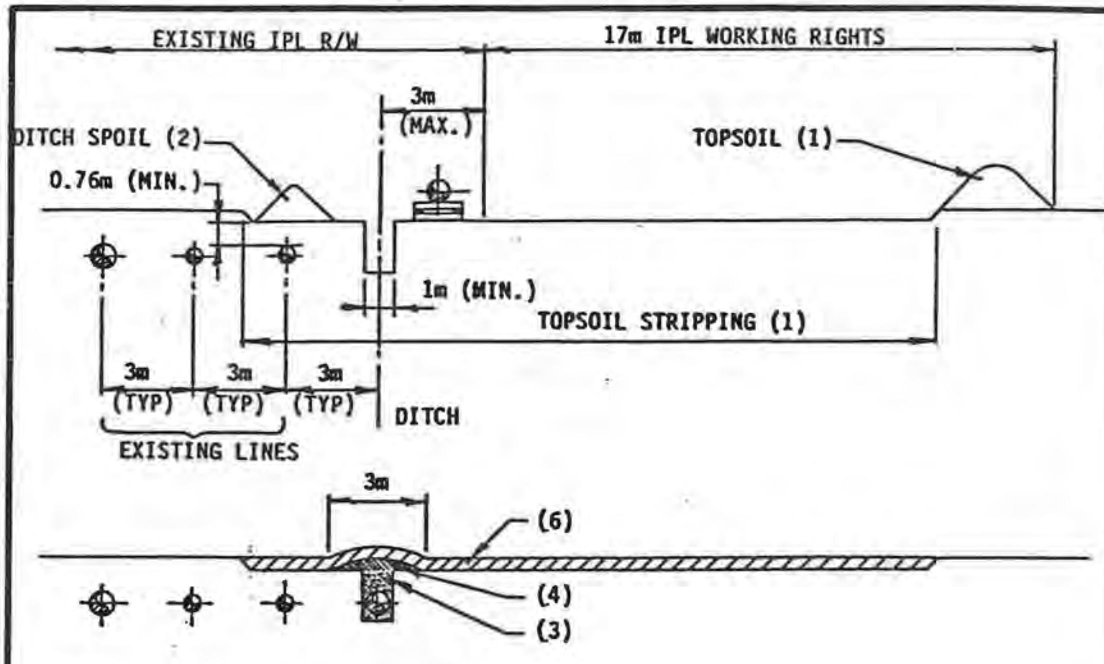
In 1986 and 1987, the construction right-of-way was typically 25 m in width as defined by legal agreements. The pipe was laid approximately 3.0 m away from the closest existing IPL pipeline on a right-of-way which contained three or more other pipelines.

Prior to any major construction activities, topsoil was carefully salvaged from the full construction right-of-way and stockpiled at the edge of the working side (Figure 2). The merits of this full right-of-way stripping method versus other soil conservation techniques are discussed more completely in Mutrie and Wishart (1988) but are summarized as:

- o minimizes damage to topsoil structure that can result from repeated travel of heavy construction equipment on the topsoil surface,
- o avoids introducing casual construction debris and wastes (e.g. spent welding rods, paper products) into the topsoil,
- o allows work on moist soil without the potential of rutting topsoil into subsoil and subsequent mixing,
- o fully defines limits of the right-of-way and prevents indiscriminate off right-of-way travel, and
- o the large separation of topsoil and subsoil stockpiles avoids the potential for overlapping of piles and subsequent mixing.

After installing the pipe and backfilling the trench, the subsoils exposed to construction traffic were reclaimed. All rocks and debris were removed from the subsoil surface. The subsoil was then ripped with any one of a variety of deep tillage devices used during the two construction seasons. The ripping was undertaken to a minimum of 30 cm below the subsoil surface and was conducted in a criss-cross pattern to achieve effective coverage. Any rocks and debris brought to the surface were removed and, in most cases, the right-of-way was left with less rocks in the upper 45 to 60 cm (ie. topsoil depth plus 30 cm of subsoil) than off right-of-way lands. The subsoil surface was disced prior to

Figure 2: Soil Conservation Procedures Used During 1986 and 1987 Construction Programs.



NOTES:

1. STRIP TOPSOIL FROM UNDER SPOIL PILE AND ACROSS WORKING SIDE. STOCKPILE TOPSOIL ON WORKING SITE AS SHOWN. MAINTAIN A MINIMUM OF 0.76 m COVER OVER HOT LINES BY REDUCING THE DEPTH OF TOPSOIL STRIPPED AS NECESSARY. WHERE 0.83 m OR LESS COVER EXISTS PRIOR TO TOPSOIL STRIPPING, NO TOPSOIL STRIPPING SHALL BE ALLOWED OVER THE HOT LINES AND MATTING, BLANKETS OR SHEATHING SHALL BE PLACED OVER THE TOPSOIL AND UNDER THE DITCH SPOIL PILE TO PREVENT MIXING. NO TRACKED EQUIPMENT OR EQUIPMENT LARGER THAN A MODEL 12G GRADER IS ALLOWED OVER HOT LINES. NO STRIPPING OR WORK OF ANY KIND ALLOWED OVER HOT LINES WHERE THERE ARE SLEEVES OR IN SOFT GROUND. SNOW FENCE TO BE INSTALLED AROUND THESE AREAS IDENTIFIED AS SLEEVED.
2. STOCKPILE DITCH SPOIL OVER HOT LINES AS SHOWN. NO DITCH SPOIL STORAGE OVER HOT LINES WHERE THERE ARE SLEEVES OR IN SOFT GROUND.
3. BACKFILL WITH DITCH SPOIL ONLY.. RECOVER DITCH SPOIL WITH A MORMON BOARD OR EQUIPMENT LIMITED TO A MODEL 12G GRADER.
4. SPREAD ANY EXCESS DITCH SPOIL OVER 3 m AREA SHOWN AND TAPER TO LIMIT HEIGHT TO APPROXIMATELY 0.3.m.
5. CULTIVATE WORKING AREA PRIOR TO REPLACING TOPSOIL.
6. SPREAD TOPSOIL EVENLY OVER ENTIRE AREA STRIPPED. EQUIPMENT WORKING OVER HOT LINES LIMITED TO MODEL 12G GRADER.
7. CULTIVATE ENTIRE CONSTRUCTION R/W AFTER TOPSOIL REPLACEMENT AND THEN FERTILIZE ENTIRE CONSTRUCTION R/W.

topsoil replacement in order to prepare a reasonably smooth surface. This activity minimized infiltration and subsequent mixing of topsoil into the large subsoil fissures created during ripping.

With completion of subsoil treatment, topsoil was carefully returned to the right-of-way. Fertilizer was added to the topsoil for two reasons. First, to alleviate any potential loss of fertility that could have resulted from construction activities; and second, to encourage rapid replenishment of organic matter in the stripped and fallowed right-of-way soils through increased plant productivity in the following growing season. The topsoils were then tilled with a spring board cultivator to leave a rough, lumpy surface resistant to erosion and conducive to trapping of snow and infiltration of moisture.

Generally warm temperatures, dry conditions, and light to moderate winds provided ideal pipeline construction conditions through both construction periods. Topsoil stripping and replacement occurred only when soils were relatively dry to avoid damage to topsoil structure and minimize the risk of mixing topsoil with subsoil.

MONITORING PROGRAMS

Throughout both construction programs, environmental specialists continuously monitored construction activities to ensure that the soil conservation procedures were successfully implemented.

Detailed monitoring programs were undertaken during the 1987 and 1988 growing seasons to identify any locations adversely impacted from pipeline construction. Low level helicopter reconnaissance, followed by ground inspections at any identified problem sites, were conducted along the right-of-way in both spring and autumn. The spring monitoring program was conducted prior to extensive vegetation establishment thereby allowing a nearly unobstructed view of the ground surface. A quantitative monitoring program was conducted each August to coincide with the period just prior to harvest.

The quantitative monitoring program included soil and vegetation sampling at 61 separate sites. The sites were selected on the basis of suspected problems identified earlier, or representative of a typical soil or crop pattern. For comparative purposes, sampling was conducted on the 1986 and 1987 trench line, the 1986 and 1987 construction working side, off right-of-way control, and on the existing pipeline right-of-way on which three or more pipelines had previously been constructed.

The off right-of-way control site was located approximately 25 m from the ditchline in order to ensure that it had been unaffected during pipeline construction. All the sampling locations for each sampling site were selected to ensure they were of similar crop type, farm management, aspect and drainage. In order to minimize the effect of natural variability, three repetitions of measured parameters were conducted at each sample site and bulk soil samples were taken.

Crop measurements at selected sites were conducted to determine whether pipeline construction had an effect on annual crop production. Specifically, where both the right-of-way and adjacent lands were seeded to the same crop, repeated measurements of crop height and stem or crown density were taken. Evidence of inhibited germination, seedling or main stem mortality, physiologic condition and weed, pest or disease occurrence were also noted.

Soil measurements at each sampling site included: topsoil depth and texture, subsoil texture, visible salts and carbonates, compaction (either bulk density or penetrability) and stoniness. Representative samples also were collected at each site and analyzed for pH, electrical conductivity, saturation percentage, sodium adsorption ratio, calcium carbonate equivalent, organic matter content, and macro-nutrient concentrations.

TOPSOIL CONSERVATION

The depth of topsoil on right-of-way in comparison to topsoil depth off right-of-way provides evidence that topsoil was properly conserved during the construction programs. No consistent differences in depth of topsoil were observed between on and off right-of-way soils. Topsoil depth off right-of-way was much more variable, as would be expected. However, when averaged over the sample sites at each location, on right-of-way and off right-of-way values were not significantly different. Topsoil depth directly over the ditch line was occasionally slightly shallower than adjacent areas. The shallow topsoil depths over the ditch line generally result from cultivation across the ditch prior to consolidation and subsidence of the crowned backfill material. The cultivation causes a level ground surface over the crowned backfill mound and, in the process, displaces topsoil to adjacent land.

An analysis of soil textures also indicates that topsoil was not mixed with subsoils. Topsoil textures on and off right-of-way were generally the same.

Basic measures of soil chemistry provide a means of determining the effectiveness of topsoil conservation measures. Mixing can be indicated by an increase in carbonates and a decrease in organic carbon in the topsoil. At all sites sampled there were no significant differences between off right-of-way and on right-of-way carbonates or organic carbon concentrations in the topsoil.

Analyses of soil fertility show that if any mixing of topsoil and subsoil did occur, it did not significantly affect soil fertility. The beneficial effects of the addition of commercial fertilizer were still evident on many sites one year after application.

On areas with saline and sodic subsoils, electrical conductivity (EC) measurements and sodium absorption ratios (SAR) can indicate if there has been mixing of subsoil with topsoil. Only two sites were noted where EC exceeded 4 mS/cm and SAR exceeded 8. At both sites, however, the control values exceeded that for the construction right-of-way for EC and/or SAR.

Collectively, the data on topsoil depth, texture, chemistry and fertility, demonstrated that topsoil has been successfully conserved.

SUBSOIL COMPACTION

Cone penetrometer measures of soil strength (resistance) were undertaken at five sites in the 1986 program and 16 sites in the 1987 program. Bulk densities of the upper 7.5 cm of the B horizon were measured at three further sites. All sampled sites were selected to represent worst case situations where soils had remained in the upper plastic state during construction.

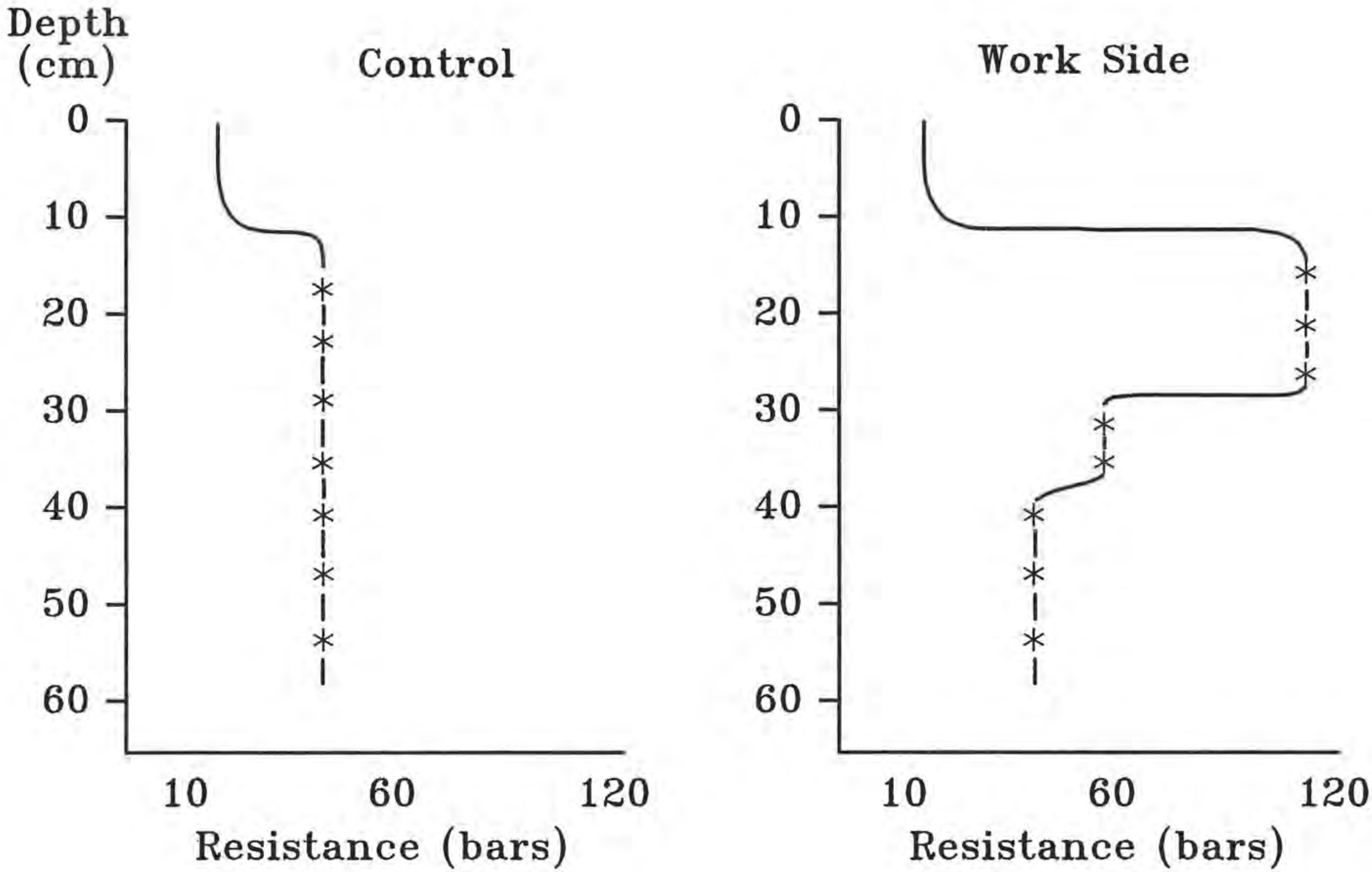
The data from the 1986 program indicated no measurable difference in soil resistance to penetration among ditch line, working side, and off right-of-way sites. In all cases, the subsoils off of the right-of-way were found to be as resistant to penetration as those on the right-of-way. It is interesting to note that while the smallest diameter cone was used (i.e. 2.0 cm^2), penetration measurements at tillage depth were greater than the 147 p.s.i. limit of the instrument scale. These data indicate that the off right-of-way soils have been compacted by normal use of tillage tools.

At the three sites where bulk density was measured, the right-of-way was found to either have slightly lower or approximately equal densities to those off right-of-way.

The cone penetrometer designed at the Alberta Environment Centre in Vegreville, Alberta was used in 1987. The smaller cone tip allowed for collection of data from the more dense soils where resistance to penetration often exceeded 100 bars in off right-of-way soils. As was observed in 1986, the ripping program appeared to have successfully alleviated any residual compaction.

One interesting exception was noted. The replacement section near Hardisty, Alberta was located in an area of aeolian and alluvial sands which, due to their porous nature, were not ripped. However one small field, which was located on a fluvial terrace, was underlain by silty loam to silt subsoils. At this site resistance to penetration at the 15 to 30 cm depth reached 110 bars relative to 45 bars off right-of-way (Figure 3). The site was subsequently deep tilled in the autumn of

Figure 3: SOIL PENETRABILITY COMPARISON BETWEEN ON AND OFF RIGHT-OF-WAY SITES PRIOR TO DEEP RIPPING



1988. It was not possible to determine whether compaction has contributed to reduced crop production at this site, because crops in the adjacent uncompacted ditch line and old pipeline right-of-way were equally poor relative off right-of-way production. It is suspected that low soil moisture conditions in the spring of 1988 had a more significant effect on crop production than subsoil compaction.

These data indicate that without ripping, compaction of subsoils can be expected to persist. It also appears from these data that wherever measures taken to alleviate soil compaction (ie. deep tillage to 30 cm below subsoil surface) were implemented, they were successful.

CROP RESPONSE

Measurements of crop production were undertaken at 18 sites at the end of the 1987 and 1988 growing seasons. Wherever total precipitation from the end of construction to June of the following year exceeded about 250 to 300 mm, there were little differences manifest in terms of plant height, density and average seed head length. In several locations, the right-of-way sites showed greater productivity than off right-of-way sites, probably in response to the fertilizer applied after topsoil was replaced. In contrast, where total precipitation for the same period averaged less than 200 mm, the crops on the construction right-of-way were poor or virtually non-existent, while off right-of-way crops germinated and emerged (although in droughtier areas of Saskatchewan were of very low productivity). Stripping, replacing and cultivating topsoils exposed a large soil surface to atmospheric drying. While stockpiled, topsoils experienced enhanced drainage characteristics and had a low surface area exposed to precipitation. Deep ripping of subsoils to alleviate potential compaction resulted in aerated, drier soils, to a depth of up to 60 cm below soil surface, than would occur at off right-of-way locations. In addition, the fertilizer applied at the end of construction activities lowered osmotic water potential in the soils. Collectively, these processes produced much drier soil conditions to a considerable depth on the right-of-way relative to off right-of-way soils. It is apparent that where precipitation from the end of construction to early summer was insufficient to replenish soil moisture, germination was delayed and in extreme cases never appreciably occurred.

A comparison of wheat crop response, as expressed by total height of all plants per 0.1 m^2, at a site near Edmonton to a wheat crop near Regina shows that differential crop response was not related to inherent soil characteristics (Figures 4 and 5). At both sites, percent organic matter, used as a measure of topsoil conservation, indicated that topsoil was properly salvaged. Crop production at Edmonton was approximately equal among sites while at Regina both the old pipeline right-of-way and the control site had significantly greater production than crops on the 1987 construction right-of-way. At the Regina site, it is interesting to note that soil quality on the old right-of-way was

Figure 4: SOIL – CROP COMPARISON SITE NEAR EDMONTON

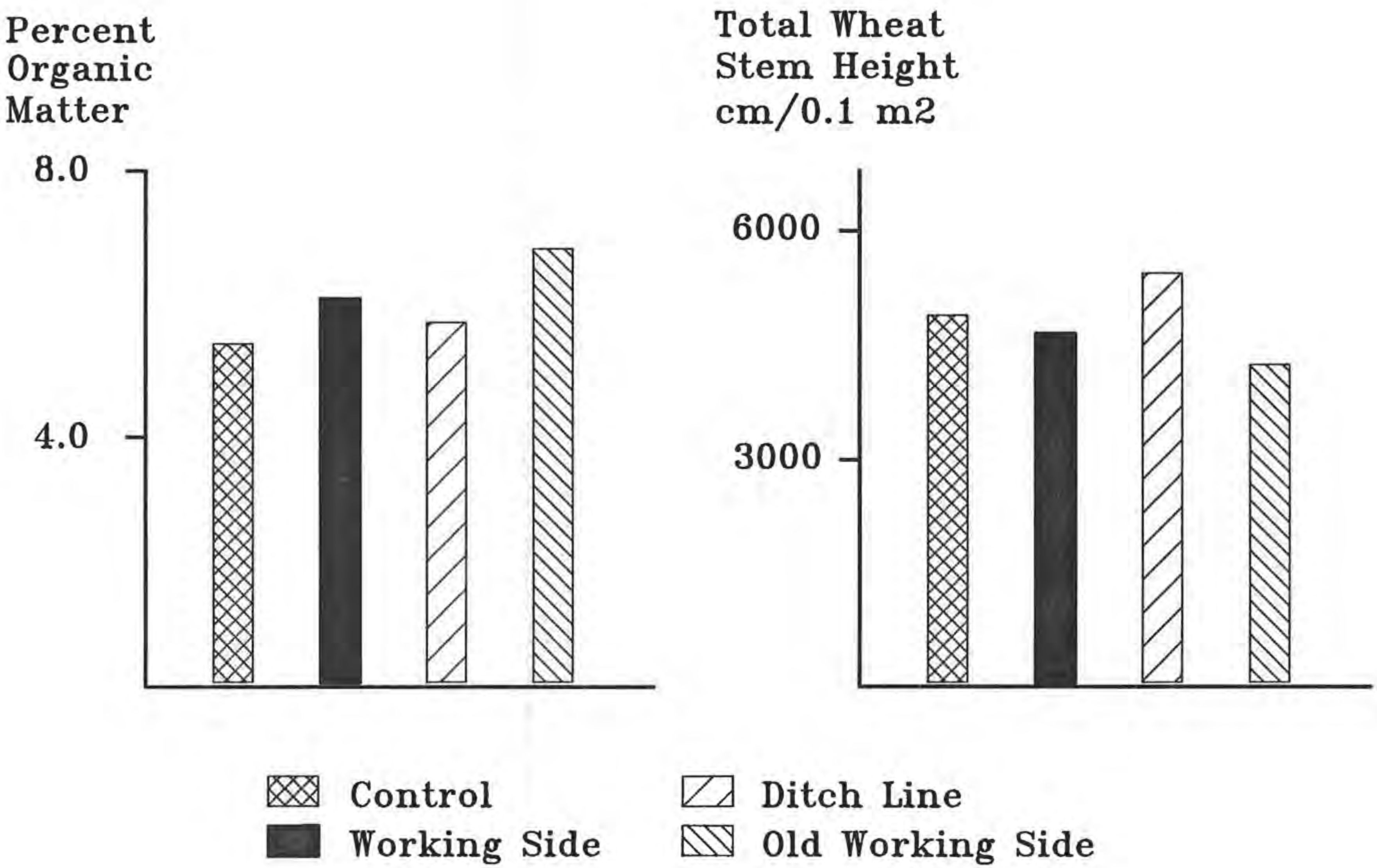
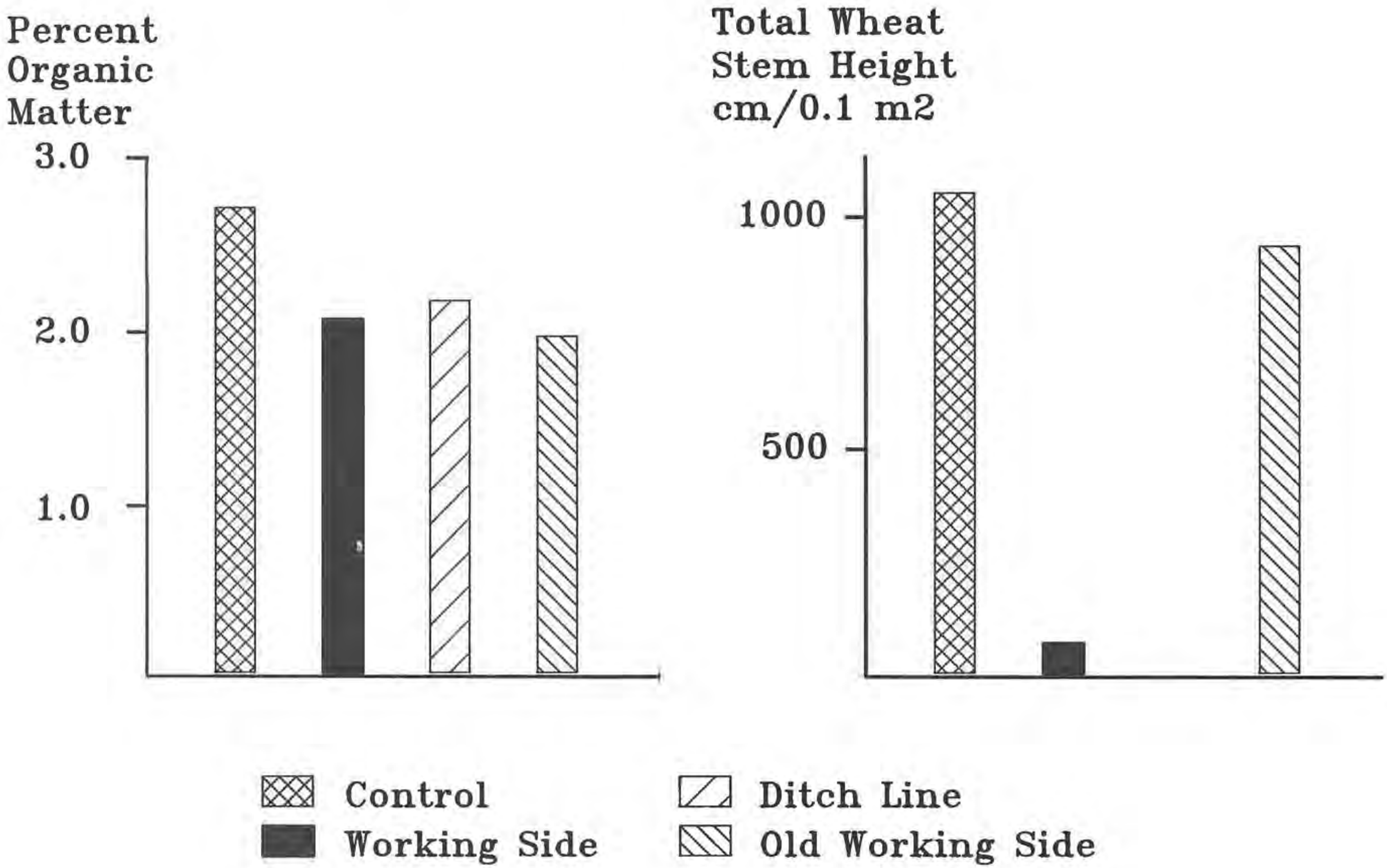


Figure 5: SOIL – CROP COMPARISON
SITE NEAR REGINA



slightly poorer than that of the 1987 construction right-of-way in terms of organic matter, carbonates, EC, SAR and macro-nutrients yet crop production was greater. This further indicates that soil moisture conditions determined crop production differences among sampling locations and not any long-term, more significant impairment of soil quality.

Since transpirational water demand is low on lands with poor crop production, soil moisture increases more rapidly than on adjacent land with productive crops. This theory is applied to dry land farming areas where lands are periodically summer fallowed to conserve soil moisture. Similarly, areas where differences in crop production were evident between on and off right-of-way sites through the 1987 growing season showed no differences the next year in spite of the relatively droughty conditions that persisted through 1988.

The temporary nature of soil moisture deficits also was evident from observations of crop development during first growing season after construction. In eastern Alberta and western Saskatchewan, little or no germination had occurred on the 1987 construction right-of-way by mid-June 1988 while off right-of-way soils had crop production typical of the region. A series of moderate late June and early July precipitation events occurred and the right-of-way crops then germinated. Crops on the right-of-way were much less mature in September (in the case of canola, right-of-way crops were still in flower) than off right-of-way crops, but reached comparable heights and densities.

CONCLUSIONS

The monitoring data clearly indicate that full right-of-way stripping of topsoils and ripping of subsoils can be effective in conserving soil quality. However, the extensive working of these soils during the stripping, ripping and replacement operations can result in significant drying of the soils. If the following growing season is relatively dry, a reduction of crop yield on the right-of-way can be expected. Data collected indicate that even if the second growing season following construction is also dry, a reduction in crop yield on the right-of-way relative to adjacent land will not persist.

LITERATURE CITED

Button, R. G. and E. de Jong. 1970. Effect of pipeline installation on soil productivity. Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, Saskatchewan. Publication No. M17.

Culley, J. L. B. and B. K. Dow. 1988. Long-term effects of an oil pipeline installation on soil productivity. Can. J. Soil Sci. 68: 177-181.

Hardy Associates (1978) Ltd. 1983. Evaluation of pipeline reclamation practices on agricultural lands in Alberta. RRTAC Report No. 83-3. Edmonton, Alberta.

Kemper, W. D., B. A. Stewart, and L. K. Porter. 1971. Compaction as it effects soil conditions: D. effects of compaction on soil nutrient status. Pages 178-189 in K. K. Barnes, W. M. Carleton, H. M. Taylor, R. I. Throckmorton, and G. E. VanderBerg, eds. Compaction of agricultural soils. Am. Soc. Agric. Eng., St. Joseph, Mich.

Mackintosh, E. E., L. de Vries, and M. K. Hoffman. 1984. Rehabilitation of agricultural lands: Dawn-Kerwoop loop pipeline. Submitted to Union Gas Limited.

Mutrie, D. F. and D. M. Wishart. 1988. Evaluation of alternative procedures and equipment for conserving topsoil during pipeline construction in western Canada. Presented at the 1988 Alberta Chapter, Canadian Land Reclamation Conference, Kananaskis, Alberta, September 22 and 23, 1988.

Raney, W. A. 1971. Compaction as it affects soil conditions: E. Summary. Page 125 in K. K. Barnes, W. M. Carleton, H. M. Taylor, R. I. Throckmorton, and G. E. VanderBerg, eds. Compaction of agricultural soils. Am. Soc. Agric. Eng., St. Joseph, Mich.

Shields, J. A. 1980. Possible impact of pipeline construction on farmland. Land Resource Research Institute, Research Branch, Agriculture Canada, Ottawa.

Tomar, S. S., M. B. Russell, and A. S. Tomar. 1981. Effect of subsurface compaction on root distribution and growth of wheat. Z. Acker-Pflanzenbau. 150: 62-70.

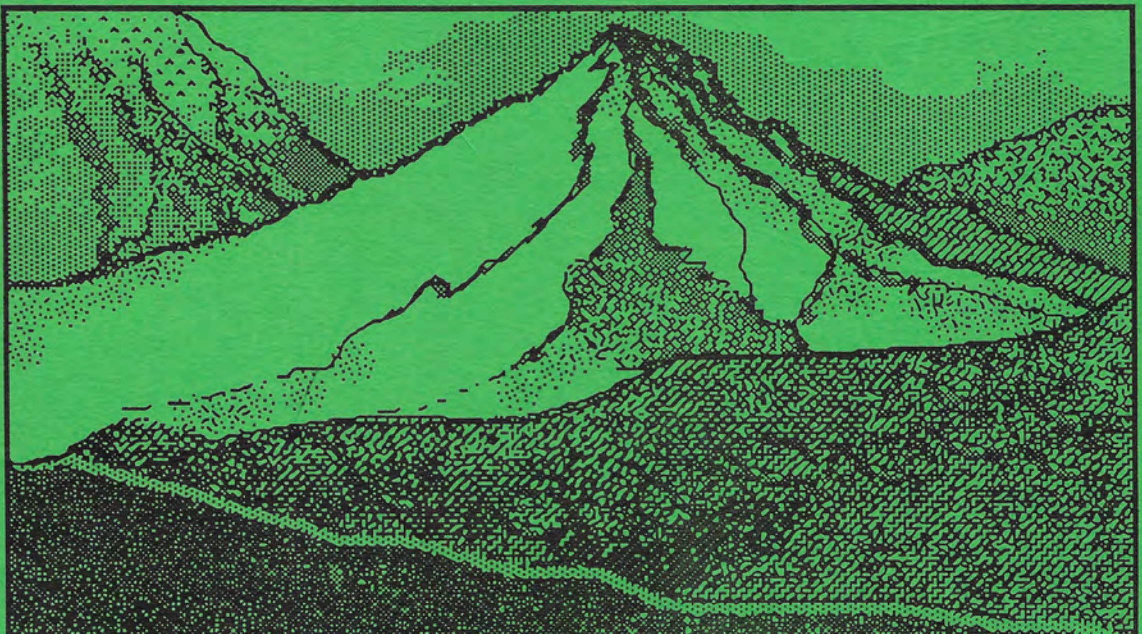
Wilhelm, W. W. and L. N. Mielke. 1988. Winter wheat growth in artificially compacted soil. Can. J. Soil Sci. 68: 527-536.

Alberta Conservation & Reclamation Conference '88

Proceedings of a Conference jointly sponsored by

the Alberta Chapters of the

Canadian Land Reclamation Association and the Soil and Water Conservation Society



held September 22-23, 1988
Kananaskis Village, Alberta

ALBERTA CONSERVATION AND RECLAMATION CONFERENCE '88

Proceedings of a Conference

Jointly Sponsored by the Alberta Chapters of the

Canadian Land Reclamation Association

and

Soil and Water Conservation Society

Held September 22 and 23, 1988

at the Lodge at Kananaskis, Alberta

C.B. Powter, compiler

1989

TABLE OF CONTENTS

All papers are presented here as submitted by the authors; the material has not been edited.

This report may be cited as:

Powter, C.B. (compiler), 1989. Alberta Conservation and Reclamation Conference '88. Proceedings of a Symposium sponsored by the Alberta Chapters of the Canadian Land Reclamation Association and the Soil and Water Conservation Society. 183 pp.

ACKNOWLEDGEMENTS

The two sponsoring groups wish to acknowledge the efforts and support of the following individuals and organizations, without whom the conference would not have been a success:

Alberta Environment, Land Reclamation Division - Mailing

David Walker (Walker and Associates) - Registration and Graphics for the Proceedings Cover

Betty Meier (Alberta Environment, Land Reclamation Division) - Registration

Chris Powter (Alberta Environment, Land Reclamation Division) - Session Chairman

Larry Brocke (Alberta Environment, Land Reclamation Division) - Session Chairman

John Toogood - Session Chairman

Al Watson (Alberta Environment, Land Reclamation Division) - Audio visual

Grace LeBel (Kananaskis Centre for Environmental Research) - Conference facilities and accomodations

Dr. Dennis Parkinson (Kananaskis Centre for Environmental Research) - Opening remarks

Dr. James McMahon (Utah State University) - Luncheon address

Andy Russell - Banquet address