EVALUATION OF ALTERNATIVE PROCEDURES AND EQUIPMENT FOR CONSERVING TOPSOIL DURING PIPELINE CONSTRUCTION IN WESTERN CANADA[1]

Dean F. Mutrie[2] and Donald M. Wishart[3]

ABSTRACT

Topsoil conservation has become standard practice on pipeline construction in western Canada over the last 30 years. Pipeline contractors have used a variety of procedures and equipment with different results. Whereas some equipment is conventional, many contractors have specially modified conventional equipment or invented new machines to strip and replace topsoil faster and more efficiently. These practices are evaluated from the perspective of practicality and effectiveness in conserving soil capability for agriculture. There is no one procedure or piece of equipment which is universally applicable to all situations. Rather, it is important to match the appropriate procedure and equipment to the field conditions experienced on the right-of-way. Skilled operators and inspectors are prerequisites to any successful topsoil conservation program.

INTRODUCTION

In the 1950's, the pipeline industry in western Canada made little effort to conserve soil capability for agricultural production. By the mid 1980's, industry had pioneered the development of new procedures to the state that topsoil conservation had become an integral part of pipeline construction. Various procedures have been used depending upon soil characteristics, farming practices and the season of construction. The procedures described in this paper are drawn primarily from construction practices in western Canada (Provinces of Alberta, Saskatchewan, and Manitoba) where over 160,000 kilometres of pipelines have been built.

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[2] Dean F. Mutrie, President, TERA Environmental Consultants (Alta.) Ltd., #205, 925 - 7th Avenue S.W., Calgary, Alberta, T3E 0M1.

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

In western Canada, topsoil generally varies from 5 to 30 cm in depth. The terrain is typical of a flat prairie landscape and the climate is quite severe (only 100 frost free days and 350 to 500 mm of annual precipitation, 30% falling as snow). Most land is used for the growing of annual cereal or oilseed crops, for hay production or as pasture. Hay and pasture lands develop a thick sod layer whereas lands annually cultivated do not. The procedures discussed in this paper are equally applicable to other areas where the soil characteristics, climate and farming practices are similar.

TOPSOIL CONSERVATION

In this paper, topsoil is defined as the organic rich surficial soil horizon managed for agricultural production. There have been a number of Canadian studies to document the effects of pipeline construction on soils and agriculture (Button and de Jong 1970, de Jong and Button 1973, Toogood 1974, Shields 1980, Culley et al. 1982, and Hardy Associates Ltd. 1983, in addition to unpublished post construction monitoring studies undertaken by the major pipeline operators). In most cases where topsoil was not conserved, a reduction in soil quality and crop yields was found, particularly in the first few years following construction. The major problem associated with poor topsoil conservation procedures are mixing and compaction. Mixing causes: a loss or dilution of organic matter and nutrients in the topsoil; increased concentrations of harmful salts left on or near the surface; and increased stoniness caused by bringing rocks in the lower trench up to the surface. Compaction causes the formation of a hardpan which is impenetrable by plant roots.

In most reported cases where topsoil was conserved, the negative impacts were shortlived. Some beneficial effects have been noted as well. Regardless of research results, the pipeline industry has adopted topsoil conservation as standard practice because it accelerates the return of agricultural soils to original productivity. The preservation of soil capability for agricultural production is the overall objective of topsoil conservation.

PIPELINE CONSTRUCTION PROCEDURES

Typical pipeline construction consists of a series of sequential activities commencing with staking the boundaries of the right-of-way which usually ranges from 15-25 m in width. The right-of-way is cleared and graded with topsoil stripped and stockpiled using conventional equipment such as bulldozers or graders. The width and depth of topsoil stripping is sensitive to landowners' requests. The pipe is strung, bent, welded and coated before the ditch is excavated to a depth of 1.2-2 m, normally by a bucket wheel ditcher. Backhoes are used at road crossings for bellholes or at side bends and other areas where a wider and deeper ditch is required. Spoil (subsoil) from the ditch is piled on the edge of the right-of-way. The pipe is lowered into the ditch and backfilled with the spoil which is then compacted. If necessary, the right-of-way is ripped to relieve compaction and the topsoil spread back over the area that was stripped. Rocks and other debris are

removed before cultivating the right-of-way. The right-of-way is then seeded and fertilized to the landowners' specifications.

Typical pipeline construction activities are frequently modified as circumstances dictate. On some projects, the pipe has been installed in a narrow ditch or been plowed in without a ditch. Larger projects have allowed the use of specialized equipment for handling topsoil.

This paper discusses the various pipeline construction procedures in western Canada using both conventional and specialized equipment.

TOPSOIL CONSERVATION PROCEDURES

The impact of pipeline construction and the effectiveness of restoration procedures depends on soil conditions, construction methods and weather conditions during construction. Methods that are effective in summer may not be practical when the work must be carried out in frozen soil. Wet weather can turn a satisfactory operation into a quagmire necessitating stoppage of work and a change of procedures. The only way to deal with these problems is to select construction procedures to suit both the soil characteristics and the expected weather conditions . . . and be prepared to change.

This section examines seven topsoil conservation procedures which are described below and evaluated on table 1.

Procedure 1: No Stripping

In certain circumstances, no topsoil is conserved during construction. Both topsoil and subsoil are excavated together in a single operation, the excavated material is spoiled in a windrow beside the ditch and the ditch is backfilled with the mixed topsoil and subsoil. Many kilometers of pipeline have been constructed in this manner in past years before there were concerns about protecting soil quality. Nevertheless, this procedure still has valid applications.

Procedure 2: Ditchline Stripping

The next case involves stripping only the width of the ditch. Some people refer to this procedure as pilot ditching or double ditching. Width of stripping ranges from 1-2 m. Generally the topsoil is stored on the working side of the right-of-way (see fig. 1). If there is not too much topsoil the pipe layup can be located outside this small windrow and lowering-in can lift the pipe over the topsoil. In some cases there may be enough soil that it is necessary to flatten the pile and work on top. Although less efficient, it is also possible to strip the ditchline to the spoil side and blade the material to the edge of the spoil pile.

Procedure 3: Blade Width Stripping

As shown on figure 1, blade width stripping is similar to the previous procedure but a wider area is stripped (3.5-4.5 m) depending on

TABLE 1

EVALUATION OF ALTERNATIVE TOPSOIL CONSERVATION PROCEDURES

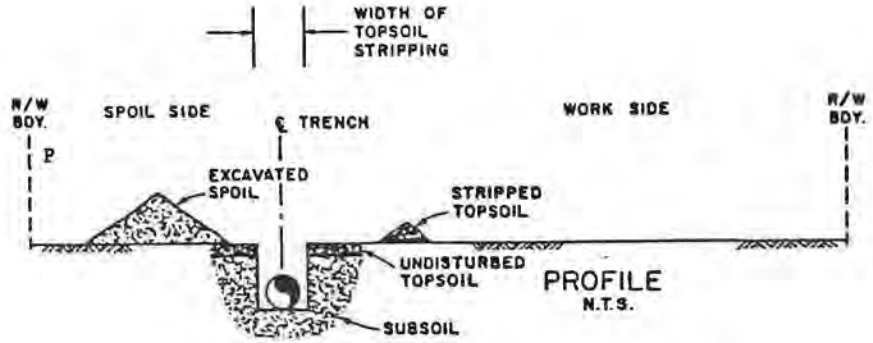
PROCEDURE AND USE	Potential For:[1] Mixing/Compaction		Relative Cost[1] Construction	/Reclamation	Advantages	Disadvantages	EVALUATION AND COMMENTS
1. NO STRIPPING Common 20 years ago. Currently used at landowner request or with specialized equipment on marginal land.	H	H(TS) L(SS)	N/A	M	-Fast and efficient	-Sidecast topsoil mixed with subsoil. -Mixing under spoil pile -Compaction & rutting on work side. -Can cause loss of soil quality from mixing (stones, salts) and compaction. -Provides rough surface for ditcher. -Disposal of displaced spoil is a problem.	-Generally inappropriate unless topsoil is absent to thin (0-10 cm), land use is stony native pasture or bush and pipe diameter is small (<20 cm). In these situations, the appropriate alternative procedure is to minimize ROW width and disturbance by narrow trenching, restricting ROW grading and not scalping the sod layer during backfill. May also be appropriate on irrigated lands where owners request narrow ditch and minimal grading to prevent changes in grade, which may be a more crucial concern than topsoil/subsoil mixing.
2. DITCH LINE STRIPPING Common on hay and pasture lands.	M	H(TS) L(SS)	L-M	M-H	-Relatively fast. -Minimizes mixing over ditch. -Minimal disturbance to sod layer.	-Sidecast topsoil mixed with subsoil. -Mixing under spoil pile -Compaction & rutting on work side. -Rough surface for ditcher. -Depth control difficult to achieve. -Difficult to replace topsoil over crowned ditch without exposing spoil. -Disposal of displaced spoil is a problem.	-Appropriate in the following situations: deep topsoil (> 30 cm) on cultivated land where subsoil quality is good and some mixing can be tolerated; hay and pasture lands where landowner is concerned about disturbing a wide swath of established plants and sod layer helps to minimize compaction and accurate separation of spoil; and frozen soils (see #7 below). -Stripping a little wider than ditchline can prevent mixing sidecast topsoil with subsoil.
3. BLADE WIDTH STRIPPING Common on hay and pasture lands.	M	H(TS) L(SS)	L	M	-Relatively fast and effective. -Provides level surface for ditcher. -Easier to replace topsoil over crowned ditch. -Minimizes mixing over ditch. -Disposal of displaced spoil is less of a problem.	-Stockpiled topsoil confines working space. -Mixing under spoil pile -Compaction on working side. -Extra disturbance of sod layer.	-Appropriate on hay and pasture lands where some mixing can be tolerated; where the amount of excavated subsoil would overfill the ditch during backfill and must be feathered out to each side of the ditch (eg. a large diameter line which displaces more spoil than a small diameter line). -Inappropriate for cultivated lands because spoil pile sits on topsoil unprotected by a vegetated mat.

[1] H = High, M = Moderate, L= Low, TS = Topsoil, SS = Subsoil, N/A Not Applicable

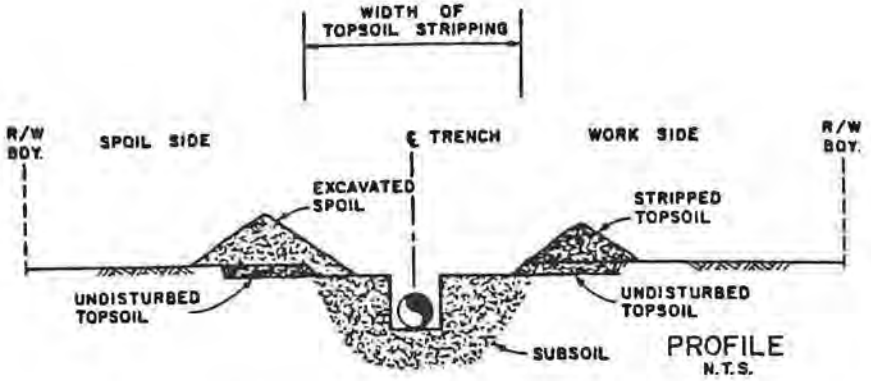
TABLE 1 Cont'd

PROCEDURE AND USE	Potential For:[1] Mixing/Compaction	Relative Cost[1] Construction/Reclamation	Advantages	Disadvantages	EVALUATION AND COMMENTS
4. DITCH PLUS SPOIL SIDE STRIPPING Most common procedure on cultivated lands.	L-M H(TS) L(SS)	M M	-Minimizes mixing of topsoil pile with subsoil pile. -Facilitates topsoil replacement over crowned ditch. -Provides level surface for ditcher.	-Compaction and loss of structure of topsoil may occur on work side (requires cultivation). -Driving on topsoil surface can potentially introduce garbage, weed seeds, and rocks on working side (also true for all but No.6.	-Appropriate on cultivated lands when schedule can accommodate wet weather shutdowns and where compaction may not be a major concern, such as on coarse textured soils or on a smaller project with lighter equipment making fewer passes. -Appropriate on hay/pasture if subsoil quality is poor.
5. FULL RIGHT-OF-WAY STRIPPING Sometimes used on cultivated lands on larger projects.	L L(TS) H(SS)	H L	-Minimizes mixing & compaction of topsoil. -Allows work to continue longer during wet weather. -Rocks, weeds, garbage not introduced to topsoil. -Permits rock removal to greater depth. -Less topsoil structure damage. -Provides level surface for ditcher.	-Requires extra wide right-of-way. -Requires ripping to relieve subsoil compaction. -May dry soils to a greater depth.	-Appropriate on cultivated lands when schedule cannot accommodate extended wet weather shutdown such as on a larger project or when much of the route crosses imperfectly to poorly drained fine textured soils.
6. THREE PHASE STRIPPING Used rarely on soils with highly sodic or saline subsoil or near surface bedrock.	L H(TS) L(SS)	H M	-Provides level surface for ditcher.	-Requires extra ROW for third pile. -Accurate separation of salt-free and salt-rich subsoils is difficult.	-Inappropriate under almost any circumstance. The contact between the salt/sodic-free subsoil (B horizon) and salt/sodic-rich subsoil (C horizon) is too variable for construction equipment to accurately separate in the field. Taking extra ROW contradicts the principle of minimizing disturbance. The appropriate alternative is to overstrip the topsoil to include some of the salt-free subsoil and treating as Procedure 2-5above.
7. STRIPPING FROZEN SOILS Common on winter projects on cultivated, hay and pasture lands.	M L(TS) L(SS)	M-H M-H	-Prevents mixing over ditch. -Minimizes compaction by working on frozen soils.	-Difficult to maintain accurate depth control. -May require ripping topsoil first which can be slow and cause some mixing. -Excessive wear and tear on some equipment. -Rough surface for ditcher.	-Appropriate when project schedule dictates winter construction and on soils with medium to high moisture contents at freeze-up. -Can be a difficult task approached in token fashion or a challenge to improve construction equipment.

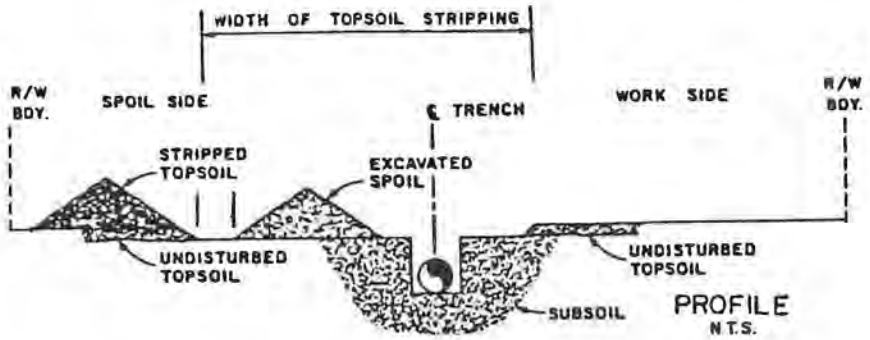
Figure 1 - Topsoil Conservation Procedures



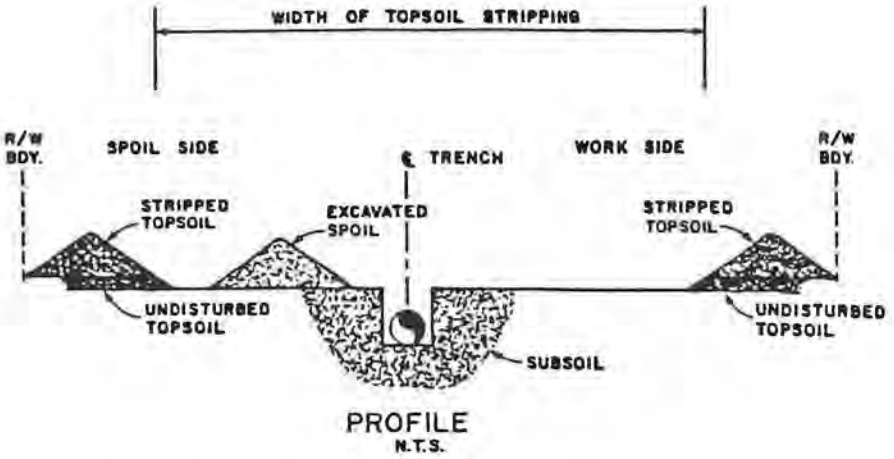
PROCEDURE #2 & #7. DITCH LINE STRIPPING



PROCEDURE #3. BLADE WIDTH STRIPPING



PROCEDURE #4. DITCH PLUS SPOIL SIDE STRIPPING



PROCEDURE #5. FULL RIGHT-OF-WAY STRIPPING.
(Two-pile option)

the size of ditcher to be used. The stripped width is generally wider than the outside dimension of the ditcher tracks to provide a level surface for the ditcher. The topsoil pile can be windrowed on the working side or spread in a flat pile to work on top. Alternatively, it could be windrowed to the edge of the spoil side, although the earlier comment about moving topsoil longer distances would apply.

Procedure 4: Ditch Plus Spoil Side Stripping

In the three previous methods the subsoil pile sits on topsoil (or the vegetative mat) during the period the ditch is open. In absence of an effective sod-like vegetative mat, recovery of the subsoil back to the ditch will inevitably result in either some subsoil left on the surface or some topsoil lost into the ditch. When topsoil is shallow and subsoil quality is poor, this mixing should be minimized.

One of the most common methods of topsoil conservation on cultivated land is to strip the spoil side as well as the ditchline. In this way the subsoil pile is placed on subsoil, not on topsoil, and recovery operations cause less mixing. The width stripped extends from the outside of the ditcher track on the working side to the outside of the subsoil pile while ensuring separation from the topsoil windrow at the edge of the right- of-way (see fig. 1). Alternatively the topsoil is stockpiled on the working side and either flattened and used as a surface to weld the pipe on or spread over the working side topsoil. On a typical 15 m right-of-way, the width stripped is 5-8 m.

Procedure 5: Full Right-of-Way Stripping

On some projects, the entire width of the right-of-way is stripped (except the area where the topsoil is stockpiled). Usually the topsoil is placed in a continuous windrow along the edge of the right-of-way opposite from where the spoil pile will go. Occasionally when topsoil is deep, it is windrowed on both edges of the right-of-way (see fig. 1).

Procedure 6: Three Phase Stripping

In a few cases, an effort has been made to separate potentially toxic subsoils from the surface. If the C horizon is highly sodic or saline material, the ditch is excavated in three lifts: first lift for the salt/sodic-free topsoil removal from 15 to 30 cm; second lift with a ditcher to the bottom of the salt/sodic-free B horizon at 50 to 100 cm total depth; followed finally to the bottom of the ditch with another pass of the ditcher for salt or sodic rich material. The topsoil is stored at the outside edge of the spoil side, the second lift as normal on the spoil side and the third lift of toxic material on the stripped working side. Each lift is then returned to the ditch in the proper order to keep the toxic material at the bottom.

Procedure 7: Stripping Frozen Soils

As a rule, it is preferable to carry out pipeline construction on agricultural land when the ground is not frozen. In some case, the right-of-way has been prestripped before freeze-up. However, this is not always possible so some specialized procedures and equipment have been developed. Generally topsoil removal is done as part of right-of-way preparation and the topsoil is stockpiled at the edge of the right-of-way. It is not usually possible to recover and replace frozen topsoil during rough clean-up in the winter so it is necessary to do topsoil replacement and final clean-up in the spring. On frozen ground it is most common to strip only the ditchline.

Discussion

Comparing procedures 1 to 5, the wider the topsoil stripped, the higher the construction costs but the lower the reclamation or clean-up costs. There is also less concern about mixing and compaction. Full right-of-way stripping appears to be the ideal, albeit expensive, approach but its success in maintaining soil capability for agricultural production is critically dependent on the effectiveness of ripping the subsoil on the working side. Otherwise a hardpan under the topsoil can develop which acts as an impediment to water movement and plant rooting. Ripping subsoil can be difficult and time consuming but can have potentially positive impacts by breaking up the compacted B horizon common in native western Canadian soils. Chisel plowing or cultivating the subsoil to a depth of 5-10 cm is a token attempt to relieve compaction and not a substitute for ripping the subsoil to 30 cm or more with the proper equipment. Ditch plus spoil side stripping represents a compromise on cultivated lands, the trade-off being that construction must be shut-down during wet weather to prevent severe rutting, compaction and loss of topsoil structure. It is acknowledged that it is easier to relieve compaction of topsoil than subsoil. However, should significant compaction occur to depths below the topsoil, relieving this subsoil compaction without causing mixing with topsoil requires specialized tillage equipment.

The size of construction project usually affects the decision of which procedure to apply. The potential for compaction is greater on a large project than a small one. A large project such as 300 kilometres of 200 mm pipe involves numerous pieces of large, tracked and rubber-tired equipment, a wide ditch and a working side graded to allow high speed travel. The financial implications of wet weather shut down may be severe. On the other hand, a small project such as 16 kilometres of 150 mm line involves few pieces of smaller and lighter equipment and a rougher working side. The project schedule may be able to accommodate longer wet weather delays. Whereas full right-of-way stripping may be appropriate on the large project, it may be economically unfeasible on the small project. Nevertheless, topsoil conservation procedures on small projects warrant just as serious consideration inspection as on large projects because the majority of pipeline projects are small ones.

Three phase stripping is an experimental procedure which has been attempted in a few situations but found to be of little value. In addition to the reasons provided on table 1, several researchers have indicated that mixing B and C horizon subsoils together (which occurs during conventional pipeline construction, after the topsoil has been stripped), can improve soil structure and crop yields (Cook et al. 1973, Krogman and MacKay 1980, Hermans 1981) on lands with highly sodic or saline subsoils. These results have been attributable to higher moisture storage capacity, better rooting depth and higher pH after hardpans or remnant hardpans are broken up and the calcium and nutrients from lower depths brought to the surface.

In general, efforts should be made to conserve topsoil even during winter construction. The notable exceptions to this are the conditions under which maintaining a narrow ditch is appropriate. Leaving the established sod layer intact is of greater reclamation value than trying to strip a thin layer of topsoil. Experience has shown that it is difficult if not futile to effectively strip, stockpile and replace less than 10 cm of topsoil. At the other end of the scale, there is little to be gained by stripping more than 30 cm of topsoil which is usually deeper than the plough layer being worked by the farmer.

Regardless of which procedure is used, several additional cautions are noteworthy:

- To prevent mixing, topsoil should be stripped and stockpiled wherever the right-of-way is graded.
- Topsoil should be stripped wider at locations where wider or deeper than normal ditch is required (crossings of roads, rail lines, foreign lines, watercourses and sidebends) or wherever the ditch will be excavated by a backhoe rather than a ditching wheel.
- To prevent loss of soil structure and wind erosion, topsoil should not be worked when saturated, nor during periods of high winds.
- A series of passes by equipment allows more accurate salvage of topsoil and is preferred to stripping the entire topsoil and depth in a single pass.
- To ensure that topsoil is not left shallow over the ditch line, it is preferable to feather the displaced subsoil out and cover it with sufficient topsoil.

EQUIPMENT FOR TOPSOIL CONSERVATION

Conventional Equipment

Stripping and replacement of topsoil normally uses conventional pipeline equipment such as rubber-tired graders or tracked bulldozers. Other equipment conventionally used includes bucket wheel ditchers, "step blades" and "mormon boards". When stripping topsoil, the wheel ditcher is set for a shallow pass of 15-30 cm and stockpiles the topsoil

on the opposite side of the ditch from the subsequent spoil pile. With respect to frozen soils, the ditching wheel may be preceded by a "ripper cat" which is a large (D8 or D9 class) tractor equipped with one, two or three ripper shanks. To strip a narrow width of 1.5-2 m, the blade of a grader or dozer can be fitted with a short "step blade" on the bottom of the main blade. The "mormon board" is only used during topsoil replacement. It is a 2-2.5 m wide steel scoop-like blade attached to a cable operated crane which sits on the right-of-way and casts the board behind the topsoil pile which sits on the edge of the right-of-way. The cable is then tightened, drawing the topsoil back towards the centre of the right-of-way where it is accessible to graders and bulldozers to complete final topsoil replacement.

Specialized Equipment

Pipeline contractors have shown considerable initiative in inventing or modifying unconventional equipment for use on topsoil conservation (TERA Environmental Consultants 1985). A heavy duty rubber tired Ditch Witch has been used to excavate ditches 25-60 cm wide. The spoil is side cast to both sides of the ditch, rather than just one side as in the case of a standard bucket wheel ditcher. The overall width of disturbance is 1.2-1.5 m. A similar machine is the Rotor Ripper which is mounted on a D7 tractor unit and cuts a 25-35 cm ditch. Small diameter pipelines have been installed without a ditch at all using a deep plow pulled by a large bulldozer. The "ditch" collapses immediately behind the pipe so no backfilling is required. One manufacturer has fabricated a step blade attachment for a bulldozer that is hydraulically adjustable from the cab. Another has mounted a mobile caterpillar track on the front of a a D9 bulldozer. This "power dozer" has been used for both topsoil stripping and replacement. A third manufacturer has built an auger backfiller by mounting a screw-like auger to the front of a D8 tractor. Another adaptation made for replacing topsoil is known as a "flyswatter" which is a D4 or Gradall bucket mounted on the arm of a backhoe.

Two equipment manufacturers in Alberta have modified a large wheel ditcher for use in winter topsoil stripping. The drive train has been strengthened, the wheel assembly surrounded in a housing, the buckets changed and the spoil conveyor modified. The machine can strip a 1.8 m wide area and discharge the material on the work side. NOVA, an Alberta Corporation has developed a machine which under winter conditions, is able to strip 1 m width of topsoil to a controlled depth. The winter topsoiler is a hydraulically driven "Rock Saw Trencher" mounted on a D9 tractor. The cutter has been modified to make it wider and shorter and more suitable for topsoil stripping. A conveyor system allows placement of topsoil in a windrow beside the trenchline. The operator controls the cutting depth from the cab on the instructions of a swamper.

Evaluation of Equipment

The various pieces of equipment used in western Canada for topsoil stripping and replacement on pipeline construction are evaluated on

table 2. In general, conventional equipment works well except for the limitations noted on the table. Some equipment like bulldozers and graders has widespread application while others like the step blade or winter stripper are specific to one procedure. Topsoil replacement can be slow, which is likely the reason that several innovations have been made to replace the mormon board. Plowing-in is perhaps the ideal procedure but is limited by size of pipe. One company experimentally plowed-in a 219.1 mm line but found that the three D9 tractors required to tow the plow caused substantial terrain disturbance (Seager personal correspondence[1]). A 114.3 mm diameter pipe appears to be the practical upper limit for plowing-in. The specialized equipment for stripping frozen soils is an improvement over conventional equipment. However, widespread application is presently limited by the small number of available machines as is the case for several other pieces of equipment. This factor has caused problems on several construction projects when the specialized machine breaks down and no substitute can be used while repairs are made. Hopefully, this problem will be solved by contractors bringing more specialized units into circulation so that each project will have two machines. This will always be a problem in the case of specialized machines especially those with only seasonal needs.

The key comment to make with respect to topsoil stripping and replacement equipment is that the machine is only as good as the operator. Skilled operators and knowledgeable inspectors are prerequisites for a successful topsoil conservation program (many companies in western Canada employ specialized inspectors with training in soil sciences to help oversee topsoil stripping and replacement activities).

CONCLUSIONS

There is no one topsoil conservation procedure which can be recommended to cover all situations. Blanket application of one procedure will result in loss of soil capability for agricultural production in some cases and overkill in others. Agricultural land use, soil type and depth, season of construction, presence of saline or sodic materials at trench depth, size of project, and a host of other parameters influence the decision of which procedure is best suited for a particular field. Topsoil conservation should be kept simple. The greater number of procedures and more frequent changes from one procedure to another, the higher the construction cost and the greater potential for incorrect implementation by construction crews. Likewise, when selecting which procedure to use, environmental planners should be aware of the corresponding type of equipment required. If a contractor shows up on-site without that equipment, successful execution of topsoil conservation will be jeopardized. For example, the most skilled operator cannot do a good job of stripping topsoil with a backhoe because the machine is designed to dig rather than work in a horizontal plane. At the other extreme, planners should be aware of equipment availability and not

[1] Seager, R., 1987. Personal correspondence. NOVA, An Alberta Corporation, Calgary, Alberta.

TABLE 2

EVALUATION OF TOPSOIL CONSERVATION EQUIPMENT

	EQUIPMENT	USE	APPROPRIATENESS FOR TOPSOIL CONSERVATION PROCEDURE[1]							COMMENTS
			NO STRIPPING	DITCH LINE	BLADE WIDTH	DITCH & SPOIL	FULL ROW	3 PHASE[2]	FROZEN SOILS	
CONVENTIONAL EQUIPMENT	Grader (Motor patrol or maintainer)	Common(both stripping & replacement)	N/A	A	A	A	A	NOT RATED	N/A	-Provides accurate separation of soil horizons but cannot handle thick depths in a single pass. Best used as trailer behind bulldozers. -Appropriate for respreading topsoil.
	Bulldozer (D6-9)	Most Common (both stripping and replacement)	N/A	N/A	A	A	A		N/A	-Can push more material than a grader but achieves less accurate separation. Best used in advance of a grader. -Appropriate for respreading topsoil
	Bucket Wheel Ditcher	Common (stripping only)	N/A	A	N/A	N/A	N/A		I	-Accurate depth control is difficult, especially in winter when it may have to be preceded by a ripper cat. Cannot strip less than 15 cm. -Hard on equipment in winter. Important to keep new teeth on the buckets.
	Backhoe(hydraulic excavator)	Uncommon (stripping only)	N/A	I	N/A	N/A	N/A		I	-Not appropriate because machine is designed for digging rather than stripping.
	Step Blade	Common (stripping only)	N/A	I-A	N/A	N/A	N/A		I-A	-Depth of blade cannot be adjusted. May be inappropriate if blade is set to strip too shallow or too deep. Appropriate on frozen soils if preceded by ripper cat. -It is advantageous to fit the main blade with floats on each side so it rides more smoothly over the ground surface.
	Mormon Board	Common (replacement only)	N/A	N/A	N/A	I-A	I-A		N/A	-Appropriate for pulling topsoil pile from edge of right-of-way while minimizing off right-of-way damages. -May be inappropriate if allowed to "gouge" by operator. -Slow.

[1] A = Appropriate, I = Inappropriate, N/A = Not Applicable

[2] Not rated because procedure itself is seldom appropriate.

TABLE 2 Cont'd

	EQUIPMENT	USE	APPROPRIATENESS FOR TOPSOIL CONSERVATION PROCEDURE[1]							COMMENTS
			NO STRIPPING	DITCH LINE	BLADE WIDTH	DITCH & SPOIL	FULL ROW	3 PHASE[2]	FROZEN SOILS	
SPECIALIZED EQUIPMENT	Ditch Witch (R100) and Rotor Ripper	Occasional but localized (1 of each machine in Alberta)	A	I	N/A	N/A	N/A	NOT RATED	I	-Appropriate where narrow trenching and minimal grading on small diameter lines is specified (native pasture land, irrigated land). -Has difficulty ditching through stony ground. -Would have difficulty with depth control on stripping ditchline and frozen soils.
	Deep Plow	Occasional but localized	A	N/A	N/A	N/A	N/A		I	-Ideal for small diameter (<10 cm lines on native pastureland. Minimal disturbance. -Requires a lot of pulling power so sod layer may be damaged.
	Hydraulic Step Blade	Uncommon (1 machine in Alberta) (stripping only)	N/A	A	N/A	N/A	N/A		A	-Appropriate because stripping depth is adjustable. -See Step Blade for other comments.
	Power Dozer	Uncommon (1 machine in Alberta) (stripping & replacement)	N/A	N/A	A	A	A		N/A	-Combines power of a bulldozer with the ability of the grader to sidecast topsoil. -Can quickly move deep topsoil (30 cm) in a single pass but may require a tow cat. -Slowed by hard or compacted topsoil.
	Auger Backfiller	Occasional (replacement only)	N/A	N/A	N/A	A	A		A	-Minimizes off ROW damages. Fast. -Pulverizes soils which may be advantageous if topsoil is cloddy or frozen.
	Flyswatter (Backhoe with a blade replacing bucket)	Occasional (replacement only)	N/A	N/A	A	A	A		N/A	-Minimizes off ROW damages. Appropriate for pulling back topsoil pile but not for respreading. -Faster than a Mormon Board.
	Modified Bucket Wheel Ditcher	Occasional (2 machines in Alberta) (stripping only)	N/A	A	N/A	N/A	N/A		A	-Especially appropriate for winter use because it has the power and depth control to accurately strip topsoil. -Conversion of standard ditching wheel is relatively cheap.
	NOVA's Rock Saw Winter Stripper	Occasional (1 machine in Alberta) (stripping only)	N/A	A	I	N/A	N/A		A	-Ideal for winter use (see comments directly above) because designed specifically for this purpose. -Has been used to strip wider than ditch line at road crossings but requires repeated passes. -Can be fast (up to 6 km/day) -Can be used to make rock ditch. -Conversion of standard Rock Saw is expensive. -Suffers frequent breakdowns.

unnecessarily restrict the range of equipment which can be used - a sensitive issue since it may give one contractor the edge in the bidding over another otherwise qualified contractor.

The pipeline industry in western Canada has come a long way on topsoil conservation in the last 30 years. Now that topsoil conservation is recognized as being an integral part of standard pipeline practice, it will undoubtedly benefit from the advances in pipeline contruction technology which inevitably arise from a highly competitive industry.

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TABLE OF CONTENTS

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