THE AGRICULTURAL, FORESTRY, RECREATIONAL AND WILDLIFE OPPORTUNITY COST OF PIPELINES, HYDRO LINES AND HIGHWAYS

by

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Abstract

The opportunity cost of conveyance corridors; highways, hydro lines and pipelines is the monetary value of resource uses foregone; the lost value of physical production resulting from the allocation of land to right-of-way use. Theoretical models were developed for calculating the resource uses foregone and under the criteria of measurability and availability of data, practical equations for conveyance corridors traversing agricultural and forested areas were formulated.

Use of practical equations was illustrated by creating hypothetical corridors through the Municipalities of Elton and North Cypress (agricultural application) and through Township 61, Ranges 27 and 28 (forestry application).

Conflict between rights-of-way and recreational areas was difficult to quantify and strict economic analysis of opportunity costs was not possible. An alternative technique of reclamation, reparation and mitigation (RRM) was therefore proposed for evaluating opportunity costs.

Difficulty in defining wildlife prices and determining the effects of corridors on wildlife prevented the use of the developed economic equation. Thus the alternative technique of RRM was suggested to quantify wildlife opportunity costs.

Application of the model produced a comparison of corridor opportunity costs. For a hypothetical corridor, 120 feet wide and 42 miles long traversing agricultural land the highway had a loss of $1,087,000 and the hydro line with wooden towers a loss of $4000 with steel towers, $13,000. The pipeline had a range of opportunity costs from a benefit of $11,000 to a

loss of $127,000. All values were calculated for 50 years, undiscounted.

One equation was derived for all corridors in forested areas. Application of this model to a hypothetical corridor, 120 feet wide and 12.6 miles long produced for all corridors, an opportunity cost of $151,000 (calculated for 50 years undiscounted).

A questionnaire inquiring about the effects of pipelines on soil productivity was sent (summer 1973) to farmers having a pipeline traversing their property. Nine percent of the respondents indicated an increase in yield due to the pipeline, 25 percent reported no change and 66 percent indicated a decrease in crop yield. However, general lack of data on effects of pipelines on soil productivity suggest the need for further study.

Numerous ways are available for reducing opportunity costs of corridors; of which multiple use is one of the best. All land has potential for wildlife utilization and a review of literature suggests that corridors are suitable for wildlife production. Thus where active primary production is not possible or too costly it is recommended that steps be taken to use idle right-of-way lands for wildlife enhancement and production.

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Part 1 : Introduction

The problem

With increasing importance placed on proper and efficient land planning in all sectors of land use, a need exists for complete and thorough investigation of all aspects of land-demanding resource projects. Rising world populations place continual pressure not only on renewable natural resources but more fundamentally on land available for production. It is increasingly evident that long-term use and allocation policies must be formulated and implemented to prevent land abuse. Ad hoc land use planning strategies must be eliminated with policies formulated with substantiated facts and judgments to insure adequate productive land for succeeding generations.

One aspect of land use policy is the formulation of laws and regulations affecting the allocation and use of land as indicated by information presented in the analysis of resource development products. Conveyance corridors are land-demanding development projects for which complete analysis is often not attained. A review of literature and personal communications dealing with the evaluation of conveyance corridors reveals that the important area of opportunity costs accruing to land resources is often neglected.

Manitoba embraces 46,346 miles of roads and highways, 37,493 miles of hydro transmission and distributional lines and 3911 miles of pipelines

(Table 1 and Appendix I), all expanding and all decreasing availability of productive land to varying degrees. To enhance the information base upon which decision-makers may make decisions relating to many aspects of conveyance corridor policy in Manitoba, this report is directed at the following problems.

1) What is the theoretical structure required to analyze opportunity costs of conveyance corridors?
2) Do corridors have any beneficial impacts?
3) To what degree is land used by conveyance corridors in Manitoba?

Objectives

1) To develop a practical method of calculating opportunity costs of conveyance corridors traversing agricultural and forestry lands.
2) To discuss and emphasize the need for considering the use of wildlife lands and recreational areas for conveyance corridors, and to present the difficulties in formulating a strict economically justified opportunity cost analysis technique to evaluate conveyance corridors in recreational and wildlife areas.
3) To determine some corridor effects on wildlife and assess the suitability of rights-of-way as habitat.
4) To study some effects of various corridors in soil productivity.

Method of analysis - theoretical opportunity cost framework

With established guidelines for developing benefit-cost structures, relevant criteria applicable to an opportunity cost framework will be cited

Table 1. Mileage and acreage of land used by pipelines, hydro lines and highways in Manitoba.

Corridor type	Miles (N)[a]	Land used (acres)[b]	Potential for wildlife and agriculture (acres)[c]	Land taken out of production (acres)[d]
Gas pipelines	2834	2815	--	--
Oil pipelines	1077	1455	--	--
Hydro voltage hydro lines	4536	109737	89260	--
Highways	46346	583508	444716	138792
Total		697515	533976	138792

[a]Figures for gas and oil pipelines are total number of miles of all reported pipes. This is not a reflection of the number of miles of rights-of-way as a number of lines may be in the same corridor (Statistics Canada 1973a;47, 1973b:40-41).

Figures for hydro transmission lines do not include two lines of the same voltage in one corridor. Circuit mileage for lines is 9225 miles. The mileage of pole type is 2724 of steel tower structures and 5673 of wooden pole structures. Total of all transmission and distribution line mileage is 37493. (Manitoba Hydro personal communication).

[b]Figure for gas line represents right-of-way of the TransCanada Pipelines (Personal communication), which equals approximately 258 miles with average corridor width of 90 feet. Figure does not include distribution line acreage.

Figure for oil line represents right-of-way of Interprovincial Pipe Line Ltd. (Personal communication), which equals approximately 200 miles with average corridor width of 60 feet. The figure does not include distribution line acreage.

[c]Oetting (1971a, 1971b).

[d]Land not available for production due to driving surface, etc.

and used to prepare a general opportunity cost equation for conveyance corridors traversing forested and agricultural lands.

Considering the measurability of various costs and benefits determining opportunity costs, a practical economic equation will be presented. This technique requires:

1) Identification of relevent costs and benefits based on theoretical economic guidelines.

2) Identification of elements comprising various costs and benefits.

3) Mathematical procedures for calculation of costs and benefits leading to a final opportunity cost value.

4) Discussion of measurability of costs and benefits determined by availability, practicality and economics of measuring specified elements comprising costs and benefits.

Method of analysis - application - agricultural land

The major objective here is to apply the established method of calculating opportunity costs to the three conveyance corridors. Since the most important effects of corridors on arable land are to reduce the amount of land available for production and change soil fertility, a technique utilizing soil productivity maps and corridor elements is needed so that primary production losses or gains (in dollar values) may be applied to each right-of-way. This technique requires:

1) A suitable formulation for soil productivity in Manitoba for derivation of crop yields.

2) Statistical data for calculation of the amount of land used by each corridor type.

3) Statistical data as to price and time horizons for calculation of various costs and benefits.

4) Derivation of relative opportunity cost values for comparison purposes.

Method of analysis - application - forested land

Forestry, like agriculture, is a primary land use industry. Materials required are:

1) Formulation of mean annual forest increment which is in reality a productivity classification.

2) Application of conveyance right-of-way statistics as they apply to forested areas.

3) Statistical data as to price and time horizon for calculation of various costs and benefits.

4) Derivation of relative opportunity cost values for comparison purposes.

Method of analysis - recreation

Realizing the difficulties in assessing corridor effects on recreational land, analysis will proceed with a discussion of problems involved and a presentation of an alternative technique to alleviate some identified problems.

Method of analysis - wildlife

Various forms of wildlife occur everywhere in Manitoba and all land has potential for wildlife production. Since it is extremely difficult, if not impossible to assess wildlife benefits in dollar values, the method of evaluation of corridor effects will be directed at why economic evaluation is not possible and how corridors can be beneficial to wildlife. An alternative method for evaluation of wildlife affected by corridors will also be attempted.

Part 2 : Theoretical and practical opportunity cost guidelines and equations

The importance of opportunity cost analysis in evaluating costs for the benefit of the decision-maker is its basic application. According to Pfiffner and Presthus (1967:109) the decision-maker is concerned with:

> "...rational choice and with the barriers to it stemming from lack of information, value conflicts between participants in a decision, failure or inability to assign priorities to the values sought, and the problems of a 'contingent universe' in which one can rarely anticipate all the possible consequences of his actions. While these conditions seem to make decision making less rational than we would like, they arise because conditions in the real world are inevitably ambiguous and tentative."

With rapid utilization of land by the conveyance corridor, development of the theoretical framework for opportunity cost analysis and its practical application may provide the decision-maker with added information for his evaluation.

Opportunity cost analysis of proposed and existing corridors will affect decisions relating to a wide variety of aspects directly or indirectly resulting from this particular land u[illegible]ific areas of concern wherein opportunity cost analysis may enlighten any future decision are:

1) location of right-of-way routes,

2) rationalization of right-of-way routes,

3) physical dimensions of corridors,

4) policy considerations of resulting surface disturbance,

5) multiple-land use along the corridors and

6) maintenance policies and land use enhancement policies.

Opportunity costs are values foregone in the utilization of land for corridor purposes rather than its highest alternative use. In the strictest definition, all economic costs are opportunity costs. However, this report uses a narrower definition and considers only the value of foregone resource use opportunity, the value of lost physical production, as opportunity costs.

Applying this definition to problem areas suggested above, it is evident that analysis of taking land out of production or diminishing its production capabilities and considering the ramifications of development may influence each of the problems in the following manner.

Opportunity costs, (specifically the lost monetary value of crops, forage and timber) may, if considered in a benefit cost analysis, decrease the desirability of routing highways, pipelines and hydro lines through highly productive land. It may also suggest the grouping of corridors to minimize costs of lost production but also alleviate many of the intangible and external costs resulting from the corridors. Consideration of these costs may lead to evaluation of criteria used in deciding corridor dimensions, that policies now may be outdated and revision of technical priorities may be required. Surface disturbance, multiple-land use, maintenance, land enhancement and abandonment policies affect the final out-come of opportunity cost analysis. For elements and variables composing the functional relationship of opportunity cost values are related to existing policies followed by corridor operators. Respectively, delineation and interrelationships of elements to opportunity cost values will detail to decision-makers and planners effects of corridor land use in comparable dollar terms. In total, the analysis is circular. All areas of concern have interrelationships which must be considered. No area can be evaluated or analyzed for its own purpose but must be viewed as an element of a whole. Thus opportunity cost analysis acts as a link between all elements: physical, political, social and technical, as it is an expression, in part, of them all.

General guidelines for the opportunity cost equation

Opportunity cost evaluation is only a technique for making decisions within an existing political, social, economic and technical framework, and in simplified terms deals with enumeration and evaluation of values foregone. It is essentially the delineation of elements and variables which will affect a wide spectrum of decisions.

Therefore of prominent importance are general guidelines or principles underwhich analysis will be performed. Prest and Turvey (1965:686) outlined the significant questions to be answered for cost-benefit analysis, of which the relevant items to this report are:

1) Which costs and which benefits are to be included?

2) How are they to be valued?

3) What are the relevant constraints?

Answers to these questions will form the economic framework of this analysis.

1. Delineation of costs and benefits

This report is directed at a particular category of costs and benefits which are directly related to installation of a corridor. Thus opportunity costs resulting from possible investment of capital into other alternative projects are not considered. Many authors dealt with this aspect (Feldstein 1964) and full documentation may be found in the literature.

Due to the nature of corridors and to simplify the analysis, it is assumed that no market interrelationship between production of eletricity, oil or providing vehicle routes on production of crops, forage and timber, or any effect of the corridor on the price of crops, forage or timber.

Direct costs

These are costs of goods which must be surrendered to construct, operate and maintain the corridor (Sewell et al. 1961) and are limited to those goods obtainable only from the used corridor land.

External costs

These are non-marketed by-products (costs) which accrue to some other body and which the producing entity of the externality is not charged for the cost. The question then becomes to what degree should the costs be accounted for?

McKean (1958) suggested that originators of the externality (corridor operator) should account for actions which alter physical production capabilities of others (in this case particularly the land resource) or satisfactions that consumers attain from given resources. However, the originator of the cost should not be liable for side-effects reflected in off-setting prices of products or factors. Thus the operator in this first case must account for lost production of crops from a unit of land if that land cannot support production any longer due to an oil spill resulting from a pipeline burst. The second case refers to purely transfer or distributional items. Incidental and sequential price changes of goods should be eliminated (Prest and Turvey 1965).

Direct benefits

Direct benefits accruing to the corridor are defined as those net values or more specifically the increased production capability of the land resource itself. These benefits are limited to a measure of the physical increased yield of the land resulting from the physical alteration of the land by the corridor operator.

External benefits

External benefits are non-marketed by-products which are positive in value and accrue to some other person and which the producing entity of the externality is never given credit (Seldon and Phillips 1973).

Guidelines presented by McKean (1958) as applied to external costs are applicable here and are the principles deciding benefits to be considered.

Corridor life

The time horizon over which opportunity costs are to be calculated vary between corridor type and decision-making time frame. As Prest and Turvey (1965:690) suggested:

> "Estimation of length of life is clearly a highly subjective process depending on assessments of the physical length of life (in the case of corridors not as important

> as structures are readily replaced), technological changes, shifts in demand, emergence of competing products and so on."

It is evident that time horizons are not specific and are to be considered judgment factors.

2. Evaluation - measurement of costs and benefits

Cost and benefits defined for corridors should be to the greatest extent possible expressed in monetary terms, as determined by the market system.

Quantification of costs and benefits requires assumptions about the general level of prices to be used. Irrespective of the constant current price level or future price level to be used, all elements of costs and benefits must be evaluated at the same level (Sewell et al. 1961). It is also suggested (Prest and Turvey 1965) that adjustments are required for expected prices of future inputs and outputs to allow for changes in relative prices of the items involved (that is, changes in price due to factors such as shortages of supply), but not for expected changes in the general price level (inflation). As stated by Sewell et al. (1961:14):

> "It is essential, however, that any expected individual price changes which may significantly alter the relationship between the values of benefits and costs from that based on today's prices be taken into account."

Intangibles - costs and benefits

Intangibles defined by various authors (Devine 1966, Prest and Turvey 1965) are those elements and factors which are not directly quantifiable, or if quantifiable, cannot be valued by the market system.

Sewell et al. (1961:16) defined intangibles as:

> "...services not usually bought or sold at a price or a fee, nor can their value be derived indirectly from the secondary products produced by using these services."

It must, however, be realized that intangibles and unmeasurable costs and benefits may have an important role in the decision-making process. Thus every effort should be made to point out intangibles and unmeasurable elements and factors within the text of the opportunity cost analysis.

3. Constraints governing analysis

There are a number of constraints which affect, limit and determine the factors relating to costs and benefits which are to be considered. Eckstein (1961) as explained by Prest and Turvey (1965) suggested a number of constraints under which analysis must be considered. The applications of these constraints (discussed in relation to benefit-cost analysis) to opportunity cost analysis of conveyance corridors is as follows.

First are physical constraints relating to the production loss function of a corridor through agricultural and forestry land. This is the consideration of factors, elements, dimensions and variables relating to lost or diminished production of land resulting from corridor installation and all secondary and intangible factors.

Legal constraints, that is laws (statutes and departmental acts) reflect costs and benefits to be analyzed and must be considered.

Since analysis has an objective, to help in decision-making, formulation and completion of analysis must comply with administrative constraints. It must consider administrative capabilities and monetary budget limitations of the organization for whom the analysis is being done.

Finally, social or more specifically ethical and value constraints of the population must be considered. Recent events have shown that the greatest addition to benefit-cost analysis has been changing ethical and value standards of society regarding the environment and intangible and external costs and benefits accompanying resource development. Analysis of opportunity costs must therefore consider those elements which society deems relevant to resource development.

4. Accounting stance

Installation of conveyance corridors has varied economic impacts on different agencies and groups within a nation. Three economic viewpoints will be discussed: national, provincial and primary producer.

To clarify evaluation of opportunity cost of the different viewpoints, realistic assumptions are required. For the provincial stance the assumptions are:

1) The foregone monetary value of agricultural and forestry commodities lost due to a single corridor does not significantly affect the provincial economy and negligible impacts occur within the respective industries involved.

2) The total value foregone of physical products from all conveyance corridors in a province "may" have an affect on the provincial economy.

For the national viewpoint the assumption is:

1) The foregone monetary value of commodities from all corridors within a province does not adversely affect the national economy or the appropriate industries as a whole.

For the individual or primary producer the assumption is:

1) The foregone monetary value of commodities lost due to a corridor affects the primary producer's income.

Under the first provincial assumption, the value foregone required is the net value of commodities lost. Since no decrease occurs in the economy or various industries involved (that is, no significant change in employment, wages, incomes, etc.) no commercial or social opportunity costs are foregone (Hildebrant-Young and Associates Ltd. 1970:80). Net value of the opportunity cost equals selling price minus production costs.

The second provincial assumption is qualified by "may", simply because of the difficulty in demonstrating possible opportunity cost impact of all corridors on provincial economy and appropriate industries. If the result of conveyance corridors is to restrict the economy and industries involved, that is to reduce output, wages, employment, etc., then there is a commerical and social value foregone. Thus, the required level of opportunity cost evaluation is gross value of products lost. The opportunity cost of commodites foregone equals selling price minus only value of those goods and services which must be imported to produce the commodites.

For the individual who acquires his income from primary production of commodities foregone, opportunity cost of the corridor is the monetary decrease in income resulting from decreased production. This decrease in income is net value of goods produced, found by subtracting from selling price the costs of production.

In evaluating opportunity costs from the national viewpoint, Hildebrant-Young and Associates Ltd. (1970:82) stated:

> "...it is usually the case that the measure of opportunity costs for a national point of view produces an estimate of only relatively small magnitude of opportunity foregone... The vast abundance of natural resources within Canada makes it unlikely that a harvest foregone in one area of the nation cannot be replaced by a harvest of equal size from hitherto unused resources in some other location within the country."

Since resource use foregone does not critically affect the national economy, the value of pure economic rent foregone is the level of evaluation required (Hildebrant-Young and Associates Ltd. 170:49).

Barlowe (1972:157-158) defined economic rent as:

> "...the surplus of income above the minimum supply price it takes to bring a factor into production.
>
> Economic rent...can be viewed largely as a short-run economic surplus that a productive factor or an operator can earn because of unexpected demand or supply conditions. Over longer time periods, the supply and demand for the commodity in question come into balance, and the phenomenon of economic rent disappears."

Considering this definition, the opportunity costs of agricultural and forestry commodities foregone from the national viewpoint are negligible and are assumed to equal zero. Since the evaluation is dependent on pure economic rent and assuming long-run equilibrium (evaluation horizons are of considerable duration), no pure economic rent exists.

Evaluation and development of opportunity cost framework for conveyance corridors becomes simplified because of assumptions and arguments presented on accounting stance. Further, assuming no services or goods must be imported to produce commodities under investigation the following values of opportunity cost are required:

1) provincial viewpoint - no corridor impact, net value,
2) provincial viewpoint - some corridor impact, gross value,
3) individual viewpoint - some corridor impact, net value,
4) national viewpoint - no corridor impact, no opportunity cost.

Equations to be developed will be directed specifically at defining the provincial viewpoint, considering no corridor impact, and the individual viewpoint.

Guidelines discussed for identification of costs and benefits, criteria of evaluation, constraints affecting analysis and accounting stance will now be used to develop a series of opportunity cost functions for the three conveyance corridors (pipeline, hydro line and highway) traversing agricultural and forestry lands.

Four major categories of costs and benefits have been outlined in the guidelines presented for opportunity cost analysis. These four categories direct and external costs and direct and external benefits will be used as the groups into which specific elements, dimensions and variables will be placed in discussion and development of specific opportunity cost equations. It must be noted that only those elements which have been identified by way of literature research, personal communication and field research are considered.

Elements of the opportunity cost function - previous use agriculture

1. Highways

Value of allocating land for corridor use depends on direct, external and intangible costs, minus direct, external and intangible benefits. Specific elements or variables composing each major category in relation to agricultural land used for a highway corridor are discussed below.

Direct cost is the net value of obtainable agricultural products surrendered in order to construct, operate and maintain the corridor. Specifically, value of lost and/or diminished production depends on:

1) amount of land used or made unproductive,

2) productivity of the land for growing agricultural products,

3) amount of lost production (that is, decrease in the numerical amount of yield attainable),

4) market price of the product,

5) production costs required to obtain agricultural goods,

6) value of any secondary agricultural production.

External and intangible costs identified with highway corridors are:

1) value of lost production resulting from weeds originating in the corridor,

2) value of lost production due to pollution both chemical and noise from increased traffic and construction of the highway,

3) value of lost wildlife habitat and wildlife killed during the construction phase and by traffic using the corridor,

4) value of change in the environment viewed as lost esthetics.

Direct benefits are increases in production of land resulting from the corridor. No direct benefits are known to occur with a highway corridor traversing agricultural land.

The only non-marketed third person benefit identified for a highway corridor is the value of increased wildlife habitat which may occur along the corridor.

The time horizon over which opportunity cost values may be calculated are of a judgment nature. In reality, they may be considered infinite as highways may be continually improved and repaired. Even if they are abandoned and the physical structures are left in place, production is still restricted.

Mathematics of the opportunity cost equation

To obtain total opportunity cost value, the various costs must be added together and benefits subtracted.

There are four major components associated with direct costs. They are:

1) value of lost production where more land is required for construction than is stipulated for the legal width of the corridor,

2) value of lost production due to the driving surface,

3) lost value of production due to the ditch,

4) value of lost production due to severance (severance refers to other lands not confined to the corridor but affected by the corridor, in that the land is too small to work due to location of the corridor or is inaccessible for operation due to construction of the corridor).

Essentially, each component is the result of calculating amount of crops lost and multiplying it by the price for that crop. The procedure is to multiply the area used in a productivity zone by the crop yield of that zone times the percentage of production lost (expressed as a decimal) to obtain the numerical amount of production lost, then multiplying this amount by market price paid for the crop. These amounts are then summed for each individual component through various productivity zones. To complete the calculation, all direct cost components are added. To obtain net value of production lost, marginal cost of production is subtracted.

Marginal costs, and not average costs, of production are used because it does not necessarily follow that taking a few acres of land out of production from a farm unit will decrease total costs of production proportional to the amount of land made unproductive. As stated in Chapter 4 by Friesen (1966:17-18):

> "It must be realized however, that by taking the cost of production into consideration; it does not necessarily follow that having lost the use of the five or three acres, as the case may be the owner saves that amount per year in the cost of producing the crop of his other lands...According to the evidence of the owners, an owner traverses

> his cultivated field at least four or five times per year in the growing of his crop thereon, and on summer fallow at least three times.
>
> The larger the field to be operated, the less the cost of operation thereof. A field of say 160 acres of grain or summer fallow, can be worked at considerable less expense in total and per acre than two or more fields totalling 160 acres."

There are a variety of components for each external and intangible cost and benefit accruing to a highway corridor. Since many components are difficult to define and the elements so varied, specific procedures in calculating each will not be discussed. Each externality and intangible is considered an entity unto itself; the external and intangible costs are additive to direct costs and external and intangible benefits are subtracted.

Opportunity cost equation

In mathematical notation[1], the opportunity cost components are symbolized:

$$OC = (\sum A_c PUP'REYF) + (\sum A_d PUP'REYF) + (\sum A_t PUP'REYF) + (\sum A_s PUP'REYF) - (V_t Y) - (M_c Z) + S + B + C + H - J$$

where:

OC = the total opportunity cost (net value of goods lost for a specified time horizon).

$(\sum A_c PUP'REYF)$ = monetary value of lost goods from the land where construction width exceeds legal width. It is the sum of monetary value of lost goods by soil productivity zone.

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[1]The notation used here is a simplification of the mathematical meaning intended. The proper notation is,

$OC = (\sum_{i=1}^{N} A_{ci} P_i UP_i' R_i EYF) + \ldots$ Where 'i' is a specific productivity zone and the value foregone in every zone is calculated and summed.

$(\sum A_d PUP'REYF)$ = monetary value of lost goods by soil productivity zone due to the driving surface.

$(\sum A_t PUP'REYF)$ = monetary value of lost goods associated with land used for the ditch.

$(\sum A_s PUP'REYF)$ = monetary value of lost goods associated with land not operable due to severance.

$(V_t Y)$ = monetary value of any secondary agricultural use made of the corridor.

$(M_c Z)$ = total marginal cost of production along the corridor and on severed land.

S;B;C;H;J = specific externalities and intangibles.

where:

A_c = the area, by productivity zone, of extra land required for construction; found by subtracting the legal final corridor width from the construction width, by productivity zone, and multiplying by the length of the corridor in that zone; unit of measurement acres.

P = soil productivity of the land by crop type; unit of measurement usually bushels per acre.

U = constant reflecting any expected change, increase or decrease in the productivity, (yield) of the land due to technology, superior management or soil erosion, etc.; no unit of measurement.

P' = percentage change (decrease) in production-productivity of the land due to the corridor, expressed as a decimal. For example, the driving surface of a highway will not allow any production of agricultural goods, therefore, P = 100 percent loss expressed as 1.

R = market price for the particular crop grown in the specified productivity zone; unit of measurement is dollars/bushels.

E = constant reflecting any expected change in prices paid for crops resulting from such situations in the market as shortages or shifts in demand; no unit of measurement.

Y = time duration over which costs will be calculated. There are different time horizons required; Y is a general symbol and must be specified for each component being calculated. Thus in regard to the component of direct costs where construction width exceeds legal width, the time horizon is expressed for a period until construction is finished and the extra land required is returned to production. The time horizon needed to calculate the value of goods lost to the driving surface may depend on the physical life of the highway pavement assuming it is then returned to production. Generally, however, it is a judgment measurement; unit of measurement is years.

F = constant reflecting agriculture practice of land use. Since land is often laid fallow for the purpose of rejuvenation of soil productivity, the opportunity cost value must allow for land not being utilized every year. In Manitoba it is common practice to leave land fallow every third year. Thus a factor reflecting this practice must be included for Manitoba.

A_d = area, by productivity zone, of land required by the driving surface (pavement plus shoulder). Found by multiplying driving width by the length per soil zone; unit of measurement is acres.

A_s = area, by productivity zone, lost to severance; unit of measurement is acres.

A_t = area, by productivity zone, required for the ditch (that area between edge of driving surface and edge of corridor right-of-way); unit of measurement is acres.

V_t = net value of any secondary agricultural production obtained within the corridor; unit of measurement is dollars.

M_c = total marginal cost of production required to produce goods foregone; unit of measurement is dollars.

Z = constant reflecting any expected change in marginal cost of production resulting from such situations as changing technology and superior management; no unit of measurement.

S = net value of lost production due to weeds originating in the corridor and the responsibility of the corridor operator; unit of measurement is dollars.

B = net value of lost goods due to pollution (chemical and noise) resulting from traffic and construction of the corridor; unit of measurement is dollars.

C = net value of lost wildlife or habitat due to construction of the corridor or by traffic travelling the highways; unit of measurement is dollars.

H = net value of the change in the native environment viewed as esthetics; unit of measurement is dollars.

J = net value of increased wildlife or wildlife habitat within the corridor; unit of measurement is dollars.

Measurability of opportunity cost variables

It is necessary to discuss measurability of each element within the general equation to determine extent of error introduced and to provide for a practical equation considering the state of knowledge available for corridor evaluation.

Elements will be divided into groups for simplicity of analysis based on measurability and availability of data.

Measurable

With any proposed route plan for a highway, dimensions of the right-of-way are usually stated. Therefore many required elements can be measured (in their appropriate units or units capable of conversion) directly from blueprints or are available within the text of the plan. Elements obtainable here are: A_c, A_d, A_t, P', A_s.

Elements presented below are available from different agencies and literature sources. They are:

P - productivity of agricultural land by crop type, agency: Manitoba Crop Insurance Corporation.

R - prices for crops, available from a number of sources and agencies; however, the level of prices used must be defined fully for proper evaluation.

E - constant relating to expected change in price; can be measured and in many cases have been evaluated. The factor used must be compatible with guidelines discussed earlier.

F - constant relating to normal agricultural operations of rotation of crops, agency: Department of Agriculture.

Not measurable - difficult to measure - no data available

V_t - net value of secondary agricultural production along the corridor is difficult to measure as no records are kept stating percentage of the area used for secondary production and there are no data as to exact nature of use. It is also difficult if not impossible to predict possible secondary use along the corridor. However, where available it must be included.

M_c - total marginal cost of production is the sum of the individual (farmer) marginal costs of production along the entire route. Individual marginal costs vary with the type of farming operation, amount of land being farmed and managerial superiority of the individual, all of which make measuring of these cost difficult.

U - constant relating to expected change in productivity is dependent on capability of the land, management techniques and technological change. No figure can be quoted and data are limited, making this element non-measurable at present.

Z - constant relating to expected change in production marginal costs is not measurable because of its dependence on the individual operator and technology for which detailed data are not available.

S - value of lost production due to weeds originating from the corridor. As the spread of weeds is dependent on many factors, it is almost impossible to ascertain the origins of weeds within a field to a particular area. The fact that weeds might be spread over a great distance makes this variable non-measurable in most situations.

B - cost of pollution (chemical and noise) resulting from traffic and construction. This element is composed of a variety of situations practically all impossible to measure, particularly costs or value of pollution viewed in relation to people and production. The case becomes, what value or cost is accrued to the person or persons, resulting from increased noise level. The fact that most people cannot relate noise level to dollar values makes the evaluation of the element impractical from this economic stance. The same situation also arises when chemical pollutants are released into the air; people are not accustomed to relating chemical pollutants to dollar values or more specifically, cannot. Costs of pollution can in certain instances be evaluated, for example, an oil spill of a truck draining into a field. However, resultant loss of production occurring ten miles away due to exhaust fumes would be very difficult to evaluate.

H - value of change in native environment viewed as esthetics. Esthetics has a loose relationship between viewers and the particular object being viewed, since esthetics or a component of esthetics (beauty) is in the eye of the beholder. What is beautiful and desirable to one person may generate no emotional response in another. However, given this descrepancy, the problem is, how does one value esthetics? At present, analytical ability in this area cannot ascertain with certainty and accuracy, except in some theoretical models, the value of esthetics. Thus the value of esthetics is non-measurable.

C - value of wildlife destroyed by construction and corridor traffic is another variable whose measurability is dubious. Although numerous studies place monetary values on wildlife, the analysis is usually geared to game animals. Therefore, the vast majority of wildlife species are neglected or assumed to have no value. The diversity of values expressed, the tremendous amount of research required to estimate wildlife kills and analysis of costs makes this element non-measurable.

J - value of wildlife and habitat generated by the corridor. The rationalization concerning the value of killed wildlife suggests that this element is also non-measurable, not only for the reasons cited but owing to the great expense required to produce comparative inventories such that the quality of wildlife increase can be ascertained.

Resulting practical opportunity cost equation for a highway corridor within agricultural land

$$OC = (\sum A_c PP'REYF) + (\sum A_d PP'REYF) + (\sum A_t PP'REYF) + (\sum A_s PP'REYF) - (V_t Y)$$

Using the criteria of measurability and availability of data, all external and intangible costs and benefits have been eliminated. It is realized and emphasized that although these factors are difficult to measure in monetary terms (if not impossible for some), some method of considering them is necessary (eg. rank-ordering) to fulfill the purpose of providing decision-makers with accurate and informative data.

2. Hydro transmission lines

Development of a hydro line right-of-way opportunity cost equation will follow the format used previously. Elements and variables composing each major cost and benefit category identified are as follows.

Direct cost of agricultural goods surrendered in order to construct, operate and maintain a hydro line corridor depends upon: amount of land used, productivity of the land, degree of lost production, market price of the goods and production costs of obtaining the goods.

The third person and intangible costs associated with this corridor are: monetary value of lost production to all lands from weeds originating under the hydro structures, value of noise costs during the construction phase, value of lost wildlife habitat or wildlife killed during the construction phase or by the structure itself and value of the change in the environment viewed as lost esthetics.

As in the case of a highway corridor, no direct benefits were observed for a hydro right-of-way.

The only external benefit realized by a hydro corridor is the value of increased wildlife and habitat which may result under the towers.

Mathematics of the opportunity cost equation

The total opportunity cost value is equal to the addition of various cost categories minus total value of benefits. The procedure required to calculate the value of each category is the same as that presented for a highway corridor. Various elements comprising each group are multiplied by each other to obtain a final result, the only difference being the specific elements involved.

Direct cost group depends upon: value of goods lost due to the hydro structures, value of lost production due to construction and value of goods surrendered due to severance.

External costs and benefits are composed of numerous elements and variables and are dealt within the manner previously completed for the highway corridor.

Opportunity cost equation

Using notation, opportunity cost components may be represented by the following equation:

$$OC = (\sum A_b PUP'REYF) + (\sum A_o PUP'REYF) + (\sum A_s PUP'REYF) - (M_c Z) + S + B + C + H - J$$

where:

OC = total opportunity cost value (net value of goods lost for a specified time horizon).

$(\sum A_b PUP'REYF)$ = monetary value of lost goods from the land due to the hydro line towers.

$(\sum A_o PUP'REYF)$ = monetary value of lost goods from the land due to construction.

$(\sum A_s PUP'REYF)$ = monetary value of lost goods associated with land not operable due to severance.

$(M_c Z)$ = total marginal cost of production along the corridor and on severed land.

S;B;C;H;J = specific externalities and intangibles.

where:

A_b = area used by hydro structures, by productivity zone; found by multiplying basal area of the structure by the number of structures per productivity zone; unit of measurement is acres.

A_o = area used for construction, by productivity zone; unit of measurement is acres.

All other denoted elements and variables have definitions as previously defined for a highway corridor.

Measurability of opportunity cost variables

Since most elements and variables have been previously discussed for a highway corridor, only those new elements and variables will be discussed as to their ability to be measured.

The new variables (A_b and A_c) are measurable and available from planning records or technical data.

<u>Resulting practical opportunity cost equation for a hydro line corridor on agricultural land</u>

$$OC = (\sum A_b PP'REYF) + (\sum A_o PP'REYF) + (\sum A_s PP'REYF)$$

3. <u>Buried pipelines</u>

As discussed for highway and hydro transmission line corridors, opportunity cost value for a buried pipeline also depends on direct, external and intangible costs and benefits. Elements identified for each are discussed below.

Monetary value of direct costs foregone (agricultural products) due to construction, operation and maintenance of a buried pipeline corridor depends upon: amount of land used, land productivity, degree of lost production, market price of the goods and production costs of acquiring the agricultural commodities.

Third person costs associated with a buried pipeline corridor are: monetary value of noise costs and value of wildlife killed during construction.

Direct benefits accruing from a corridor are defined as any increase in the production capability of the land resource. Disturbance of the soil by digging of a trench and the clean up following installation of the line may give rise to some increase in crop yield. Value of the direct benefit depends on: amount of land with increased capacity, amount of increased yield, market price of the goods and production costs of acquiring agricultural products.

No external benefits have been identified for a buried pipeline corridor.

Mathematics of the opportunity cost equation

The value of the opportunity cost equation is equal to the summation of direct, external and intangible costs minus direct benefits for a pipeline corridor. The procedure is to identify elements composing each category of costs and benefits and perform mathematical operations required to attain desired results as previously completed for the other corridors.

The direct cost group is composed of: value of goods lost due to construction, value of goods lost annually over the trench resulting from decreased productivity, value of goods lost annually in the location of the clay bank due to decreased productivity and value of goods lost due to severance during construction.

The direct benefits are composed of the value of increased yield over the trench due to increased productivity of the soil resulting from either the restructuring of the soil texture or heat given off by the line.

External costs are dealt with as previously outlined for a highway corridor.

Opportunity cost equation

Costs and benefits of a pipeline corridor and variables comprising these groups may be denoted as follows:

$$OC = (\sum A_o PUP'REYF) + (\sum A_k PUP'REYF) + (\sum A_L PUP'REYF) + (\sum A_s PUP'REYF) - (\sum APUD'REYF) - (M_c Z) + B + C$$

where:

OC = total opportunity cost (net value of goods lost for a specified time horizon).

$(\Sigma\ A_oPUP'REYF)$ = monetary value of lost goods due to construction of a pipeline.

$(\Sigma\ A_kPUP'REYF)$ = annual monetary value of lost goods confined to the trench area.

$(\Sigma\ A_LPUP'REYF)$ = annual monetary value of lost goods confined to the clay bank area.

$(\Sigma\ A_sPUP'REYF)$ = monetary value of goods associated with land not operable due to severance.

$(\Sigma\ APUD'REYF)$ = monetary value of goods obtained due to increased productivity of the soil resulting from installation of the line.

(M_cZ) = total marginal cost of production along the corridor and on severed land.

B;C = specific externalities and intangibles.

where:

A_k = area used for the trench, by productivity zone; found by multiplying width of the trench by its length in each productivity zone; unit of measurement is acres.

A_L = area used for the clay bank, by productivity zone; unit of measurement is acres.

A = area of land where increased productivity of the soil is realized; unit of measurement is acres.

D' = increased productivity change obtained; expressed as a decimal percent of the normal yield realized; no unit of measurement.

All other elements presented in this equation are the same as those defined for a highway.

Measurability of the opportunity cost equation

Only those variables which are decidedly different or have a particular feature not previously considered will be discussed. Those not discussed are the same as described for a highway corridor.

Measurable

Elements available from the planning records are A_k and A_L.

Difficult to measure

P' and D' - change in productivity of the soil associated with the trench and clay bank presents a problem of quantification. The change in productivity affecting the yield is related to change in capacity of the soil due to disturbance. Two studies which have dealt with this aspect present completely different results. A general observation reveals that there may be an increase, decrease or no change in yield over the trench, with change related to soil type and construction procedures used in laying the line. However, these variables must be measured if any reasonable value is to be presented. Such techniques as detailed field studies or questionnaires to individual land owners will provide an approximation of these variables.

Resulting opportunity cost equation for a buried pipeline corridor within agricultural land

$$OC = (\sum A_o PP'REYF) + (\sum A_k PP'REYF) + (\sum A_L PP'REYF) + (\sum A_s PP'REYF) - (\sum APD'REYF)$$

Elements of the opportunity cost function - previous use forestry

The equation to express opportunity cost value of a highway, hydro transmission line or pipeline through forested land depends in general on the categories of costs and benefits expressed for a right-of-way traversing agricultural land, major groups being direct, external and intangible costs and direct, external and intangible benefits.

Since no timber growth is allowed along conveyance corridors due to maintenance problems, physical factors of driving surfaces, ditches, trenches, clay banks and towers have a negligible role in evaluation of opportunity costs. With the elimination of these factors, development of the opportunity cost equation is simplified with the result that one equation can be formulated to represent the three conveyance corridors.

Following established guidelines for economic evaluation of opportunity costs, costs and benefits identified will be presented in a manner similar to those developed for agricultural land.

For any corridor traversing forested land, direct cost is the value of timber surrendered in order to construct, operate and maintain the corridor. This cost will depend on:

1) amount of land used or made unproductive,

a) productivity of land, (its yield of timber),

3) amount of yield lost,

4) market price of timber,

5) production costs of obtaining forestry goods and

6) value of any secondary use of the corridor.

The third person and intangible costs identified are:

1) Value of wildlife killed and habitat destroyed during construction and from clear-cutting of the right-of-way (pipelines, hydro lines and highways). Additional to a highway corridor is the extra wildlife killed from traffic.

2) Value of the change in the native environment viewed as lost esthetics.

3) Net value of lost initial and annual timber growth due to windfall.

4) Value of lost production due to pollution (chemical and noise) during construction (hydro line, pipeline and highway). Additional cost accruing to a highway corridor is lost production to pollution from traffic.

No direct benefits have been identified for any corridor traversing forested land.

External and intangible benefits identified are:

1) Net value of potential and actual increase in wildlife habitat due to the creation of openings in forested areas. The magnitude of this value will differ between a highway corridor and the other two corridors, as the driving surface is not available for wildlife.

2) Since corridors will physically allow some traffic in the form of off-road vehicles and pedestrian use, the corridor may offer some recreational experience value.

3) Net value of the corridor as a fire break and access route for fire protection.

Mathematics of the opportunity cost equation

Total opportunity cost value is equal to the summation of all costs minus benefits.

The direct cost group is composed of:

1) value of merchantable timber lost along the cleared right-of-way,

2) value of lost annual tree growth along the cleared right-of-way,

3) value of secondary use occurring along the corridor.

To obtain total value of the direct cost, each of the sub-costs are calculated by finding the amount of timber lost and multiplying by the market price of timber and subtracting marginal costs of producing the goods. Sub-costs are added together and the net value of any secondary production occurring along the corridor is subtracted.

Since many of the external and intangible costs and benefits are difficult to quantify and many factors must be considered, each externality and tangible is dealt with as a separate entity. Thus external costs are additive to direct costs with external benefits subtracted.

Opportunity cost equation

In mathematical terms, costs and benefits forming the opportunity cost equation for a highway, hydro line or pipeline corridor traversing forested land may be represented as follows:

$$OC = (\sum A_c GXP'RE) + (\sum A_m PUP'XREY) - (V_t Y) - (M_c Z) + C + H + O - Q - I - J$$

where:

$(\sum A_c GXP'RE)$ = monetary value of merchantable timber lost to construction of the corridor by clear-cutting.

$(\sum A_m PUP'XREY)$ = monetary value of lost annual tree growth along the corridor over a specified time horizon.

$(V_t Y)$ = net monetary value of any secondary production operations occurred along the corridor.

$(M_c Z)$ = total marginal cost of timber production along the corridor.

C; H; O; Q; I; J = specific externalities and intangibles.

where:

A_c = area clear-cut for construction purposes, by productivity zone; unit of measurement is acres.

G = merchantable volume of timber occurring in each productivity zone; unit of measurement cubic feet.

X = tree species mix expressed as a decimal percent, by productivity zone. This is required to calculate the volume of timber by species within each zone.

P' = decimal percentage of production loss along the corridor. Since the corridor is clear-cut, P' = 1 can be eliminated from the equation.

R = market prices of different species of trees; unit of measurement dollars/cubic feet.

E = constant reflecting any expected change in prices paid for timber resulting from such situations in the market as shortages or shifts in demand; no unit of measurement.

A_m = area kept clear-cut for operation of the corridor, by productivity zone; unit of measurement is acres.

P = productivity of the land, the annual timber yield, commonly named mean annual increment; unit of measurement is cubic feet per acre per year.

U = constant reflecting any expected change, increase or decrease in productivity (yield) of the land due to technology, superior management, etc.; no unit of measurement.

Y = time duration over which costs will be calculated; unit of measurement is years.

V_t = net value of any secondary production obtained from the corridor; unit of measurement is dollars.

M_c = total marginal cost of production required to produce goods foregone; unit of measurement is dollars.

Z = constant reflecting any expected change in marginal cost of production resulting from such situations as changing technology and superior management; no unit of measurement.

C = net value of lost wildlife or habitat due to construction of the corridor or by traffic; unit of measurement is dollars.

H = net value of the change in the native environment viewed as esthetics; unit of measurement is dollars.

O = net value of destroyed timber due to windfall; unit of measurement is dollars.

I = net value of the corridor as a fire break and as an access route for forest protection; unit of measurement is dollars.

Q = net value of the corridor for recreational use; unit of measurement is dollars.

J = net value of increased wildlife or habitat within the corridor; unit of measurement is dollars.

Measurability of opportunity cost variables

Evaluation of elements comprising the forestry opportunity cost equation will be discussed in a similar manner as presented for agriculture.

Elements will therefore be divided into categories based on their ability to be measured and sources of quantification.

Measurable

With direct measurement from technical plans the elements A_c and A_m may be measured.

A number of agencies, notably Manitoba Forest Inventory Section, prepare maps and timber volume tables for the major part of forested regions in Manitoba. The following elements or the means to calculate the value of these elements can be acquired from this agency:

G - gross merchantable timber volume.

X - forestry maps prepared by Forest Inventory show estimated species mix comprising the various tree stands.

P - productivity, that is the mean annual incremental growth of various stands, though not directly available, can be calculated.

R - prices of timber by species is usually of a confidential nature; however, it is possible to attain these values.

E - constant relating to change in timber prices over time can be measured, however, with the price of timber depending on substitutes which replace wood, any reliable factor is difficult to attain.

Y - time horizon for the life of a corridor may be estimated and for the most part, the time horizon chosen depends primarily on the required evaluation wanted.

Not measurable

Only those variables not previously discussed in respect to a highway corridor through agricultural land will be presented here. Elements which are not measurable and have been discussed previously are U, V_t, M_c, Z, C, J, and H.

The new elements not measurable are:

O - value of trees destroyed due to windfall present a problem in evaluation. The expense of field work and continual surveillance of the corridor make inclusion of this element economically unfeasible.

I - value of the corridor as a fire break and an access route for fire protection is a difficult element to quantify. At present little information is available from which this element can be determined.

Q - value of the corridor as an access route and as a recreational area presents problems of inventory and pricing of a public good. Given the complexity of evaluating this element, it is assumed to be unmeasurable.

Resulting practical opportunity cost equation for a pipeline, hydro line and highway corridor within forestry land

$$OC = (\sum A_c GXRE) + (\sum A_m PXREY) - (V_t Y)$$

Discussion

There are specific cases and elements which have not been delineated in the models for calculating opportunity cost. No account has been made for the direct benefits of drainage by highway ditches or benefits accruing to corridors which have aided producers by clearing land which is then used for agricultural production. Also opportunity costs of abandoning corridors have been neglected.

Given specific corridors however, these benefits and costs are significant considerations of opportunity cost analysis and should be included, where possible.

Summary

Major elements comprising opportunity cost equations are direct, external and intangible benefits and costs. Through agricultural areas corridor dimensions, physical structures within the corridor and elements relating to soil fertility are major variables affecting final equations. Only one equation, with major adjustments to variables, is required to express opportunity cost of conveyance corridors through forested regions. Major elements of this formulation are maintained and initial corridor width, as the right-of-way is kept clear-cut.

Part 3 : Application - agricultural land

Total acreage of arable land in Manitoba is about 19 million. In 1971, 48 percent was planted to crops, 14 percent pasture and 34 percent unimproved or in other uses (Manitoba Dept. Agric. 1972). Although a possibility exists to increase the amount of productive land by improving land not yet of an arable nature, total land for agriculture in Manitoba is fixed with the result that land use other than agriculture will decrease the amount of land available for farm production.

Conveyance corridors have a direct effect on production capabilities of this land and a conflict exists between agriculture and corridor rights-of-way.

The amount of agricultural production derived from a portion of land depends on climate, topography, specifically soil type and soil capability. Soil and climate determine to a great extent what kind of crops can be grown and what yields are possible. For this reason opportunity costs of different conveyance corridors are directly related to soil fertility and climate. In the application of any opportunity cost equation, a basis for determining actual yields for a particular portion of land is necessary. The Manitoba Coop Insurance Corporation (MCIC) soil productivity scale and maps provide a system whereby yields of different crops may be obtained for different locations throughout the agricultural zone of the province.

MCIC classification

The MCIC classification (Ewanek 1973) is directed at productivity of agricultural land as a method of providing an equitable program of crop insurance coverage for farmers. With the intended introduction of crop insurance in Manitoba a project of soil productivity indexing or rating was initiated by the Manitoba Department of Agriculture, the Department of Soil Science, University of Manitoba and Manitoba Soil Survey.

The method of formulation of this classification was:

1) Use of soil survey reports as a basis for soil productivity ratings, from which major soil types were selected and 35 year average yields for wheat, oats and barley were applied.

2) A rating system consisting of 10 classes (denoted A through J, A being the highest productivity, J the lowest, with subclasses C through H subscripts) was established and benchmarked (major) soils were allocated to the appropriate class according to the long-term crop yields.

3) All soils previously mapped were compared with the characteristics of the benchmark soils and placed into the appropriate class.

4) A continuing program of field inspection and questionnaires from insured farmers provides an ongoing up-date of soil productivity within Manitoba.

With establishment of soil productivity classification, ratings were applied to each quarter section of agricultural land in the province. For reasons of practicality however, the rating applied to each quarter section pertains only to the cultivated and/or potentially arable land within the quarter section. For reasons ranging from more than one type of soil in a quarter section to changes in drainage, topsoil, depth, salinity, topography, and stoniness each quarter section was field inspected so one productivity rating could be applied. In addition to formation of a productivity index and the application of this index to various quarter sections of arable land within Manitoba, it became necessary for the incorporation of risk areas within the province. There are 15 risk areas now being employed in the program, delineating various areas of similar soils and/or climate into common groups.

Thus in establishment of such a technique the soil classification of yields is the same within each risk area, but vary between risk areas.

Using the soil productivity classification suitable for Manitoba (MCIC), it is possible to produce a general type of calculation regarding opportunity costs of using arable land for hydro line, highway and pipeline rights-of-way.

Production - productivity changes

The three corridors have varying production - productivity changes associated with different aspects of corridor rights-of-way (Table 2). Highway driving surfaces result in a 100 percent loss in production, ditch agricultural capacity varies. Where highway ditches traverse rich crop land, opportunity cost is the value of lost crops minus values from ditch crops, if any. Where ditches pass through hay and pasture land, opportunity cost may be zero if they are again used for these purposes and where there was no previous use and new ditches are hayed, then an opportunity benefit may be realized. During the construction period however, the land is totally absent of use and production is zero.

Hydro line structures restrict land use 100 percent. However, construction and installation of hydro structures do not require removal of crops or extreme disturbance of pasture land. Production loss is mainly

Table 2. Major highway, hydro line and pipeline factors affecting production and productivity.

Corridor type	Factor	Production change (%)
Highway	Driving surface	100
	Ditches	Varies
	Construction width	100
Hydro line	Structures	100
	Construction width	Varies
Pipeline	Trench	Varies
	Clay bank	Varies
	Construction width	100

in the form of vehicle tracks through crops and represents only a partial loss. Opportunity benefits may arise where the hydro line opens up new land for crops, hay or pasture.

Pipeline trenches may produce an increase, decrease or no change in agricultural production - productivity. This is also the case with the pipeline clay banks. Thus there is an opportunity cost where production is decreased, a benefit where it is increased and no cost or benefit where it does not change production. However, during construction of the pipeline all crops are destroyed and production loss is 100 percent.

Calculation of opportunity costs

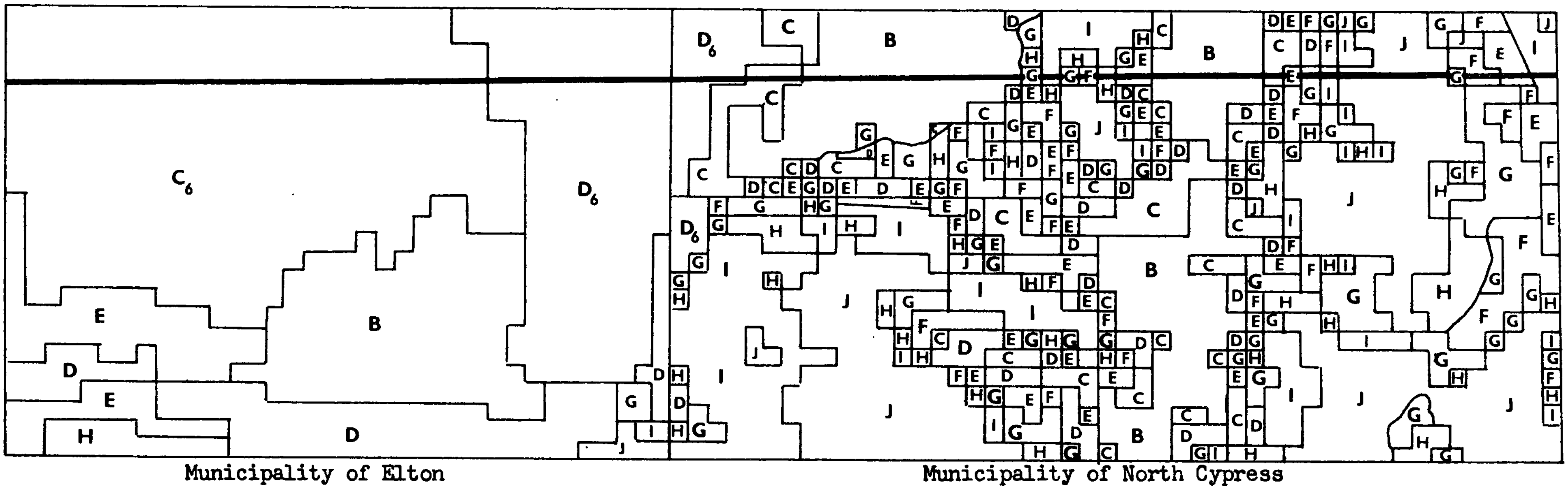
To illustrate use of the opportunity cost equation and obtain a comparison of costs involved in different types of right-of-ways, hypothetical corridors are drawn across two adjacent municipalities, Elton and North Cypress (Fig. 1). Areas transected by the corridors embrace a wide variety of productivity zones, from C and D in risk area 6 to B through J in risk area 4.

1. Highways

The hypothetical highway (similar to provincial trunk highways) has the following specifications:

1) 2-lane paved road with shoulders,
2) driving and parking width of 50 feet,
3) total ditch width of 70 feet,
4) overall highway right-of-way 120 feet,
5) construction width assumed to be equal to the legal corridor width,
6) all lands traversed are planted to wheat.

Since construction width equals legal maintained width, direct cost



LEGEND

Hypothetical corridor ———

Scale (miles) 1 2 3 4

Productivity zones (bu/acre, wheat)

C_6 – 26.0	D – 23.4	H – 20.0
D_6 – 25.0	E – 23.4	I – 16.6
B – 27.0	F – 22.2	J – 8.4
C – 24.2	G – 21.2	

All zones not numbered from risk area 4.

Figure 1. Municipalities of Elton and North Cypress showing productivity zones and hypothetical corridor.

($\sum A_c PP'REYF$) equals zero and is eliminated. To simplify further no land is assumed to be lost to severance and the cost ($\sum A_s PP'REYF$) equals zero. The constant E is also omitted, with the opportunity cost equation being:

$$OC = (\sum A_d PP'RYF) + (\sum A_t PP'RYF)$$

The first step in solving the opportunity cost equation is to obtain the number of miles of various soil productivity zones traversed by this corridor. The acres lost to the driving surface and shoulders are calculated along with acres used for ditches, through each zone. Driving surfaces and shoulders represent a total production loss; it is assumed that the ditches would also sustain a total production loss, (no haying etc. would be attempted along the route). Finally, production loss in bushels of wheat along the right-of-way is calculated for the particular zone (Table 3.)

1) Total length of highway traversing C_6 = 13 miles.

2) Yield in zone C_6 = 26 bu/acre (wheat).

3) Acres of C_6 lost to driving surface and shoulders = 78.78 (50 ft/8.25 = 6.06 acres/mi, 6.06 acres/mi x 13 = 78.78 acres; 8.25 foot width/mi yields 1 acre of right-of-way).

4) Acres of C_6 lost to ditches = 110.24 (70 ft/8.25 = 8.48 acres/mi; 8.48 x 13 = 110.24 acres lost over 13 miles of C_6).

5) Total C_6 wheat loss = 4914.52 bu assuming 100 percent loss of wheat production on the driving surface, shoulder and ditches, (driving surface and shoulder is 78.78 acres x 26 bu/acre (wheat) = 2048.28 bu; ditches is 110.24 acres x 26 bu/acre (wheat) = 2866.24 bu; total is 2048.28 + 2866.24 = 4914.52 bu of wheat.

Total results of each productivity zone are then multiplied against the price of wheat. One third of this figure is deducted to allow for fallow land.

Table 3. Wheat loss in various productivity zones of Elton and North Cypress municipalities due to highway corridor.

Productivity zone	Length (mi)	Yield (bu/acre, wheat)	Land lost to		Wheat lost to		Total wheat loss (bu)
			Driving surface (acres)	Ditches (acres)	Driving surface (bu)	Ditches (bu)	
C_6	13.00	26.0	78.78	110.24	2048.28	2866.24	4914.52
D_6	5.00	25.0	30.30	42.40	757.50	1060.00	1817.50
D_6	2.00	25.0	12.12	16.96	303.00	424.00	727.00
B_4	9.00	27.0	54.54	76.32	1472.58	2061.64	3533.22
C_4	2.00	24.2	12.12	16.96	293.30	410.43	703.73
E_4	2.25	23.4	13.64	19.08	319.18	446.47	765.65
F_4	1.50	22.2	9.09	12.72	201.80	282.38	484.18
G_4	2.00	21.2	12.12	16.96	256.94	359.55	616.49
H_4	0.50	20.0	3.03	4.24	60.60	84.80	145.40
I_4	1.75	16.6	10.61	14.84	176.13	246.34	422.64
J_4	3.00	8.4	18.18	25.44	152.71	213.70	366.41
Total	42.00		254.53	356.16	6042.02	8454.55	14496.74

Solving for the agricultural opportunity cost equation:

OC = Total bushels of wheat lost to driving surface and ditches x price of wheat

OC = 14496.74 bushels x \$2.25

OC = \$32,617.67 - 1.3 (fallow land)

OC = \$21,745.11

The final loss is thus \$21,745.11 the first year. Extrapolating this to 50 years (Table 4), the cost accumulated to \$1,087,250.00.

2. Hydro lines

A similar procedure is followed in the calculation of opportunity costs of hydro lines. For simplification the constant E is eliminated and no land is lost to severance, thus the cost ($\sum A_s PP'REYF$) equals zero and is eliminated from the equation. The equation is:

$$OC = (\sum A_b PP'RYF) + (\sum A_o PP'RYF)$$

For this example, two typical hydro structures are used in the tabulation of lost production (Table 5). The types are:

1) two-line corridor of steel structures of 25 ft by 25 ft base, five structures/mi/line.
2) two-line corridor of wooden structures of 20 ft by 3 ft base, eight structures/mi/line.

Construction corridor for both types is 120 ft wide or 14.55 acres /mi. A 10 percent crop (wheat) loss is assumed.

At a wheat price of \$2.25/bu, the dollar value lost to steel structures is 143.04 bu x \$2.25 = \$321.84. The dollar value lost to construction is 1450.66 x \$2.25 = \$3263.99. Then,

Table 4. Opportunity costs of hypothetical highway corridor over 50 years.

Year	Annual loss 1/3 fallow ($)	Cumulative loss 1/3 fallow ($)
1	21745	21745
5	21745	108725
10	21745	217450
20	21745	434900
30	21745	652350
40	21745	869800
50	21745	1087250

Table 5. Wheat loss in various productivity zones of Elton and North Cypress municipalities for hypothetical hydro line corridor.

Productivity zone	Length (mi)	Yield (bu/A)	Steel towers (N)	Wood towers (N)	Area lost to towers: steel (acre)	Area lost to towers: wood (acre)	Wheat lost to towers: steel (bu)	Wheat lost to towers: wood (bu)	Area lost to construction (acre)	Wheat lost to construction (bu)
C_6	13.00	26.0	130	208	1.865	0.287	48.49	7.46	189.15	491.79
D_6	5.00	25.0	50	80	0.717	0.110	17.93	2.75	72.75	181.88
D_6	2.00	25.0	20	32	0.287	0.044	7.18	1.10	29.10	72.75
B_4	9.00	27.0	90	144	1.291	0.198	34.86	5.35	130.95	353.57
C_4	2.00	24.2	20	32	0.287	0.044	6.95	1.06	29.10	70.42
E_4	2.25	23.4	22.5	36	0.323	0.050	7.56	1.17	32.74	76.61
F_4	1.50	22.2	15	24	0.215	0.033	4.77	0.73	21.83	48.46
G_4	2.00	21.2	20	32	0.287	0.044	6.08	0.93	29.10	61.69
H_4	0.50	20.0	5	8	0.072	0.011	1.44	0.22	7.28	14.55
I_4	1.75	16.6	17.5	28	0.251	0.039	4.17	0.65	25.46	42.27
J_4	3.00	8.4	30	48	0.430	0.066	3.61	0.55	43.65	36.67
Total	42.00		420	672	6.025	0.926	143.04	21.97	611.11	1450.66

OC = (\$321.84) + (\$3263.99)

OC = \$3585.83

Allowing for one third land held fallow, OC = \$2390.55 for one year.

The dollar value lost to wooden structures is 21.97 bu x \$2.25 = \$49.43. The dollar value lost to construction is equal to 1450.66 bu x \$2.25 = \$3263.99.

Then,

OC = (\$49.43) + (\$3263.99)

OC = \$3313.42

Allowing for one third land held fallow, OC = \$2208.95 for one year.

Opportunity costs of these lines over a 50 year period are shown in Table 6 and 7.

3. Buried pipelines

Statistics used for the effect of pipelines on soil productivity and crop yields to calculate opportunity costs are derived from a questionnaire sent to farmers having a pipeline corridor traversing their property and two reports concerned with pipelines and soil productivity.

Button et al. (1971:54) concluded that there was no significant decrease in crop yield associated with pipeline installation in Saskatchewan (Appendix II), stating:

> "...on soils in the area studied, pipeline installation did not cause significant yield decreases. The yield on the clay bank was not significantly different from the undisturbed field, regardless of the year of pipeline installation. On Chernozenic soils the yield on the trench was not significantly different from the undisturbed field. In the first two years after pipeline installation,

Table 6. Opportunity cost of hypothetical hydro line corridor over 50 years - steel structures.

Year	Annual loss 1/3 fallow ($)	Cumulative loss 1/3 fallow ($)
1	2391	2391
5	215	3251
10	215	4326
20	215	6476
30	215	8626
40	215	10776
50	215	12926

Table 7. Opportunity cost of hypothetical hydro line corridor over 50 years - wood structures.

Year	Annual loss 1/3 fallow ($)	Cumulative loss 1/3 fallow ($)
1	2209	2209
5	33	2341
10	33	2506
20	33	2836
30	33	3166
40	33	3496
50	33	3826

> the yield on the trench was less than on the undisturbed field. However, the differences were not statistically significant. On the Solonetzic soils the yield was significantly greater on the trench than on the undisturbed field. In dry years, on recently installed pipelines, the yield differences are small and not significant."

The study was based on small diameter pipes (6-12 in.) with trench widths one and a half to two feet. It is signifcant that many of the sample plots used to represent the yield over the trench exceeded trench width, possibly biasing the results.

Toogood (Personal communication) investigated relationships between crop yields and pipeline installation on 10 farms in Alberta. Pipes in this study included a 6-5/8 inch gas line and 16, 24 and 34 in. dia. oil lines, with respective trench widths of 20, 24, 64 and 74 in. Unlike Button's results, Toogood concluded that pipeline installation generally improved crop yield over the trench width. In seven fields the yield increase ranged from 7.5 to 28.3 bu/acre (Appendix III). Results of this study may be biased, however, since farmers changed their regular management techniques on three fields and provided extra cultivation on the pipeline corridor. Also, few suitable fields could be sampled in 1968 as the growing season was abnormal.

A questionnaire (Appendix IV) was sent in 1973 to two farmer groups having pipelines on their property to obtain estimates of the effect pipelines had on crop yield. One group has a gas pipeline corridor traversing their land, the other group an oil pipeline corridor. Results relating to crop yield are summarized in Table 8 and Appendix V.

The survey showed for those farmers who returned the questionnaire, nine percent reported an increase in yield due to pipeline installation, 25 percent indicated no change in yield and 66 percent reported a decrease

Table 8. Questionnaire results of pipeline effects on crop yield as estimated by farmers.

Response to questions	Interprovincial oil pipeline (%)	TransCanada gas pipeline (%)	Combined (%)
Effect of line on crop yield			
Increase	9	11	9
Decrease	68	63	66
No change	23	26	25
Median percentage decrease in crop yield	23.5	17.5	23.5

in crop yield.

No statistical inferences could be attained as the sampling was not followed by a covering survey to those who did not answer the questionnaire. There may also be a bias in the results as they reflect the farmers' estimates of pipeline effects with no covering field work accompanying the questionnaire. However, results obtained from the two groups, both in different locations of the province and having different types of pipelines, were very similar in a number of questions.

The median value for the percentage decrease in crop yield due to the pipeline was 23.5 percent. No median for increase in crop yield could be obtained, however, two farmers reported increases of 6-10 percent, one 11-15 percent and one between 16-20 percent.

Results of this questionnaire reflect the reponding farmers' assessment of pipeline effects on crop yield and provide a third and overall differing evaluation of the effect pipelines have on crop yield.

To illustrate the calculation of opportunity costs for pipelines, a hypothetical corridor was assumed, containing four pipes and trenches of the following dimensions, laid at different times:

	Pipe diameter	Trench width
	42 in.	8.5 ft.
	36 in.	6.5 ft.
	36 in.	6.5 ft.
	34 in.	6.0 ft.
Total width		27.5 ft.

It is also assumed that no loss occurs under the clay bank and no production is lost to severance during the construction phase. Each construction right-of-way was assumed to be 80 ft wide, resulting in 9.7

acres/mi or 38.8 acres/mi for the total construction width over the four construction periods. The crop lost in all productivity zones was wheat. To simplify further, the constant E is eliminated. The final equation is:

$$OC = (\sum A_o PP'RYF) + (\sum A_k PP'RYF) + (\sum APD'RYF)$$

Although changes in the productivity of soil may vary by soil zone the calculations (Tables 9 and 10) presented are completed considering first, decreased productivity along the entire corridor and second, increased productivity along the corridor. Since only two situations are considered, the final opportunity cost values calculated are derived in the first case by assuming benefit ($\sum APD'RYF$) to equal zero and completing the calculation. For the second situation of increased productivity, direct cost ($\sum A_k PP'RYF$) was assumed to equal zero and then the calculation completed.

A summary of the opportunity cost values over a time horizon are presented in Tables 11 and 12.

Errors in calculation

A calculation is only as good as its data base. The opportunity cost calculation presented in this paper has errors which must be accounted for and corrected. These errors are:

1) Opportunity change (loss or gain) associated with pipelines is not know. There is general conflict in the effect of pipeline installation on soil fertility (Button et al. 1971, Toogood, personal communication and questionnaire). This conflict covers all possible types of effect, from increases to decreases in fertility and even no change. Thus at this time it is impossible to determine the actual opportunity

Table 9. Wheat loss in various productivity zones of Elton and North Cypress municipalities for hypothetical buried pipeline corridor.

Productivity zone	Length (mi)	Yield (bu/A)	Area used trench (acre)	Assumed productivity change loss or gain (± bu.) 5%	10%	15%	20%	25%	30%	Area lost to construction 4-period (acre)	Wheat loss to construction (bu)
C_6	13.00	26.0	43.29	56.28	112.56	168.84	225.12	281.40	337.68	504.40	13114.40
D_6	5.00	25.0	16.65	20.81	41.62	62.43	83.24	104.05	124.86	194.00	4850.00
D_6	2.00	25.0	6.66	8.33	16.66	24.99	33.32	41.65	49.98	77.60	1940.00
B_4	9.00	27.0	29.97	40.46	80.92	121.38	161.84	202.30	242.76	349.20	9428.40
C_4	2.00	24.2	6.66	8.06	16.12	24.18	32.24	40.30	48.36	77.60	1877.92
E_4	2.25	23.4	7.49	8.76	17.52	26.28	35.04	43.80	52.56	87.30	2042.82
F_4	1.50	22.2	5.00	5.55	11.10	16.65	22.20	27.75	33.30	58.20	1292.04
G_4	2.00	21.2	6.66	7.06	14.12	21.18	28.24	35.30	42.36	77.60	1645.12
H_4	0.50	20.0	1.67	1.67	3.34	5.01	6.68	8.35	10.02	19.40	388.00
I_4	1.75	16.6	5.83	4.84	9.68	14.52	19.36	24.20	29.04	67.90	1127.14
J_4	3.00	8.4	9.99	4.20	8.40	12.60	16.80	21.00	25.20	116.40	977.76
Total	42.00		139.87	166.02	332.04	498.06	664.08	830.10	996.12	1629.60	38683.60

Table 10. Opportunity costs of hypothetical buried pipeline corridor.

Percent change (±)	Wheat lost or gained over trench (± bu)	Value (± $)[a]	Value - lost construction (-$)[a]	Trench and construction loss		Opportunity costs	
				loss ($)	gain ($)	loss 1/3 fallow ($)	gain 1/3 fallow ($)
5%	166.02	374	87038	87412	86665	58275	57777
10%	332.04	747	87038	87785	86291	58523	57527
15%	498.06	1121	87038	88159	85917	58773	57278
20%	664.08	1494	87038	88532	85544	59021	57029
25%	830.10	1868	87038	88906	85170	59271	56780
30%	996.12	2241	87038	89279	84797	59519	56531

[a]Values computed at $2.25/bu. wheat.

Table 11. Opportunity cost of hypothetical pipeline over 50 years - loss in production, (1/3 fallow).

Loss (%)	Years after installation 5	10	20 (-$)	30	40	50
Annual						
5	58275	249	249	249	249	249
10	58523	498	498	498	498	498
15	58773	747	747	747	747	747
20	59021	996	996	996	996	996
25	59271	1245	1245	1245	1245	1245
30	59519	1494	1494	1494	1494	1494
Cumulative						
5	58275	59510	62000	64490	66980	69470
10	58523	61013	65993	70973	75953	80933
15	58773	62508	69978	77448	84918	92388
20	59021	64001	73961	83921	93881	103841
25	59271	65496	77946	90396	102846	115296
30	59519	66989	81929	96869	111809	126749

Table 12. Opportunity costs of hypothetical pipeline over 50 years - increase in production (1/3) fallow.

Cumulated gain (%)	Years after installation 5	10	20	30	40	50
	(-$)					
5	57779	56534	54044	51554	49064	46574
10	57527	55037	50057	45077	40097	35111
15	57278	53543	46073	38603	31133	23663
20	57029	52049	42089	32129	22169	12209
25	56780	50555	38105	25655	13206	755
30	56531	49061	34121	19181	4241	+10699

cost of pipelines.

2) Throughout the calculations shown, the factor of superior management and technological change has not been included. Using fertilizer at or above the recommended rates, for example, produces an increase in crop yield for all soil productivity ratings in Manitoba of about 15 percent in wheat (Ewanek 1973). This increase will affect final opportunity cost figures if all farmers fertilized their land.

3) In 1972 the price of wheat per bushel was $1.75; during the summer of 1973 the price rose to $2.25 due to world shortage. Some account of the food shortages as reflected in price (constant E) should have been included.

4) Productivity (yield) values, represented for each soil zone are a modified yield based on a 35-year average for wheat in Manitoba and extrapolated to cover other crops. Since these figures do not represent the actual yield achieved along the hypothetical corridor, there may be some error involved.

5) Calculations assumed a continuous cropping area which, in most cases, is not the rule. Such allowances for road rights-of-way and small clumps of bush are all eliminated from the calculation. This error, which is small, can be remedied when a proposed route plan is known.

6) Examples presented in this paper all assume a single crop situation (wheat). When exact opportunity costs are needed, a survey of general planting practices in a specific area will provide a closer opportunity cost value where a variety of crops is involved.

7) There is also a variety of errors which are directly related to the amount of land used for corridor construction and maintenance. Since

no account has been made for these situations, they will be listed:

a) land lost to severance,

b) sterilization of the ground around wooden hydro structures for purposes of weed and fire prevention,

c) land lost due to construction facilities such as borrow pits along highways,

d) land used for maintenance and construction roads when a corridor is being completed.

9) There may also be a loss in yield due to weed proliferation from hydro structures and highway ditches.

10) The loss of production due to periodic right-of-way maintenance.

11) The season when construction takes place is also an important factor which has been neglected. In all cases discussed, construction was assumed to occur during the working season. However, if construction is started and completed in the off-season, substantial opportunity cost values are eliminated.

In most cases these errors will result in increased opportunity cost.

Summary

A comparison of opportunity cost values for the three conveyance corridors (Table 13) reveals that in order of decreasing opportunity cost, the following list of corridor types may be made for the 50th year:

1) Highway

2) Pipeline
   a) for all decreased productivity percentages
   b) for no change in productivity
   c) for increased productivity percentages of 5, 10, 15 percent

3) Hydro line - steel structures

Table 13. Comparison of opportunity costs (cumulated 1/3 fallow figures) of hypothetical highway, hydro line and pipeline corridors.

Corridor type	Length (mi)	Width (ft)	Years after installation 1	5	10	20	30	40	50
			($000's)						
Highway	42	120	22	109	217	435	652	870	1087
Hydro line									
a) steel	42	120	2	3	4	6	9	11	13
b) wood	42	120	2	2	3	3	3	3	4
Pipeline decreased productivity									
5%	42	120	-	58	60	62	64	67	69
10%	42	120	-	59	61	66	71	76	81
15%	42	120	-	59	63	70	77	85	92
20%	42	120	-	59	64	74	84	94	104
25%	42	120	-	59	65	78	90	103	115
30%	42	120	-	60	67	82	97	112	127
Increased productivity									
5%	42	120	-	58	57	54	52	49	47
10%	42	120	-	58	55	50	45	40	35
15%	42	120	-	57	54	46	39	31	24
20%	42	120	-	57	52	42	32	22	12
25%	42	120	-	57	51	38	26	13	1
30%	42	120	-	57	49	34	19	4	+11
No change	42	120	-	58	58	58	58	58	58

4) Pipeline - for increased productivity percentage of 20 percent

5) Hydro line - wooden structures

6) Pipelines - for increased productivity equal to or greater than 25 percent

For increased productivity greater than 25 percent, the pipeline corridor after 50 years becomes a benefit, assuming that the increased productivity is attained for the full 50 year period.

For hydro transmission line corridors and pipeline rights-of-way the major loss results from the initial construction phase. Highways are the exception since the nature of the corridor precludes any production in the majority of cases and the initial construction loss is accumulated over the relevant time horizon desired.

With the 120 ft corridor width the cost/acre for 50 years for each corridor type (following the list defined above) is:

1) Highway			-$ 35.59/acre/year
2) Pipeline	a)	5%	-$ 2.29/acre/year
		10%	-$ 2.65/acre/year
		15%	-$ 3.02/acre/year
		20%	-$ 3.40/acre/year
		25%	-$ 3.77/acre/year
		30%	-$ 4.15/acre/year
	b)		-$ 1.90/acre/year
	c)	5%	-$ 1.52/acre/year
		10%	-$ 1.15/acre/year
		15%	-$ 0.77/acre/year
3) Hydro line			-$ 0.42/acre/year
4) Pipeline		20%	-$ 0.40/acre/year
5) Hydro line			-$ 0.13/acre/year
6) Pipeline		25%	-$ 0.02/acre/year
		30%	+$ 0.35/acre/year

Part 4 : Application - forested land

Opportunity cost analysis of conveyance corridors through forested regions of Manitoba require detailed statistics of productivity and present merchantable volumes of timber. Productivity and merchantable volume information is available from forest inventory methods used in Manitoba. These methods revised in 1962 when point sampling and computer processing were introduced, divide the province into nine Forest Regions, each subdivided into management units (MU).

All productive forest land is classified into one of four cover types with non-productive forest land described under four groupings and non-forested land denoted in eight categories.

Volume calculations provide gross, net and net operable stand and stock volume tables, with volumes shown by type-aggregate. Area tables are worked out for the Forest Zone only and are divided by land status, ownership and productivity. Productive forest land is broken down by cover type and sub-type. In addition, area and volume summaries are produced on a MU or forest region basis (Bickerstaff and Hirvonen 1969).

Forest productivity differs in its meaning from that expressed for agriculture. Manitoba Forest Inventory Section described productivity as the division of land in the forest zone as to forested productive, forested non-productive and non-forested. For opportunity cost calculations, productivity of forested lands is defined as the yield (growth) obtained from a specified area in cubic feet/acre/year. It is the mean annual increment (MAI) of tree growth as determined by the equation:

$$MAI = \frac{\text{total volume increment up to rotation age}}{\text{rotation age}}$$

Methodology - forest productivity maps

Forest productivity maps form the basis of opportunity cost calculations of conveyance corridors through treed regions. The method used in developing productivity maps for Township 61, Ranges 27 and 28 in Management Unit 56 (R. Lamont personal communication) is:

1) Working groups for which MAI's were calculated are; jackpine (Pinus banksiana), black spruce (Picea mariana), white spruce (Picea glauca), balsam fir (Abies balsamea), trembling aspen (Populus tremuloides), balsam poplar (Populus balsamifera), white birch (Betula papyrifera) and tamarack (Larix laricina).

2) Each working group was divided into its sub-type codes. For example, each working group is composed of various sub-types relating species type to percentage volume in stand. The jackpine working group is summarized from stands containing 71-100 percent jackpine, 40-70 percent jackpine with spruce (cover type softwoods) and 51 percent and over jackpine, jackpine 50 percent and under with red pine and jackpine 50 percent and under with spruce (cover type softwood - hardwood), (Appendix VI).

3) By definition MAI is total volume increment up to rotation age divided by rotation age. An approximation to the volume increment is gross merchantable volume at rotation age divided by rotation age of the

working group. With gross merchantable volumes (GMV) for each sub-type in the working group contained in the Stand Stock Volume Tables for Forest Management Units 51 - 57, volumes were applied to various sub-types identified for each working group. To prevent double counting MAI's are calculated on fully stocked mature stands, (those volumes for sites 1 and/or 2 and cutting class 4 with crown closures 3 and 4). Since required productivity ratings are based on acres, aerial data were obtained from MU 56 - Area Reports (Revised March 28, 1973). The resultant approximated mean annual increment formula is:

$$\text{MAI} = \frac{\sum (\text{GMV x area})}{(\sum \text{area})\ (\text{rotation age})}$$

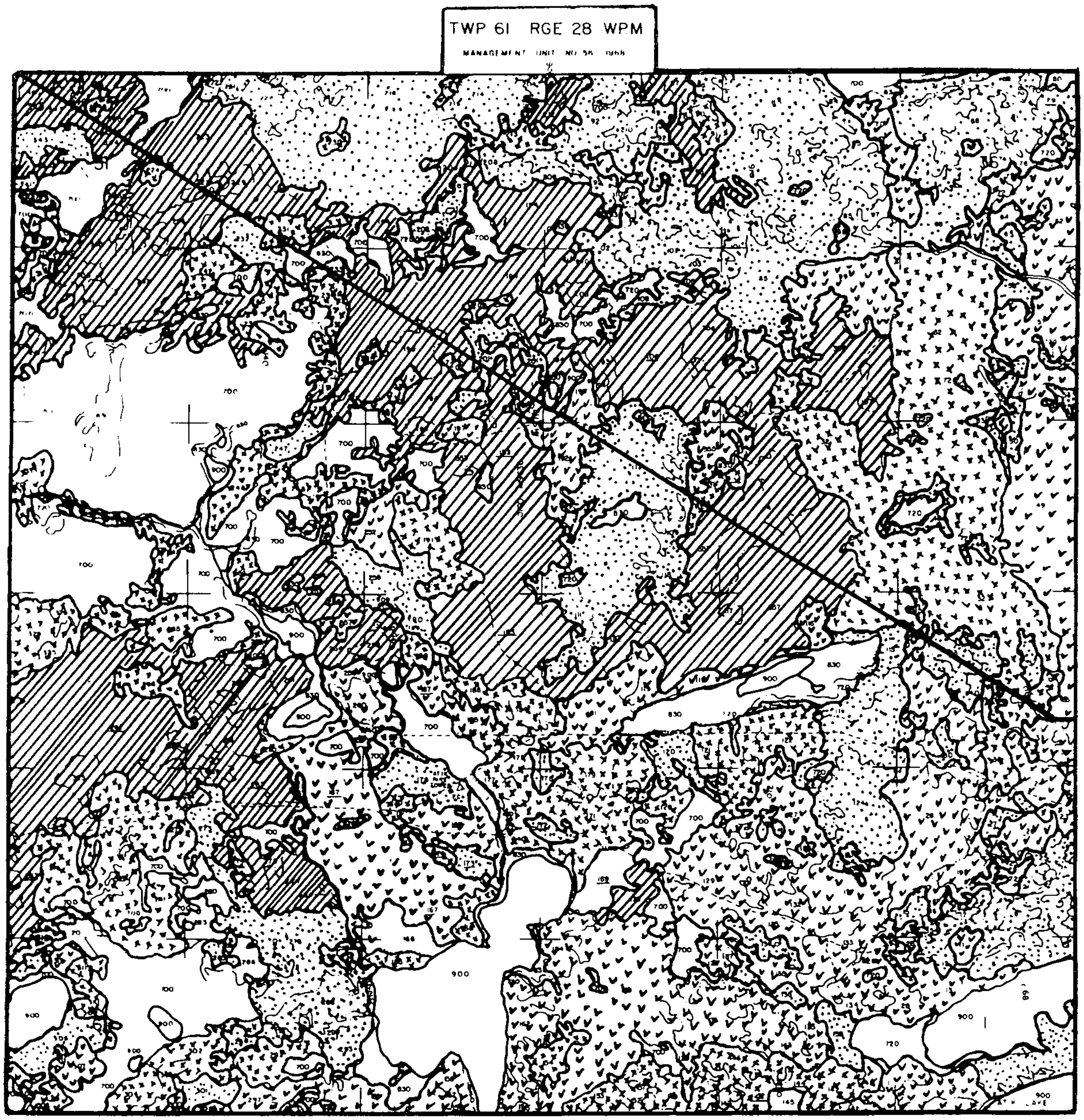
4) By application of the estimated mean annual increment formula, all productivity ratings in cu ft/acre/year were calculated for each working group. Example: jackpine, Range 27 (Appendix VII),

MAI = (2193027/1246 x 75) = 23.47 cu ft/acre/year.

5) With all MAI's calculated, results were compiled on Manitoba Forest Inventory Section maps of Township 61, Ranges 27 and 28, which relate stand number to cover type.

Calculation of opportunity cost

With development of productivity forest maps for Township 61, Ranges 27 and 28, a hypothetical route plan (hydro line, pipeline and highway corridor) was constructed through the area, (Figs. 2 and 3). Using on overlay, the route was divided into segments equal to specific stands which the corridor traversed. The right-of-way is 120 ft wide, construction width equals corridor operating width and no multiple use



LEGEND

Hypothetical corridor ———

Scale: 1inch = 1 mile

Working group	Code	MAI (cu ft/acre)
Jack pine		22.32
Black spruce		19.80
White spruce		21.38
Trembling aspen		27.65
Treed muskeg	700	—
Willow/alder	720	—
Marsh-muskeg	830	—
Unclassified	840	—
Water	900	—

Figure 2. Township 61, Range 28 showing derived forest productivity map and hypothetical corridor.

LEGEND

Hypothetical corridor ————

Scale: 1inch = 1 mile

Working group	Code	MAI (cu ft/acre)
Jack pine		23.47
Black spruce		22.14
White spruce		22.09
Trembling aspen		28.49
Treed muskeg	700	—
Willow/alder	720	—
Marsh-muskeg	830	—
Unclassified	840	—
Water	900	—

Figure 3. Township 61, Range 27 showing derived forest productivity map and hypothetical corridor.

(haying, recreation, pasture) is involved.

Three major steps are required to obtain the total opportunity cost value for the corridor. First is calculation of the volume lost initially from clear-cutting during construction; second, calculation of the annual lost volume of timber and third, calculation of the dollar value of the timber.

A) <u>Calculation of the annual volume loss of timber by species (Appendix VIII)</u>

For the purpose of illustration, map segment No. 25 will be calculated in detail:

1) Total length of segment No. 25 = 0.1688 mi.

2) Acres used by corridor = 2.4553 (120 ft/8.25 x 0.1688 = 2.4553 acres).

3) Productivity of segment No. 25 (stand 183) = 22.32 cu ft/acre/year.

4) Total annual production (growth) for segment No. 25 = 54.80 cu ft (22.32 x 2.4553 = 54.80 cu ft).

5) Since the species mix for this stand is 50 percent jackpine, 30 percent trembling aspen, 10 percent white spruce and 10 peccent black spruce, the volume growth by species is:

Jackpine	=	27.40 cu ft/year	(.5 x 54.80	= 27.40)
Trembling aspen	=	16.44 cu ft/year	(.3 x 54.80	= 16.44)
White spruce	=	5.48 cu ft/year	(.1 x 54.80	= 5.48)
Black spruce	=	5.48 cu ft/year	(.1 x 54.80	= 5.48)

This method is continued for each map segment and grand totals are derived by each species along the entire corridor (Table 14).

B) <u>Calculation of initial volume loss due to clear cutting of the right-of-way (Appendix IX)</u>.

Map segment No. 25 will be illustrated:

1) Total volume loss equals 4110 cu ft (2.4553 acres x 1674 cu ft =

Table 14. Total annual volume loss of timber by species type along hypothetical corridor

	Species type - volume loss (cu ft)							
	Total	TA	JP	BS	WS	BF	TL	WB
Volume	4196[a]	1821	878	715	715	4	1	13

[a]Figure 4196 differs from the sum of species volume due to insufficient data in some stands as to species mix.

4110 cu ft); acres used for segment No. 25 equal 2.4553 and the weighted average gross merchantable volume for this working group equals 1674 cu ft.

2) Volume lost by species is:

Jackpine	= 2055 cu ft (.5 x 4110 = 2055)
Trembling aspen	= 1233 cu ft (.3 x 4110 = 1233)
White spruce	= 411 cu ft (.1 x 4110 = 411)
Black spruce	= 411 cu ft (.1 x 4110 = 411)

Grand totals are calculated for each species type for all segments giving the volumes of timber lost to clear-cutting (Table 15).

C) Total opportunity cost value of the hypothetical corridor

For simplicity, the constant E has been deleted and the opportunity cost equation, regardless of corridor type is:

$$OC = (\sum A_c GSR) + (\sum A_m PXRY)$$

Prices used for each species are related to the value of timber at the mill before processing. Original prices were quoted in dollars/cord, assuming 85 cu ft to represent one cord (allowing for air spaces) (Table 16).

Including the price schedule, the opportunity cost equation becomes:

OC = ($\sum$ total initial volume loss by species x price for each species) + ($\sum$ total volume timber lost/year by species x price for each species)

and the opportunity cost value for the first year of the corridor is:

OC = (116978 x .21) + (68183 x .33) + (56489 x .38) + (56489 x .38) + (362 x .38) + (1080 x .18) + (1821 x .21) + (878 x .33) + (715 x .38) + (715 x .38) + (4 x .38) + (13 x .18)

= (90,306) + (1219)

= $91525

Table 15. Total initial volume loss of timber by species type along hypothetical corridor.

	Species type - volume loss (cu ft)							
	Total	TA	JP	BS	WS	BF	TL	WB
Volume	302908[a]	116978	68183	56489	56427	362	115	1080

[a]Figure 302906 differs from the sum of species volume due to insufficient data in some stands as to species mix.

Table 16. Prices of timber by species at the mill before processing[a].

Species type	Quoted price/cord ($)	Price/cu ft assuming 85 cu ft cord ($)
Black spruce	32	0.38
White spruce	32	0.38
Balsam fir	32	0.38
Jackpine	28	0.33
Trembling aspen	18	0.21
Balsam poplar	18	0.21
White birch	15	0.18
Tamarack	-	-

[a]Personal communication D. Young

Total opportunity cost values vary by year because of the annual growth loss along the right-of-way (Table 17).

Summary

Only one value for opportunity cost of any conveyance corridor traversing forested area is required due to the nature of keeping the corridor clear-cut. In this case, all conveyance corridors are equal in regard to the basic production loss but will vary when different externalities such as wildlife and recreation are taken into account.

As with corridors through agricultural land, the major component of the opportunity cost figure is the value of timber lost to construction.

The cost/acre for 50 years for this corridor of right-of-way width equaling 120 ft and 12.6 mi long is \$16.51/acre/year.

Table 17. Opportunity costs of hypothetical highway, pipeline or hydro line corridor over 50 years.

Year	Annual loss ($)	Cumulative loss ($)
1	91525	91525
5	1219	96401
10	1219	102496
20	1219	114686
30	1219	126876
40	1219	139066
50	1219	151256

Part 5 : Public recreational land

The question of allowing corridors within the boundaries of recreational land is of prime importance considering the increase in leisure time, income and demand for outdoor recreational facilities by today's society. In considering opportunity costs of conveyance corridors traversing recreational land a number of difficulties arise making the type of analysis presented for agricultural and forested areas very difficult if not impossible.

Opportunity cost elements

Principal factors required for computation of corridor opportunity cost within recreational areas, excluding any effects of corridor dimensions, are limited to the change in recreational productivity as a result of the corridor and net return value of the recreational activities. As discussed in Part 2, opportunity costs are primarily related to net value of goods surrendered in construction, operation and maintenance of the corridor, with calculation of net opportunity cost depending on measurability of the various cost and benefit elements. Therefore, it is necessary to discuss the major elements presented in relation to their measurability.

Changes in recreational productivity

When a right-of-way traverses recreational land, changes in recreational productivity are affected by the particular route involved, environment along the route, present recreational use and type of corridor installed. These factors will determine the kinds of damages created and will reflect any possible change in potential recreational end use pattern. Definition of the numerous results is therefore the major concern in economic analysis of opportunity costs. Though it is possible to count the number of trees cut within a right-of-way during construction, it is difficult to give a comparitive evaluation between a previously existing woodlot and a newly developed grassy brush community for recreational activity. The sophistication of analytical technique for equating one acre of brome grass with one acre of jackpine forest for recreational purposes is very limited. Also the present scope of analysis to evaluate the numeric change of losing a remote campsite which may be utilized by ten campers and replaced by ten bird watchers who use the corridor as access is very restrictive. For such an evaluation would require that an order of equivalence be prepared whereby one recreational activity could be numerically converted to another activity or experience. For example, one hiking experience is equal to two blueberry-picking recreational experiences.

Thus the measurement of recreational productivity change required for opportunity cost analysis is, for the most part a rather fruitless task as it requires quantification of a qualitative activity.

<u>Net value of recreational activity</u>

There are two elements which comprise net value of recreational activity, price and recreational experience.

Numerous methodologies have been designed to obtain the value of recreation, but do not present values required for this opportunity cost analysis. At best they are questionable measures of the value of recreation. For outdoor recreation, decisions to provide land for such a use are not made in context of the market place (Clawson et al. 1968:125).

> "Admission to most such areas is free, or at least not on a commercial basis. Calculations of cost, income and profits do not provide the basic criteria for decisions on use of land for this major purpose. Rather, the decisions to use or not to use land for outdoor recreation purposes is made by political processes; it is a decision for public not private action. In reaching it, calculations as to the value of recreation are seldom made, and they are not considered relevant, or at least not critical. The cost of establishing and maintaining the area is but one factor in the decisions to use it for recreation. Often it is not easy to know accurately the value that people put on outdoor recreation and their willingness to contribute to the public purse for it. Many factors enter into this type of public decision. Recreation, as a major use of land differs in this report from most or all the major land uses."

As has been suggested, decision to provide recreational land is not based totally on profit or monetary value, but on the belief that it is socially "good".

Basic to the difficulty in determining net value of recreation is definition of the particular return received from recreation. For this report, one visitor into an area, one visitor out is not the subject under consideration. It is the return that the visitor receives for his expenditure that is important. Return being the experience, decreasing stress and strain, joy and the general change in the frame of mind resulting from recreation. Presently know techniques of evaluating recreation measures the cost of the activity or willing to pay for recreation (essentially the production costs of obtaining the return) as decided by the criteria of the chosen analytical technique and not the net return value of recreation.

An illustration may best serve to clarify the difficulty inherent in evaluation of the net return from a recreation activity. A farmer spends $100 to sow 30 acres of land to wheat. His expected return is a number of bushels of wheat sold at market value minus his costs. If a corridor traverses and uses all this land, the minimum opportunity cost of the corridor, excluding any secondary effects is this value. If this same farmer spends $100 on a vacation, his return is increased happiness, a state of well-being, rest, etc. However, what are these products worth? What market price can be applied to these goods from which costs may be subtracted to obtain net value?

Alternative

Given that the decision is to continue to provide land for recreation and it is generally desirable not to allow development corridors (rights-of-way that are not needed for recreational facilities) to traverse recreational land, then an alternative evaluation technique is one or reparation, reclamation and mitigation (RRM).

This analysis of corridors is developed on the criteria of minimizing environmental impact and maximizing recreational use of the affected area. As such, evaluation is based on costs required to attain this preferred state; the costs consisting of repairing damage, replacing unique features, maintaining and enhancing the effected area. Since costs vary with corridor type, environmental state and possible end use, the only generalization that can be made is the sum of these costs give some indication of opportunity costs. It is based on the fact that development change is not desired and costs of repairing, replacing and enhancing the area provide for minimum requirement to allow continued, though to some extent, restricted optimal recreational use.

Since this technique requires that damages be repaired and maximum recreational use is made of the corridor, opportunity costs as calculated by the RRM method may be equated and compared with costs of re-routing any corridor to avoid damage. In the case of unique irreplaceable features, cost to the operator is infinite since it is not possible to replace and thus will require re-routing of the corridor to avoid such situations. This method of calculating opportunity costs does not rely on the market value of the features under consideration and thus does not fail to account for the many desired esthetics society wants to protect.

Part 6 : Wildlife

Wildlife has played a prominent role in development of Manitoba and Canada. A source of food, clothing and tools for many generations of natives, explorers and pioneers, wildlife provided the means for settlement. Now technological advancement has replaced our need for primary utilization of wildlife with recreational desires of an affluent society. Increasing world populations and more leisure time available to today's developed countries, present governmental agencies with the problem of on-going destruction of wildlife habitat and demands by society for more harvestable wildlife for recreational activities and research.

Conveyance corridors in Manitoba occur in a wide variety of environments and since all land is real or potential wildlife habitat, conveyance corridors may increase or decrease our dwindling wildlife populations.

Wildlife elements for opportunity cost analysis

There are two aspects in the consideration of wildlife and opportunity cost evaluation; first, as costs and benefits of the equations developed for corridors through agricultural and forested areas and secondly, as a specific land use. Since these aspects require essentially the same type of analysis only one evaluation of wildlife will be presented.

Wildlife, for purposes of economic analysis, must be discussed in relation to fundamental elements which comprise the opportunity cost function. For this section, guidelines presented in identification of costs and benefits, evaluation of these factors and constraints affecting analysis are essentially those developed in Part 2.

For wildlife (excluding any effect of corridor dimensions) major costs and benefits are:

1) Direct costs, the lost monetary value of wildlife surrendered to construct, operate and maintain the corridor.
   Evaluation requires; a) wildlife productivity maps, b) change in productivity as result of the corridor, c) amount of wildlife killed or habitat destroyed during construction and d) market price of the wildlife units.
2) Direct benefits, the monetary value of the increase in wildlife accruing to the corridor.
   Evaluation of this benefit requires; a) wildlife productivity maps, b) change in productivity and c) market price of the gained wildlife units.

The equation denoting either the value of wildlife for a corridor in agricultural and forested regions or for the evaluation of land used specifically for wildlife in general terms is:

$$OC = (\sum WSR) + (\sum PP'REY) - (\sum PD'REY)$$

where:

OC = total monetary value of the opportunity cost.

$(\sum WSR)$ = monetary value of wildlife killed during construction of the corridor.

$(\sum PP'REY)$ = monetary value of lost wildlife production due to decreased habitat.

$(\sum PD'REY)$ = monetary value of gained wildlife production due to increased habitat over a specified time horizon.

where:

W = numerical figure of all wildlife units killed by productivity zone.

S = species mix of all wildlife killed within each productivity zone as a decimal fraction.

R = market price of each wildlife species in dollars.

P = productivity (yield) of each zone expressed as a total numerical value of all wildlife species.

P'= change (decrease) in wildlife units expressed as a decimal percent, by species, by productivity zone.

E = constant reflecting any expected change in prices paid for wildlife units, resulting from situations of scarcity, etc.

Y = time horizon over which opportunity costs are to be calculated.

D'= change (increase) in wildlife units expressed as a decimal percent, by species, by productivity zone.

To apply the derived equation requires that each element be accounted for and that essential elements be measured. Major elements being market prices paid for wildlife use and effects P' and D' (the quantity - quality relationships of the loss and/or increase in habitat and wildlife populations) associated with various phases of corridor construction and operation. Availability of wildlife price tags and our ability to quantify corridor productivity changes of wildlife habitat and populations determines whether a quantitative or qualitative economic evaluation of wildlife opportunity costs is required.

Pricing of wildlife

Numerous articles, reports and books have been written about wildlife dollar values and other methods of evaluating the wildlife resource. A literature review distinguishes four main categories for wildlife prices:

1) gross worth of wildlife,

2) prices of the living unit of wildlife,

3) dollar values of a man-day use,

4) prices of wilderness land.

Gross worth refers to total expenditures and benefits compiled for wildlife utilization. The value often includes fees, travel, accommodation and food costs paid by hunters and recreationists and value of wildlife meat and furs. In 1955 over 11 million persons in the U. S. spent about $1 billion hunting (U. S. Dept. Interior 1956) including $494 million spent by small game hunters of which $232 million was spent on equipment, $16.6 million for food, $3.9 million for lodging and $50.1 million for transportation.

Solman (1952) reported that 48.4 million pounds of game meat was harvested annually in Canada, including 38 million pounds of deer and other big game, 3 million pounds of upland game birds and 6 million pounds of waterfowl. Assuming an average harvest cost for venison of $1.50/lb, value of the meat was $72.5 million. Adding to this the value of furs trapped in Canada of $20 million in 1955 (Cowan 1955) gives a total gross value of wildlife utilization of $92.5 million. These figures reveal the wildlife perspective in dollar values and suggest that in some manner wildlife values must be accounted for. They do not lend themselves to specific corridor opportunity cost analysis, however, because they are too broad and cannot be broken down without considerable error.

The living unit of wildlife approach attempts to price an animal in relation to its accessibility by hunters. For example, a deer within 50 miles of a hunter's home is worth $15.00. Hedlin Menzies and Associates Ltd. (1967:69) considered such an evaluation useless, and stated,

> "One basic conclusion is that economic evaluation of the living unit of wildlife is not the real productive task..."

One need only consider the number of wildlife species to envision the massive task of evaluating each species unit. Although of ideal form for evaluation of specific corridors, the amount of research and detailed surveys required to make values of this approach useful precludes its use in opportunity cost analysis.

Man-day use evaluation of prices attempts to estimate the value of a day's recreation (hunting, hiking, viewing, etc.) on the basis of the value recreationists would be willing to pay (Grower et al. 1973).

One technique is to draw on benefit - constant ratios which express the value of wildlife as constant ratios of total costs incurred to recreationists per day. Ratios of 0.6 : 1.0 (Grower et al. 1973) and .4 : 1.0 and .8 : 1.0 (Pearse-Bowden Economic Consultants Ltd. 1971) have been used for various wildlife evaluations.

Hedlin Menzies and Associates Ltd. (1967), in a survey of wildlife price tags, found that the U. S. Fish and Wildlife Service uses a range of benefits per day's use hunting of $0.50-$6.00, the U. S. Corps of Engineers use $0.50-$1.50/user day, the Inter-Agency Committee on Water Resources uses $2.00-$6.00/user-day for upland bird and waterfowl and the U. S. Dept. of Interior suggests a range of $1.50-$4.50/day for deer and antelope hunting. A tabulation of outdoor recreation values (Tables 18 and 19) shows considerable variation in values attributed to wildlife.

Table 18. Various values established for wildlife by user-day units.[a]

Type of activity	Range of values recreation day of hunting ($)
Hunting	
Small game	
mammals	0.50 to 1.50
birds	1.00 to 3.00
Waterfowl	1.50 to 4.50
Big game	
deer-antelope	1.50 to 4.50
other	2.00 to 6.00

[a]Hedlin Menzies and Associates Ltd. (1967:26)

Table 19. Dollar values for migratory birds sport values.[a]

Class	Value/hunter day	
	1939-44 average ($)	long-term projection ($)
Ducks	6.00	8.16
Geese	12.00	16.32
Woodcocks	5.00	6.80
Rails	5.00	6.80
Doves	5.00	6.80

[a]Hedlin Menzies and Associates Ltd. (1967:139)

Values presented show a wide variation in prices established for wildlife by the various agencies and that nearly all prices are for hunting. This is only one aspect of wildlife use and only one category of wildlife, with the result that all other wildlife species have little or no value.

Wilderness land and not its living wildlife can be used for estimating the value of wildlife. In basic terms, it is the value of habitat or a group of habitats within a particular region or area. A wide variety of prices have resulted for wildlife due to the influence of quality-quantity relationships, closeness to centers of population and various sizes of populations which affect not only land values but land use (Hedlin Menzies and Associates Ltd. 1967:84-87), (Table 20.)

Table 20. Wilderness land values for various locations.

Price ($)	Unit (acres)	Location
15 - 20	1	California
2	1	Minnesota
0.10	1	Florida
0.20	1	Wisconsin

Since the greater portion of Manitoba is owned by the government and many wilderness areas occur where no market value can be established because of free access, use of such wildlife prices is not justified here.

Effects of corridors on wildlife

Excluding the loss of unique habitat, individual corridors are not associated with substantial habitat change. A highway results in total loss of habitat on the driving surface. A pipeline may destroy habitat cover initially but some habitat types can be re-established over a buried pipe. However, since all land is potential wildlife habitat, additive effects of corridors on wildlife are substantial. One 25 mile road through the Red River Valley does not substantially affect the amount of habitat, but 46,000 miles of road in Manitoba has a measurable affect on the quantity and quality of wildlife habitat.

By far the most significant factor related to corridor rights-of-way is the potential and actual increase in wildlife habitat, that is produced.

Although relatively few reports deal with wildlife habitat and conveyance corridors a number of associated reports and articles have been prepared which have considerable affinity with the problem of assessing corridor affects.

Oetting (1971a, 1971b) estimated that over 500,000 acres of potential wildlife land is associated with all conveyance dorridors in Manitoba in 1972 and updated this figure to 746,000 acres in 1974 (Personal communication).

With proper vegetation management, Egler (1953, 1957) suggested that much land now idle along rights-of-way would produce wildlife.

Petrides (1942), Dambach (1948), Edminster (1950), Friley (1949), Kabat and Thompson (1963) and Besandy et al, (1968) showed that food and cover for songbirds, game animals and small mammals is available from brushy hedgrows and brushy cover along roadside rights-of-way.

Joselyn et al. (1968 and 1972) and Oetting and Cassel (1971c) showed that pheasants and waterfowl utilize roadside vegetation and that various vegetation plantings and proper methods of roadside maintenance increase the production of these species.

Ecotones, interfaces between different vegetation cover types, provide wildlife with a variety of habitats. Rights-of-way through forested areas, due to their clear-cut nature, represent ecotones and provide a variety in food and cover for many wildlife species.

Hallis and Alcaniz (1968), Lay (1966) and Davis and Winkler (1968) analyzed forage and browse production for deer produced in forest clearings and brushy areas, concluding that such breaks provide improved habitat conditions.

Morris (1954) and Ripley and Campbell (1960) found that heavy harvest cuttings in forested areas provide browse for deer. A similar study carried out on dense hardwood samplings showed that removal of selected crop trees produced a significant increase in browse production (Della-Bianca and Johnson 1965).

In a watershed experiment in Colorado, timbering operations were so arranged that narrow strips alternating with uncut strips resulted in approximately twice as much deer use of the area compared with an adjacent watershed; cut strips received three times as much use as uncut strips (Wallmo 1969).

In general, a great diversity of plants and animals and greater densities can be produced by proper utilization of all conveyance corridor rights-of-way through forested areas. With proper management, idle roadsides can offset wildlife habitat loss for many game mammals and birds.

Difficulties of applying factors of price and productivity change are many. Types of prices for wildlife are many and varied, with justification of using one price over another not sufficient in economic analysis. Although one may use a certain price, only partial indication of wildlife worth will result, for nearly all values are directed at the aspect of hunting and game animals, leaving the greater majority of wildlife species with zero dollar worth. Partial economic analysis is considered better than none at all; however, the factor of pricing wildlife is only one aspect of the analysis, the effects (productivity change) of corridors is even more important and very difficult to quantify. Excluding unique habitat and wildlife species, the vast amount of monetary resources, personnel and time required to assess the total and complete effects of corridors on wildlife will place considerable strain on any administrative body and its budgetary constraints. Thus, analysis of economic opportunity costs as outlined is not practical considering the constraints and difficulties inherent in the analysis.

Opportunity cost alternatives

An alternative method to the equation exemplifying opportunity cost is based on subjective and indirect factors of reclamation, reparation and mitigation (RRM). This technique assumed that:

1) The variability of wildlife prices and our inability to quantify corridor effects suggest that quantitative analysis of opportunity costs are "impossible" to calculate in an

effective and efficient manner.

2) All lands are potential wildlife habitat.

3) Wildlife is socially and economically desirable.

4) Corridors have an impact on wildlife.

5) Corridors show potential for wildlife enhancement.

6) Wildlife loss and non-development are costs.

These assmmptions suggest that direct quantitative evaluation of opportunity costs, though desirable, is too laborious, but that costs and benefits accruing to wildlife are acknowledged as significant and important elements of rights-of-way considerations. The indirect or RRM approach provides some indication of wildlife worth but also directs itself at providing a means by which wildlife may be enhanced and provides for minimum land use environmental impact. The technique provides an alternative method of assessing the wildlife resource as indicated by the costs required to protect, establish and maintain habitat along rights-of-way. The assessment is conducted on values resulting from three prerequisites that form the basis of the costs. The prerequisities are:

1) if habitat is destroyed, the habitat must be replaced,

2) if habitat is damaged, the habitat must be repaired,

3) if potential habitat is created, the habitat must be maintained and enhanced.

Then opportunity costs may be equated with the sum of the costs required to replace, repair, maintain and enhance habitat.

An assertion is made here that these costs, while not directly the opportunity costs of wildlife as a result of corridors, are baseline costs which indicate a minimum value for wildlife, while increasing the amount of habitat and insuring minimum environmental impact. It also provides for protection of unique habitat types and wildlife species which would have an infinite dollar value because they could not be replaced. This would suggest that the analysis could be used for comparative purposes in relocation and re-routing of corridors away from highly sensitive and irreplaceable wildlife habitats and species.

Summary

Strict economic evaluation of the monetary loss or gain along a corridor for wildlife is very difficult. However, evidence exists that if corridors are maintained properly, wildlife may be enhanced. Also the approach of indirectly equating the costs of repair, replacement and enhancement of the corridor may be viewed as the wildlife opportunity costs.

Part 7 : Conclusions and recommendations

Conclusions

1) Conveyance corridors; highways, pipelines and hydro line rights-of-way, traverse agricultural and forested areas in the majority of cases and the opportunity cost of lost physical production can generally be quantified with the equations developed in this report.

2) Through agricultural and forested areas, the value of lost commodity production due to initial construction is the most significant loss for hydro line and pipeline corridors. Since highways generally restrict production 100 percent, the total opportunity cost is some multiple of the initial construction loss.

3) Highways have the largest opportunity cost values in agricultural areas and use the most land for rights-of-way. Hydro transmission line corridors are the second largest user but do not have high opportunity cost values, with corridors having wooden pole towers less costly than those with steel structures.

4) There are numerous difficulties in estimating productivity changes caused by pipelines. From three different informational sources dealing with this aspect, results ranged from increased to decreased productivity and to no change in crop yield. It is therefore impossible to state with any certainty the exact opportunity cost value of the pipeline corridor, except to give a minimum value for opportunity cost, that is

the value of lost production due to construction (the value given for no change in productivity).

5) Opportunity costs of the three conveyance corridors in forested regions are basically equal. One equation can be used to express the costs for each corridor. The external costs and benefits are however important elements to be considered and may substantially change the perspective of the final results.

6) The exact economic effects of corridors in recreational areas is difficult if not impossible to ascertain. This may however, be over come by indirect evaluation using the reclamation, reparation and mitigation technique. This technique will minimize potential damage to any area and may result in the re-routing of corridors away from highly sensitive areas, where irreplaceable features are considered priceless. In effect the use of such a technique constitutes policy in regard to compatability of conveyance corridors with the recreational land use of an area.

7) Wildlife values and measurability of corridor effects on wild-life are difficult to assess for strict economic analysis. The RRM approach tried to alleviate this situation but is directed more specifically to the proper and efficient utilization of corridor land. This technique also constitutes corridor land use policy and has repercussions in many aspects of corridor maintenance and construction.

Recommendations

1) A field study of the effects of pipeline installation on various soil zones should be carried out in the Province. Insufficient data are available at present to ascertain with any degree of accuracy what the

effects are and thus speculation of the opportunity costs of pipelines is dubious.

2) The nuisance value of hydro structures and pipelines and the effect these structures have on production operating costs in agricultural areas should be studied. The Friesen report (1966), suggests that there are significant increases in costs of operation due to these structures and further documentation is needed to obtain a more exact value of opportunity costs.

3) A number of ways are available for reducing the opportunity costs of conveyance rights-of-way. If it is desireable from an economic position to reduce costs, some of the following provisions are recommended.

a) When planning corridor routes, highly productive land should be avoided and all corridor widths should be kept to a minimum. Also in all situations unique and irreplaceable features should be avoided.

b) Where possible, alienated land should not be allowed to remain idle. Ditches though difficult to put into productive use may provide hay etc. and wildlife habitat and should therefore be utilized.

c) When and where possible construction should occur before or after agricultural crops have been planted or harvested to eliminate the initial construction opportunity cost.

d) All corridors have potential to provide wildlife habitat. The utilization of rights-of-way, where active primary commodity production is not possible or very costly, for wildlife is the best alternative use for reducing opportunity costs. By enhancing wildlife habitat not only is there a possibility of increasing our wildlife populations but some of the esthetic damage resulting from corridors may be mitigated. Many programs are in operation now to increase, enhance and protect wildlife and wildlife habitat and conveyance corridors offer at minimal cost vast acreages of idle land for productive wildlife utilization. Therefore active work and regulations for installation, operation and maintenance should be completed to bring back into production the fruitless lands now existing within the many corridors of Manitoba.

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Appendix Ia. Mileage - acreage of land used by pipelines in Manitoba, 1970.

Diameter size of pipe (inch)	Length of line (miles)	Approximate trench width (feet)	Area used by trench (acre)
Gas lines[a]			
0-2.9	1208.8	0.50	73.26
3-5.9	482.8	0.75	43.89
6-8.9	265.1	1.75	56.23
9-12.9	52.2	2.00	12.65
13-20	44.1	4.00	21.38
≥ 21	791.1	6.00	575.35
Total	2834.1		782.76
Oil lines[b]			
0-5.9	112.8	0.75	10.25
6-8.9	242.1	1.75	51.35
9-10.9	73.0	2.00	17.70
11-12.9	10.8	2.00	2.62
13-16.9	254.0	4.00	123.15
17-18.9	10.7	4.00	5.19
21-25.9	185.0	6.00	134.55
26-29.9	1.6	6.00	1.16
≥ 30	186.5	8.00	180.85
Total	1076.5		526.82

[a] Statistics Canada (1973a:47)

[b] Statistics Canada (1973b:40-41)

Appendix I b. Mileage - acreage of land used by highways in Manitoba.[a]

Highway type	Length (miles)	Approximate driving surface width (ft)	Approximate ditch width (ft)	Area used for driving surface (acre)	Potential area for agriculture and wildlife use (acre)[b]
Provincial trunk highways					
2 lane undivided	3790.0	50	150	22970	68036
4 lane undivided	28.0	100	--	339	--
4 lane divided	187.0	100	300	2267	4099
6 lane divided	0.9	150	--	16	--
Provincial roads					
2 lane paved	977.0	50	75	5921	8533
gravel	6602.0	25	75	20006	75564
Municipal roads	34676.0	20	68	87273	288484
Unimproved roads	49.0	--	--	--	--
Total	46309.9			138792	444716

[a]Manitoba Department of Highways (Personal communication)

[b]Oetting (1971a and 1971b)

Appendix I c. Mileage - acreage of land used by hydro transmission lines in Manitoba.[a]

Line type	Length (miles)	Corridor width (ft.)	Area of corridor (acre)	Potential area for wildlife (acre)[b]
± 450 KV (D.C.)	1113	450	60709	
230 KV				
steel		150		89260
wood	1584	120		
138 KV	337	120	4920	
115 KV	1502	100	18206	
Total	4536		109737	89260

[a]Manitoba Hydro (Personal communication)

[b]Oetting (1971a and 1971b)

Appendix II a. Effect of pipeline installation on the yield of wheat (bu/acre) in 1968.[a]

Soil association and profile	Year of installation	No. of reps.	Average yield, bu/acre			Pipeline effect	Claybank effect
			Trench	Claybank	Undisturbed		
Weyburn Orthic and Solonetz-like	1957 & before	7	17.6	16.6	18.7	-1.0	-2.2
	1958-1960	7	22.6	19.9	19.7	3.0	0.2
	1963-1965	5	19.7	20.8	20.1	-0.4	0.6
	1966 & 1967	7	14.3	19.2	18.6	-4.3	0.6
	1965 & before	19	20.0	18.9	19.4	0.6	-0.4
	All years	26	18.5	19.0	19.2	-0.7	-0.2
Oxbow Rego and Calcareous	1957	9	26.6	28.9	27.0	-0.4	1.9
Orthic	1957	7	30.5	32.5	32.5	-2.0	0.1
All profiles	1957	16	28.1	30.4	29.2	-1.0	1.2
Ryerson Calcareous	1958-1960	6	36.0	31.2	28.4	7.5**	2.8
Estevan Solod	1957 & before	9	26.9	23.5	22.6	4.3*	0.9
	1958-1960	6	23.0	19.9	18.0	4.9	1.9
	1963-1965	6	32.5	24.6	23.4	9.1*	1.1
	1966 & 1967	8	22.9	22.5	21.1	1.8	1.4
	1965 & before	21	27.4	22.8	21.5	5.9***	1.4
	All years	29	26.1	22.7	21.4	4.7***	1.4
Trossachs Solodized-Solonetz	1966 & 1967	11	17.4	19.2	17.3	0.0	1.8
Estevan & Weyburn	1965 & before	40	23.9	21.0	20.5	3.4***	0.5
	1966 & 1967	15	18.9	21.0	19.9	-1.0	1.0
	All years	55	22.5	21.0	20.4	2.2**	0.6

*significant at the 90% level **significant at the 95% level ***significant at the 99% level

[a]Button et al. (1971:41).

Appendix II b. Effect of pipeline installation on the yield of wheat (bu/acre) in 1969.[a]

Soil association and profile	Year of installation	No. of reps.	Average yield, bu/acre Trench	Undisturbed	Pipeline effect
Weyburn Orthic	1957 & before	6	37.7	38.3	-0.6
	1958-1960	5	34.7	33.5	1.2
	1963-1965	5	23.2	25.5	-2.4
	1966 & 1967	9	29.2	29.0	0.2
	1965 & before	16	32.2	32.8	-0.6
	All years	25	31.1	31.4	-0.3
Oxbow Rego and					
Calcareous	1957	5	34.6	34.2	0.4
Orthic	1957	7	39.7	31.8	7.9
All profiles	1957	12	37.6	32.8	4.8
Ryerson Calcareous	1958-1960	6	38.1	34.0	4.0***
Estevan Solod	1957 & before	7	36.5	37.2	-0.7
	1958-1960	10	36.3	32.0	4.3*
	1963-1965	9	33.7	31.0	2.8
	1966 & 1967	13	33.1	29.0	4.1*
	1965 & before	26	35.5	33.0	2.4*
	All years	39	34.7	31.7	3.0**
Trossachs Solodized	1958-1960	8	35.1	30.6	4.5
Solonetz	1966 & 1967	5	36.7	33.5	3.2
Estevan & Weyburn	1965 & before	42	34.2	32.9	1.3*
	1966 & 1967	22	31.5	29.0	2.5
	All years	64	33.3	31.6	1.7

*significant at the 90% level **significant at the 95% level ***significant at the 99% level

[a]Button et al. (1971:42)

Appendix II c. Effect of pipeline installation on the yield of wheat (bu/acre) when the data from 1968 and 1969 are combined.[a]

Soil association and profile	Year of installation	No. of reps.	Average yield, bu/acre		Pipeline effect
			Trench	Undisturbed	
Weyburn Orthic	1957 & before	13	26.9	27.7	-0.8
	1958-1960	12	27.6	25.4	2.2
	1963-1965	10	21.5	22.8	-1.4
	1966 & 1967	16	22.7	24.5	-1.8
	1965 & before	35	25.6	25.5	0.1
	All years	51	24.7	25.2	-0.5
Oxbow Rego and					
Calcareous	1957	14	29.5	29.6	-0.1
Orthic	1957	14	35.1	32.2	3.0
All profiles	1957	28	32.2	30.7	1.5
Ryerson Calcareous	1958-1960	12	37.0	31.2	5.8***
Estevan Solod	1957 & before	16	31.1	20.0	2.1*
	1958-1960	16	31.3	26.7	4.6**
	1963-1965	15	33.3	27.9	5.3*
	1966 & 1967	21	29.2	26.0	3.2**
	1965 & before	47	31.9	27.9	4.0***
	All years	68	31.0	27.3	3.7***
Trossachs Solodized-Solonetz	1966 & 1967	16	23.4	22.4	1.0
Estevan & weyburn	1965 & before	82	29.2	26.9	2.2***
	1966 & 1967	37	26.4	25.3	1.1
	All years	119	28.3	26.4	1.9***

*significant at the 90% level **significant at the 95% level ***significant at the 99% level

[a]Button et al. (1971:43)

Appendix III. Average yields of grain.[a]

Field	Crop	Mean yields of grain (bu/acre)			P values*
		Pipeline	Control	Difference	
1	Barley	52.9	39.0	13.9	.05 - .01
2	Wheat	44.4	35.4	9.0	.01
3	Barley	72.5	44.2	28.3	.01
4	Wheat	41.6	29.6	12.0	.01
5	Barley	56.7	46.2	10.5	.05 - .01
6	Barley	35.9	26.4	9.5	.05 - .01
7	Wheat	29.6	22.1	7.5	.05 - .01

*P values represent probability that difference obtained was due to change variation.

.05 Probability that difference due to change is greater than 5%. Difference not considered to be statistically significant.

.05 - .01 Probability of chance variation is between 5% and 1%. Difference considered statistically significant.

.01 Probability of chance variation is less than 1%. Difference c onsidered highly significant.

[a]Toogood (Personal communication)

Appendix IV

Questionnaire sent to farmers having a pipeline right-of-way traversing their land.

---

1) Along the pipeline did your crop yield
INCREASE ______
DECREASE ______
NO CHANGE ______

2) What was the approximate "INCREASE" in yield? 1-5%_____ 6-10%_____
11-15%_____ 16-20%_____
21-25%_____ > 25%_____

3) What yield does this represent in bushels per acre? ______bu/acre.

4) What was the approximate "DECREASE" in yield? 1-5%_____ 6-10%_____
11-15%_____ 16-20%_____
21-25%_____ > 25%_____

5) What yield does this represent in bushels per acre? ______bu/acre.

6) Was there an increase in production costs due to the pipeline? YES___
NO___

7) Was your land cleared of all pipeline construction debris, (that is scrap metal, lumber, wire, etc). YES _______ NO ______

8) Did the debris, if any cause any damage to your machinery? YES___
NO___

9) Did the debris, if any cause any lost time in working the fields?
YES___
NO___

10) Would you estimate the dollar value lost due to debris, either as repairs to machinery and/or lost time? ______________.

11) Did you increase fertilizer application along the pipeline? YES___
NO___

12) What was the additional production costs/acre because of the pipeline?
$1-5 _______ $6-10 _______
$11-15 _______ $16-20 _______
$21-25 _______ > $25 _______

13) Are you satisfied with the arrangements you have with the pipeline company? YES _____ NO _____

Appendix V

Results from mailed questionnaire regarding the effects of pipeline installation on crop yield.

Question No.		Total frequency	Oil line[a]	Gas line[b]	Combined
1)					
	Increase	5	9%	11%	9%
	Decrease	35	68%	63%	66%
	No change	13	23%	26%	25%
2)	1-5%	0	0	2	--
	6-10%	2	0	0	--
	11-15%	1	1	0	--
	16-20%	1	1	0	--
	21-25%	0	0	0	--
	25%	0	0	0	--
3)	1-5 bu/acre	4	2	2	--
	Others	0	0	0	--
4)	1-5%	4	2	2	--
	6-10%	4	2	2	--
	11-15%	5	3	2	--
	16-20%	2	1	1	--
	21-25%	5	5	0	--
	25%	13	8	5	--
5)	1-5 bu/acre	7	4	3	--
	6-10 bu/acre	10	9	1	--
	11-15 bu/acre	5	3	2	--
	16-20 bu/acre	1	0	1	--
	21-25 bu/acre	1	1	0	--
	25 bu/acre	1	0	1	--
6)	Yes	19	35%	37%	36%
	No	25	47%	47%	47%
	No answer	9	18%	16%	17%
7)	Yes	28	71%	21%	53%
	No	22	21%	80%	42%
	No answer	3	9%	0%	6%
8)	Yes	14	18%	42%	26%
	No	37	79%	53%	70%
	No answer	2	3%	5%	6%
9)	Yes	18	21%	58%	34%
	No	32	74%	37%	60%
	No answer	3	6%	5%	6%

Appenxid V Continued

Question No.		Total frequency	Oil line[a]	Gas line[b]	Combined
10)	Dollars	--	--	--	--
11)	Yes	10	18%	21%	19%
	No	41	79%	74%	77%
	No answer	2	3%	5%	4%
12)	\$1-5/acre	11	5	6	--
	\$6-10/acre	9	5	4	--
	\$11-15/acre	1	1	0	--
	\$16-20/acre	0	0	0	--
	\$21-25/acre	0	0	0	--
	\$25/acre	1	1	0	--
13)	Yes	41	74%	84%	77%
	No	10	24%	11%	19%
	No answer	2	3%	5%	4%

[a] For the oil pipeline corridor, 84 questionnaires were mailed and 34 questionnaires were returned answered. Oil line belongs to Interprovincial Pipe Line Ltd.

[b] For the gas pipeline corridor, 58 questionnaires were mailed and 21 questionnaires were returned answered. Gas line belongs to TransCanada Pipeline.

Appendix VI

Subtype code[a]

Cover Type 'S'	Code	Cover Type 'M'	Code
Red pine 71%-100%	01	Red pine 51% and over	41
Red pine 40%-70%-jP	02	Red pine 50% and under-jP	42
Jack pine 71%-100%	04	Jack pine 51% and over	44
Jack pine 40%-70%-rP	05	Jack pine 50% and under-rP	45
Jack pine 40%-70%-Spruce	06	Jack pnne 50% and under-Spruce	46
Scotch pine 71%-100%	08	Scotch pine 51% and over	48
Scotch pine 40%-70%-jP	09	Scotch pine 50% and under-jP	49
White spruce 71%-100%	10	White spruce 51% and over	50
White spruce 40%-70%-bF,jP,bS	11	White spruce 50% and under-bF,jP,bS	51
Black spruce 71%-100%	13	Black spruce 51% and over	53
Black spruce 40%-70%-jP	14	Black spruce 50% and under-jP	54
Black spruce 40%-70%-bF,wS	15	Black spruce 50% and under-bF	55
Black spruce 40%-70%-tL	16	Black spruce 50% and under-tL	56
Black spruce 40%-70%-eC	17	Black spruce 50% and under-eC	57
		Black spruce 50% and under-wS, bF	58
Balsam fir 71%-100%	20	Balsam fir 51% and over	60
Balsam fir 40%-70%-Spruce	21	Balsam fir 50% and under-Spruce	61
Balsam fir 40%-70%-eC	22	Balsam fir 50% and under-eC	62
Tamarack 71%-100%	30	Tamarack 51% and over	70
Tamarack 40%-70%-Spruce	31	Tamarack 50% and under-Spruce	71
Tamarack 40%-70%-eC	32	Tamarack 50% and under-eC	72
Cedar 71%-100%	36	Cedar 51% and over	76
Cedar 40%-70%	37	Cedar 50% and under-Spruce	77
Cover Type 'N'		**Cover Type 'H'**	
Trembling aspen-rP	80	Trembling aspen 51%-100%	90*
Trembling aspen-jP	81	Trembling aspen 51%-wB(20%)	91
Trembling aspen-Spruce & bF	82		
		Birch 51%-100%	92
Birch-rP	85	Ash 51% +	94
Birch-jP	86	Elm 51% +	95
Birch-Spruce & bF	87	Oak 51% +	96
		Manitoba Maple 51% +	97
Balsam Poplar Spruce,bF,tL	88	Balsam Poplar 51% +	98**
Northern Region & Lake Winnipeg East		**Northern Region & Lake Winnipeg East**	
Hardwood 50%-74%-Pine	83	All hardwoods	99
Hardwood 50%-74%-Spruce	84		

* Code 90 - Where Aspen and Balsam Poplar together equal 51%-100%
** If bA is 50% or less with 20% + wB then classify as 91

[a]Department of Mines, Resources, and Environmental Management (1972:7).

Appendix VII

Development of mean annual increments for working groups in Township 61 Ranges 27 and 28.

$$MAI = \frac{\Sigma(\text{gross merchantable volume by subtype x area})}{(\Sigma \text{area})\ (\text{rotation age})}$$

$$\text{Weighted average gross merchantable volume} = \frac{\Sigma(\text{GMV})(\text{ area})}{(\Sigma \text{area})}$$

Working group	Type aggregate	GMV (cu ft /acre)	Area (acre)	GMV x area	MAI & average GMV
Range 27					
Jackpine	04-1-4-3	1210	50	60500	rotation
	04-1-4-4	1654	267	441618	age = 75
	06-1-4-3	1254	113	141702	
	06-1-4-4	1880	736	1383680	MAI = 23.47
	44-1-4-3	1798	--	--	
	44-1-4-4	2268	13	29484	GMV = 1760
	46-1-4-3	2056	18	37008	
	46-1-4-4	2020	49	98980	
			1246	2193027	
Black spruce	13-1-4-3	1061	38	40318	rotation
	13-1-4-4	1481	492	728652	age = 80
	14-1-4-3	1360	73	99280	
	14-1-4-4	1920	624	1198080	MAI = 22.14
	15-1-4-3	1407	289	406623	
	15-1-4-4	1958	1139	2230162	GMV = 1771
	53-1-4-4	1703	9	15327	
			2664	4718442	
	13-2-4-3	711	49	34839	rotation
	13-2-4-4	934	83	77522	age = 140
			132	112361	MAI = 6.08
					GMV = 851
White spruce	10-1-4-3	1790	142	254180	rotation
	10-1-4-4	2905	122	354410	age = 100
	11-1-4-3	1940	129	250260	
	11-1-4-4	2199	1112	2445288	MAI = 22.09
	50-1-4-3	1701	112	190512	
	50-1-4-4	2543	339	862077	GMV = 2209
	51-1-4-3	2253	118	265854	
	51-1-4-4	2130	524	1116120	
			2598	5738701	

Appendix VII continued

Working group	Type aggregate	GMV (cu ft /acre)	Area (acre)	GMV x area	MAI & average GMV
Trembling aspen	81-1-4-3	1101	50	38535	rotation age = 60
	81-1-4-4	1367	93	127131	
	82-1-4-3	1863	804	1497852	
	82-1-4-4	1765	1211	2137415	MAI = 28.49
	90-1-4-3	1331	160	212960	
	90-1-4-4	1685	3171	5343135	GMV = 1709
			5474	9357028	
Balsam Popular	98-1-4-4	2228	47	119239	rotation age = 60 MAI = 42.28
Range 28					
Jackpine	04-1-4-3	1210	160	193600	rotation age = 75
	04-1-4-4	1654	528	873312	
	06-1-4-3	1241	247	306527	
	06-1-4-4	1880	905	1701400	MAI = 22.32
	44-1-4-3	2268	9	20412	
			1849	3095251	GMV = 1674
Black spruce	13-1-4-3	1061	45	47745	rotation age = 80
	13-1-4-4	1481	1491	2208171	
	14-1-4-3	1360	238	323680	
	14-1-4-4	1920	562	1079040	MAI = 19.80
	15-1-4-3	1407	66	92862	
	15-1-4-4	1958	140	274140	GMV = 1584
	53-1-4-3	1606	7	11242	
			2549	4036880	
	13-2-4-3	711	149	105939	rotation age = 80 MAI = 8.89
White spruce	10-1-4-3	1790	73	130670	rotation age = 100
	10-1-4-4	2905	6	17430	
	11-1-4-3	1940	349	677060	
	11-1-4-4	2199	853	1875747	MAI = 21.38
	50-1-4-3	1701	137	233037	
	50-1-4-4	2543	13	33059	GMV = 2138
	51-1-4-3	2253	821	1849713	
	51-1-4-4	2130	183	389790	
			2435	5206506	

Appendix VII continued

Working group	Type aggregate	GMV (cu ft /acre)	Area (acre)	GMV x area	MAI & average GMV
Trembling aspen	81-1-4-4	1367	18	24606	rotation
	82-1-4-3	1863	959	1786617	age = 60
	82-1-4-4	1765	513	905445	MAI = 27.65
	90-1-4-3	1331	773	1028863	
	90-1-4-4	1685	332	559420	
			2595	4304951	GMV = 1659
Balsam popular	88-1-4-4	2438	9	21942	rotation age = 60 MAI = 40.63

APPENDIX VIII

ANNUAL TIMBER VOLUME LOSS BY SPECIES FOR HYPOTHETICAL CORRIDOR

MAP #	STAND #	MAI (Cu ft / Acre)	LENGTH (Miles)	SPECIES MIX (percent)	AREA USED (acres)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet)						
							TA	JP	BS	WS	TL	BF	WB
1	700	-	.0620	-	0.9018	-	-	-	-	-	-	-	-
2	350	22.32	.1500	JP8, TA2	2.1818	48.70	9.74	38.96	-	-	-	-	-
3	349	22.32	.0375	JP10	0.5455	12.18	-	12.18	-	-	-	-	-
4	347	22.32	.1500	JP8, TA2	2.1818	48.70	9.74	38.96	-	-	-	-	-
5	345	22.32	.2625	JP6, TA4	3,8182	85.22	34.09	51.13	-	-	-	-	-
6	344	22.32	.1188	JP9, TA1	1.7280	38.57	3.86	34.71	-	-	-	-	-
7	700	-	.0375	-	0.5455	-	-	-	-	-	-	-	-
8	223	22.32	.1250	JP8, TA2	1.8182	40.58	8.12	32.46	-	-	-	-	-
9	224	19.80	.1125	JP10	1.6364	32.40	-	32.40	-	-	-	-	-
10	223	22.32	.1625	JP8, TA2	2.3636	52.76	10.55	42.20	-	-	-	-	-
11	227	22.32	.0500	-	0.7273	16.23	-	-	-	-	-	-	-
12	700	-	.0375	-	0.5455	-	-	-	-	-	-	-	-
13	226	22.32	.0750	JP10	1.0909	24.35	-	24.35	-	-	-	-	-
14	223	22.32	.1500	JP8, TA2	2.1818	48.70	9.74	38.96	-	-	-	-	-
15	232	27.65	.1375	TA9, TA1	2.0000	55.30	49.77	-	-	-	-	-	-
16	231	19.80	.0750	-	1.0909	21.60	-	-	-	-	-	-	-
17	194	22.32	.0500	JP8, TA2	0.7273	16.23	3.25	12.99	-	-	-	-	-
18	700	-	.1875	-	2.7273	-	-	-	-	-	-	-	-
19	238	22.32	.0688	JP8, BS2	1.0007	22.34	-	17.87	4.47	-	-	-	-
20	234	19.80	.0500	BS7, WS2, TL1	0.7273	14.40	-	-	10.08	2.88	1.44	-	-
21	194	22.32	.2625	JP8, TA2	3.8182	85.22	17.04	68.18	-	-	-	-	-
22	199	22.32	.1375	JP7, BS3	2.0000	44.64	-	31.25	13.39	-	-	-	-
23	194	22.32	.2250	JP8, TA2	3.2727	73.05	14.61	58.44	-	-	-	-	-
24	201	27.65	.1063	TA8, JP2	1.5462	42.75	34.20	8.55	-	-	-	-	-

APPENDIX VIII Continued

MAP #	STAND #	MAI (Cu ft / Acre)	LENGTH (Miles)	SPECIES MIX (percent)	AREA USED (acres)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet)						
							TA	JP	BS	WS	TL	BF	WB
25	183	22.32	.1688	JP5, TA3, WS1, BS1	2.4553	54.80	16.44	27.40	5.48	5.48	-	-	-
26	196	27.65	.1500	TA7, JP2	2.1818	60.33	42.23	12.07	-	-	-	-	-
27	194	22.32	.1500	JP8, TA2	2.1818	48.70	9.74	38.96	-	-	-	-	-
28	192	21.38	.2375	WS6, JP2, TA2	3.4545	73.86	14.77	14.77	-	44.31	-	-	-
29	111	27.65	.6000	TA8, WS2	8.7273	241.31	193.05	-	-	48.26	-	-	-
30	109	27.65	.0875	TA7, WS3	1.2727	35.19	24.63	-	-	10.56	-	-	-
31	112	19.80	.1125	BS8, JP1, TA1	1.6364	32.40	3.24	3.24	25.92	-	-	-	-
32	357	22.32	.1750	JP7, WS3	2.5455	56.82	-	39.77	-	17.05	-	-	-
33	114	22.32	.2125	JP5, WS3, TA2	3.0909	68.99	13.80	34.50	-	20.70	-	-	-
34	357	22.32	.3000	JP7, WS3	4.3636	97.40	-	68.18	-	29.22	-	-	-
35	32	19.80	.3375	BS8, JP2	4.9091	97.20	-	-	77.76	19.44	-	-	-
36	115	27.65	.0875	TA7, WS3	1.2727	35.19	24.63	-	-	10.56	-	-	-
37	32	19.80	.0375	BS8, JP2	0.5455	10.80	-	2.16	8.64	-	-	-	-
38	41	21.38	.0875	WS5, TA4, BS1	1.2727	27.21	10.88	-	2.72	13.61	-	-	-
39	42	27.65	.0620	TA8, WS2	0.9018	24.93	19.95	-	-	4.99	-	-	-
40	43	27.65	.2813	TA7, BS2, WS1	4.0916	113.13	79.19	-	22.63	11.31	-	-	-
41	40	27.65	.0563	TA8, WS2	0.8189	22.64	18.11	-	-	4.53	-	-	-
42	32	19.80	.0750	BS8, JP2	1.0909	21.60	-	4.32	17.28	-	-	-	-
43	39	27.65	.0620	TA5, WS3, BS2	0.9018	24.93	12.47	-	4.99	7.48	-	-	-
44	32	19.80	.0620	BS8, JP2	0.9018	17.86	-	3.57	14.28	-	-	-	-
45	38	19.80	.0620	BS4, WS3, TA3	0.9018	17.86	5.36	-	7.14	5.36	-	-	-
46	32	19.80	.1000	BS8, JP2	1.4545	28.80	-	5.76	23.04	-	-	-	-
47	38	19.80	.1000	BS4, WS3, TA3	1.4545	28.80	8.64	-	11.52	8.64	-	-	-
48	35	21.38	.1125	WS6, BS2, TA2	1.6364	34.99	7.00	-	7.00	20.99	-	-	-
49	537	22.09	.1938	WS7, TA3,	2.8189	62.27	18.68	-	-	43.59	-	-	-
50	535	28.49	.0688	TA8, WS2	1.0007	28.51	22.81	-	-	5.70	-	-	-
51	700	-	.0313	-	0.4553	-	-	-	-	-	-	-	-

APPENDIX VIII Continued

MAP #	STAND #	MAI (Cu ft / Acre)	LENGTH (Miles)	SPECIES MIX (Percent)	AREA USED (acres)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet)						
							TA	JP	BS	WS	TL	BF	WB
52	535	28.49	.0375	TA8, WS2	0.5455	15.54	12.43	-	-	3.11	-	-	-
53	534	28.49	.2250	TA6, WS4	3.2727	93.24	55.94	-	-	37.30	-	-	-
54	477	22.09	.0875	WS5, TA3, BS2	1.2727	28.11	8.43	-	5.62	14.06	-	-	-
55	466	22.14	.2063	BS6, TA2, WS1, WB1	3.0007	66.44	13.29	-	39.86	6.64	-	-	6.64
56	475	22.14	.0750	BS7, TA3	1.0909	24.15	7.25	-	16.91	-	-	-	-
57	466	22.14	.2125	BS6, TA2, WS1, WB1	3.0909	68.43	13.69	-	41.06	6.84	-	-	6.84
58	474	22.14	.0500	BS7, WS3	0.7273	16.10	-	-	11.27	4.83	-	-	-
59	480	28.49	.0875	TA6, BS4	1.2727	36.26	21.76	-	14.50	-	-	-	-
60	482	28.49	.1625	TA8, WS2	2.3636	67.34	53.87	-	-	13.47	-	-	-
61	483	22.09	.0500	WS9, TA1	0.7273	16.07	1.61	-	-	14.46	-	-	-
62	308	28.49	.0375	TA9, WS1	0.5455	15.54	13.99	-	-	1.55	-	-	-
63	484	22.09	.1625	WS6, BS2, TA2	2.3636	52.21	10.44	-	10.44	31.33	-	-	-
64	485	22.09	.0688	WS7, BS3	1.0007	22.11	-	-	6.63	15.47	-	-	-
65	484	22.09	.0563	WS6, BS2, TA2	0.8189	18.09	3.62	-	3.62	10.85	-	-	-
66	720	-	.0375	-	0.5455	-	-	-	-	-	-	-	-
67	308	28.49	.0620	TA9, WS1	0.9018	25.69	23.12	-	-	2.57	-	-	-
68	309	22.09	.0375	WS3, BF3, BS2, TA2	0.5455	12.05	2.41	-	2.41	3.62	-	3.62	-
69	308	28.49	.0438	TA9, WS1	0.6371	18.15	16.34	-	-	1.82	-	-	-
70	308	28.49	.2125	TA9, WS1	3.0909	88.06	79.25	-	-	8.81	-	-	-
71	368	28.49	.0620	TA9, WS1	0.9018	25.69	23.12	-	-	2.57	-	-	-
72	299	28.49	.1688	WS4, BS3, TA3	2.4553	69.95	20.99	-	20.99	27.98	-	-	-
73	286	28.49	.2625	TA10	3.8182	108.78	108.78	-	-	-	-	-	-
74	294	22.09	.0500	WS8, BS1, TA1	0.7273	16.07	1.61	-	1.61	12.85	-	-	-
75	286	28.49	.0250	TA10	0.3636	10.36	10.36	-	-	-	-	-	-
76	293	28.49	.0375	TA8, WS2	0.5455	15.54	12.43	-	-	3.11	-	-	-
77	286	28.49	.1688	TA10	2.4553	69.95	69.95	-	-	-	-	-	-
78	289	22.09	.0750	WS6, BS3, TA1	1.0909	24.10	2.41	-	7.23	14.46	-	-	-

APPENDIX VIII Continued

MAP #	STAND #	MAI (Cu ft / acre)	LENGTH (miles)	SPECIES MIX (percent)	AREA USED (acres)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet) TA	JP	BS	WS	TL	BF	WB
79	286	28.49	.2625	TA10	3.8182	108.78	108.78	-	-	-	-	-	-
80	181	22.09	.0875	WS6, TA3, BS1	1.2727	28.11	8.43	-	2.81	16.87	-	-	-
81	286	28.49	.2188	TA10	3,1825	90.67	90.67	-	-	-	-	-	-
82	184	22.14	.1063	BS10	1.5462	34.23	-	-	34.23	-	-	--	-
83	185	28.49	.0750	TA7, WS3	1.0909	31.08	21.76	-	-	9.32	-	-	-
84	186	22.14	.2250	WS6, JP2, BS1, TA1	3.2727	72.46	7.25	14.49	7.25	43.47	-	-	-
85	206	28.49	.0938	TA7, BS1, WS1, JP1	1.3644	38.87	27.21	3.89	3.89	3.89	-	-	-
86	205	22.14	.0438	BS7, JP2, TA1	0.6371	14.11	1.41	2.82	9.87	-	-	-	-
87	206	29.49	.0620	TA7, BS1, WS1, JP1	0.9018	26.59	18.62	2.66	2.66	2.66	-	-	-
88	700	-	.1125	-	1.6364	-	-	-	-	-	-	-	-
89	190	28.49	.0875	TA10	1.2727	36.26	36.26	-	-	-	-	-	-
90	189	22.14	.0750	BS9, TA1	1.0909	24.15	2.42	-	21.74	-	-	-	-
91	190	28.49	.0500	TA10	0.7273	20.72	20.72	-	-	-	-	-	-
92	200	22.09	.2500	WS6, BS2, JP1, TA1	3.6364	80.33	8.03	8.03	16.07	48.20	-	-	-
93	199	28.49	.0620	TA9, JP1	0.9018	25.69	23.12	2.57	-	-	-	-	-
94	840	-	.0313	-	0.4553	-	-	-	-	-	-	-	-
95	198	28.49	.0500	TA10	0.7273	20.72	20.72	-	-	-	-	-	-
96	220	22.14	.3188	BS6, JP3, TA1	4.6371	102.67	10.27	30.80	61.60	-	-	-	-
97	9	22.14	.0375	BS9, TA1	0.5455	12.08	1.21	-	10.87	-	-	-	-
98	220	22.14	.0375	BS6, JP3, TA1	0.5455	12.08	1.21	3.62	7.25	-	-	-	-
99	4	28.49	.2500	TA7, BS1, JP1, WS1	3.6364	103.60	72.52	10.36	10.36	10.36	-	-	-
100	575	28.49	.0620	BS6, WS3, TA1	0.9018	25.69	2.57	-	15.42	7.71	-	-	-
101	700	-	.0375	-	0.5455	-	-	-	-	-	-	-	-
102	1	22.14	.0750	BS10	1.0909	24.15	-	-	24.15	-	-	-	-
103	1	22.14	.0563	BS10	0.8189	18.13	-	-	18.13	-	-	-	-
104	700	-	.0375	-	0.5455	-	-	-	-	-	-	-	-
105	1	22.14	.0938	BS10	1.3644	30.21	-	-	30.21	-	-	-	-
106	700	-	.1000	-	1.4545	-	-	-	-	-	-	-	- -
TOTAL			12.60		183.36	4195.84	1820.60	877.53	715.00	714.84	1.44	3.62	13.48

APPENDIX IX

INITIAL TIMBER VOLUME LOSS BY SPECIES FOR CORRIDOR FROM CLEAR CUTTING

MAP #	STAND #	GMV WEIGHTED AVERAGE (cu ft /acre)	SPECIES MIX (percent)	AREA USED (acre)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet)						
						TA	JP	BS	WS	TL	BF	WB
1	700	-		0.9018	-	-	-	-	-	-	-	-
2	350	1674	JP8, TA2	2.1818	3652	731	2922	-	-	-	-	-
3	349	1674	JP10	0.5455	913	-	911	-	-	-	-	-
4	347	1674	JP8, TA2	2.1818	3652	731	2922	-	-	-	-	-
5	345	1674	JP6, TA4	3.8182	2557	2557	3835	-	-	-	-	-
6	344	1674	JP9, TA1	1.7280	2893	289	2605	-	-	-	-	-
7	700	-	-	0.5455	-	-	-	-	-	-	-	-
8	223	1674	JP8, TA2	1.8182	3044	609	2435	-	-	-	-	-
9	224	1584	JP10	1.6364	2592	-	2592	-	-	-	-	-
10	223	1674	JP8, TA2	2.3636	3957	792	3166	-	-	-	-	-
11	227	1674	-	0.7273	1218	-	-	-	-	-	-	-
12	700	-	-	0.5455	-	-	-	-	-	-	-	-
13	226	1674	JP10	1.0909	1826	-	1826	-	-	-	-	-
14	223	1674	JP8, TA2	2.1818	3652	731	2922	-	-	-	-	-
15	232	1659	TA9, JP1	2.0000	3318	2986	332	-	-	-	-	-
16	231	1584	-	1.0909	1728	-	-	-	-	-	-	-
17	194	1674	JP8, TA2	0.7273	1218	244	974	-	-	-	-	-
18	700	-	-	2.7273	-	-	-	-	-	-	-	-
19	238	1674	JP8, BS2	1.0007	1675	-	1340	335	-	-	-	-
20	234	1584	BS7, WS2, TL1	0.7273	1152	-	-	806	230	115	-	-
21	194	1674	JP8, TA2	3.8182	6392	1279	5114	-	-	-	-	-
22	199	1674	JP7, BS3	2.0000	3348	-	2344	1005	-	-	-	-
23	194	1674	JP8, TA2	3.2727	5478	1096	4382	-	-	-	-	-
24	201	1659	TA8, JP2	1.5462	2565	2052	513	-	-	-	-	-
25	183	1674	JP5, TA3, WS1, BS1	2.4553	4110	1233	2055	411	411	-	-	-
26	196	1659	TA7, JP2	2.1818	3620	2534	724	-	-	-	-	-

APPENDIX IX continued

MAP #	STAND #	GMV WEIGHTED AVERAGE (cu ft /acre)	SPECIES MIX (percent)	AREA USED (acre)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet)						
						TA	JP	BS	WS	TL	BF	WB
27	194	1674	JP8, TA2	2.1818	3652	731	2922	-	-	-	-	-
28	192	2138	WS6, JP2, TA2	3.4545	7386	1477	1477	-	4432	-	-	-
29	111	1659	TA8, WS2	8.7273	14479	11583	-	-	2896	-	-	-
30	109	1659	TA7, WS3	1.2727	2111	1478	-	-	633	-	-	-
31	112	1584	BS8, JP1, TA1	1.6364	2592	259	259	2074	-	-	-	-
32	357	1674	JP7, WS3	2.5455	4261	-	2983	-	1278	-	-	-
33	114	1674	JP5, WS3, TA2	3.0909	5174	1035	2587	-	1552	-	-	-
34	357	1674	JP7, WS3	4.3636	7305	-	5114	-	2192	-	-	-
35	32	1584	BS8, JP2	4.9091	7776	-	1555	6221	-	-	-	-
36	115	1659	TA7, WS3	1.2727	2111	1478	-	-	633	-	-	-
37	32	1584	BS8, JP2	0.5455	864	-	173	691	-	-	-	-
38	41	2138	WS5, TA4, BS1	1.2727	2721	1088	-	272	1361	-	-	-
39	42	1659	TA8, WS2	0.9018	1496	1197	-	-	299	-	-	-
40	43	1659	TA7, BS2, WS1	4.0916	6788	4752	-	1358	679	-	-	-
41	40	1659	TA8, WS2	0.8189	1359	1087	-	-	272	-	-	-
42	32	1584	BS8, JP2	1.0909	1728	-	346	1382	-	-	-	-
43	39	1659	TA5, SW3, BS2	0.9018	1496	748	-	299	449	-	-	--
44	32	1584	BS8, JP2	0.9018	1428	-	286	1142	-	-	-	-
45	38	1584	BS4, WS3, TA3	0.9018	1428	428	-	571	428	-	-	-
46	32	1584	BS8, JP2	1.4545	2304	-	461	1843	-	-	-	-
47	38	1584	BS4, WS3, TA3	1.4545	2304	692	-	922	692	-	-	-
48	35	2138	WS6, BS2, TA2	1.6364	3499	700	-	700	2099	-	-	-
49	537	2138	WS7, TA3	2.8189	6027	1808	-	-	4219	-	-	-
50	535	1709	TA8, WS2	1.0007	1701	1368	-	-	342	-	-	-
51	700	-	-	0.4553	-	-	-	-	-	-	-	-
52	535	1709	TA8, WS2	0.5455	932	746	-	-	187	-	-	-
53	534	1709	TA6, WS4	3.2727	5594	3356	-	-	2237	-	-	-
54	477	2209	WS5, TA3, BS2	1.2727	2811	844	-	563	1406	-	-	-
55	466	1771	BS6, TA2, WS1, WB1	3.0007	5314	1063	-	3188	532	-	-	532

APPENDIX IX continued

MAP #	STAND #	GMV WEIGHTED AVERAGE (cu ft /acre)	SPECIES MIX (percent)	AREA USED (acre)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet)						
						TA	JP	BS	WS	TL	BF	WB
56	475	1771	BS7, TA3	1.0909	1932	579	-	1352	-	-	-	-
57	466	1771	BS6, TA2, WS1, WB1	3.0909	5474	1095	-	3284	548	-	-	548
58	474	1771	BS7, WS3	0.7273	1288	-	-	902	387	-	-	-
59	480	1709	TA6, BS4	1.2727	2175	1305	-	870	-	-	-	-
60	482	1709	TA8, SW2	2.3636	4039	3231	-	-	808	-	-	-
61	483	2209	WS9, TA1	0.7273	1607	161	-	-	1446	-	-	-
62	308	1709	TA9, WS1	0.5455	932	839	-	-	93	-	-	-
63	484	2209	WS6, BS2, TA2	2.3636	5221	1044	-	1044	3133	-	-	-
64	485	2209	WS7, BS3	1.0007	2211	-	-	663	1548	-	-	-
65	484	2209	WS6, BS2, TA2	0.8189	1809	362	-	362	1085	-	-	-
66	720	-	-	0.5455	-	-	-	-	-	-	-	-
67	308	1709	TA9, WS1	0.9018	1541	1387	-	-	154	-	-	-
68	309	2209	WS3, BF3, BS2, TA2	0.5455	1205	241	-	241	362	-	362	-
69	308	1709	TA9, WS1	0.6371	1089	980	-	-	109	-	-	-
70	308	1709	TA9, WS1,	3.0909	5282	4754	-	-	528	-	-	-
71	368	1709	TA9, WS1	0.9018	1541	1387	-	-	154	-	-	-
72	299	1709	WS4, BS3, TA3	2.4553	4196	1259	-	1259	1678	-	-	-
73	286	1709	TA10	3.8182	6525	6525	-	-	-	-	-	-
74	294	2209	WS8, BS1, TA1	0.7273	1607	161	-	161	1286	-	-	-
75	286	1709	TA10	0.3636	621	621	-	-	-	-	-	-
76	293	1709	TA8, WS2	0.5455	932	746	-	-	187	-	-	-
77	286	1709	TA10	2.4553	4196	4196	-	-	-	-	-	-
78	289	2209	WS6, BS3, TA1	1.0909	2410	241	-	723	1446	-	-	-
79	286	1709	TA10	3.8182	6525	6525	-	-	-	-	-	-
80	181	2209	WS6, TA3, BS1	1.2727	2811	844	-	281	1687	-	-	-
81	286	1709	TA10	3.1825	5439	5439	-	-	-	-	-	-
82	184	1771	BS10	1.5462	2738	-	-	2738	-	-	-	-
83	185	1709	TA7, WS3	1.0909	1864	1305	-	-	557	-	-	-

APPENDIX IX Continued

MAP #	STAND #	GMV WEIGHTED AVERAGE (cu ft /acre)	SPECIES MIX (percent)	AREA USED (acre)	TOTAL VOLUME LOST (cu ft)	VOLUME LOSS BY SPECIES (cubic feet)						
						TA	JP	BS	WS	TL	BF	WB
84	186	1771	WS6, JP2, BS1, TA1	3.2727	5796	580	1159	580	3478	-	-	-
85	206	1709	TA7, BS1, WS1, JP1	13.644	2332	1632	233	233	233	-	-	-
86	205	1771	BS7, JP2, TA1	0.6371	1128	113	226	790	-	-	-	-
87	206	1709	TA7, BS1, WS1, JP1	0.9018	1541	1079	154	154	154	-	-	-
88	700	-	-	1.6364	-	-	-	-	-	-	-	-
89	190	1709	TA10	1.2727	2175	2175	-	-	-	-	-	-
90	189	1771	BS9, TA1	1.0909	1932	193	-	1739	-	-	-	-
91	190	1709	TA10	0.7273	1243	1243	-	-	-	-	-	-
92	200	2209	WS6, BS2, JP1, TA1	3.6364	8033	804	804	1607	4820	-	-	-
93	199	1709	TA9, JP1	0.9018	1541	1387	154	-	-	-	-	-
94	840	-	-	0.4553	-	-	-	-	-	-	-	-
95	198	1709	TA10	0.7273	1243	1243	-	-	-	-	-	-
96	220	1771	BS6, JP3, TA1	4.6371	8212	821	2464	4927	-	-	-	-
97	9	1771	BS9, TA1	0.5455	966	97	-	869	-	-	-	-
98	220	1771	BS6, JP3, TA1	0.5455	966	97	291	582	-	-	-	-
99	4	1709	TA7, BS1, JP1, WS1	3.6364	6215	4351	622	622	622	-	-	-
100	575	1709	BS6, WS3, TA1	0.9018	1541	154	-	925	463	-	-	-
101	700	-	-	0.5455	-	-	-	-	-	-	-	-
102	1	1771	BS10	1.0909	1932	-	-	1932	-	-	-	-
103	1	1771	BS10	0.8189	1450	-	-	1450	-	-	-	-
104	700	-	-	0.5455	-	-	-	-	-	-	-	-
105	1	1771	BS10	1.3644	2416	-	-	2416	-	-	-	-
106	700	-	-	1.4545	-	-	-	-	-	-	-	-
TOTAL				183.3	302906	116978	68183	56489	56427	115	362	1080

Glossary[a]

Coding- With the advent of computer processing as a tool in forest inventory, it became necessary to develop a workable code for the various facts accumulated in field work and from photo interpretation. This code is applied to all pertaint data and maps used by Manitoba Forest Inventory. Since most data has been acquired from Forest Inventory and applied as they have defined and coded it, a brief explanation of the code will be necessary.

In a general manner the broad coding procedure may be represented by the following tree diagram:

- Total area
  - LAND 1-899
    - FORESTED 1-799
      - PRODUCTIVE 1-699
        - SOFTWOOD: 'S' 01-39
        - SOFTWOOD-HARDWOOD: 'M' 40-79
        - HARDWOOD-SOFTWOOD: 'N' 80-89
        - HARDWOOD: 'H' 90-99
      - NON-PRODUCTIVE 700-729
        - TREED MUSKEG 700
        - TREED ROCK 710
        - WILLOW/ALDER 720
        - PROTECTION FOREST 730
    - NON-FORESTED 800-899
      - BARREN-BARE ROCK 800
      - FIELDS (AGRICULTURE) 810
      - BRUSH AND SHRUB ON CLEARED PATENT LAND 815
      - MEADOW 820
      - MARCH-MUSKEG 830
      - UNCLASSIFIED 840
  - WATER 900

As the tree diagram shows, the coding can now be applied to each section as represented by the Subtype code for each cover type. With this explanation all coded data presented in this report may be identified either in this section.

Cover type - Four broad types are recognized - Softwood "S", Softwood-Hardwood "M", Hardwood-Softwood "N", Hardwood "H". Softwood "S"-includes all stands where at least 76% of the total basal area consists of coniferous species. Softwood-Hardwood Mixedwood-"M"-includes all stands where the basal area of all the coniferous species is between 51% and 75% of the total basal area. Hardwood-Softwood Mixedwood-"N"-includes all stands where the basal area of all coniferous species is between 26% and 50% of the total basal area.

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[a]Manitoba Dept. of Mines, Resources and Environmental Management (1972)

Hardwood-"H"-includes all stands where the basal area of all coniferous species is less than 25% of the total basal area.
The above cover types are determined by the percent of basal area of softwood in proportion to the total basal area found on all plots taken within a stand.

Crown closure- This is a stand density estimate made by a photointerpreter. Crown closure is the percentage of the ground within a stand covered by the crowns of trees located within the stand.
The following crown closure classes are recognized in Manitoba:

Forest regions 1, 2, 4 and 5 and the Whiteshell

Code

0 - applies to potential productive stands only
1 - 15 to 30% crown closure
2 - 31 to 50% crown closure
3 - 51 to 70% corwn closure
4 - 71 to 100% crown closure

Forest regions 3, 6, 7, 8 and 9 excluding the Whiteshell

Code

0 - 0 to 20% crown closure
2 - 21 to 50% crown closure
3 - 51 to 70% crown closure
4 - 71 to 100% crown closure

Cull factors- Percentage reduction factors by diameter group applied to Gross merchantable volume to obtain Net Merchantable Volume. The factors are based on expected and known losses due to decay, damage and shape by species and diameter group. The following factors apply to Forest Regions 3, 5, 6, 7, 8, and 9.

SPECIES	4 to 9" D.b.h.	10" and over D.b.h.
Jackpine	10%	15%
Black spruce	5%	10%
White spruce	5%	10%
Balsam fir	15%	25%
Tamarach larch	10%	10%
Hardwoods	20%	40%

Cutting class- This is a designation applied to forest stands based on size, vigor, state of development and maturity of a stand for harvesting purposes. Five cutting classes are recognized as follows:

Cutting class -0-Forest land not restocked following fire, cutting, windfall, or other major disturbances (hence, potentially productive land). Some reproduction or scattered residual trees (with net merchantable volume less than 2.5 cunits (100 cu ft) per acre may be present).

Cutting class -1-Stands which have been restocked or artificially. There may be scattered residual trees present as in cutting class 0. To be in cutting class 1, the average height of the stand must be less than 12 feet.

Cutting class -2-Advanced young growth of post size, with some merchantable volume. The average height of the stand must be over 12 feet in order to be in this cutting class.

Cutting class -3-Immature stands with merchantable volume growing at or near their maximum rate, which definitely should not be cut. The average height of the stand should be over 25 feet and the diameter should be over 3.6 inches D.b.h.

Cutting class -4-Mature stands which may be cut as they have reached rotation age ($\pm$ 10 years or 20 years on site 2 black spruce, tamarach larch and eastern cedar).

Cutting class -5-Overmature stands which should be given priority in cutting due to susceptability to decay, natural damage and insect attack.

Diameter breast-height (D.b.h.) The diameter of a tree measured at breast height (4.5 fee above ground level). Measurement at this point gives a diameter free from butt swell and is a convenient standard point for measurement. Volume estimates are based on D.b.h.

Forest management-unit — The Forest Management Unit is the basic unit of area considered for Forest Inventory purposes. Forest Management Units have been established on a variety of situations including: status and ownership, administrative units, accessibility, acceptable size and or forest cover variations.

Forest zone — The Forest Zone is the area which is producing or capable of producing forest crops and which for climatic reasons, is in the main, more suitable for the production of forests than for agricultural crops. The definition of the Forest Zone boundary is essentially the same as the definition of the Wooded District Boundary as presented in "The Fires Prevention Act" of the Province of Manitoba (R.S.M. 1954, Chapter 86).

Gross merchantable-volume — This is the volume of all species with diameters 3.6" D.b.h. and larger and is found to a specified top diameter and a stump height of one foot. For spruce and pine, top diameter is 3", for all other species, it is four inches. Volume only in Cutting Classes 3, 4, and 5 is considered.

Increment — Annual or periodic increase in volume of a tree of a stand.

Mean annual-increment — The total volume increment up to a given age divided by the age.

Merchantable volume — The volume of the portion of a tree without bark, excluding the stump (12 inches high) and the top with the bottom diameter 3 inches inside bark. Merchantable volume of a stand is the sum of the merchantable volume of all trees found in a stand.

Net merchantable-volume — The gross merchantable volume of all species with diameters 3.6" D.b.h. and larger less the respective cull factors.

Non-forested land- Includes areas a) withdrawn from timber production for a long period of time, such as cultivated fields, hay meadows, pastures, settlements, rights-of-way, gravel pits, beaches, wide ditches, summer resorts, and b) not capable of producing merchantable timber such as rock, barren, mines, marsh and muskeg.

Non-productive-forested land Includes all forest land not capable of producing merchantable wood within rotation age regardless of its existing stage of productivity.

Rotation age- Is the period of years that elapses between the formation of a stand of timber and the time when it is ready for cutting and regeneration.

		ROTATION AGES (YEARS)									
Species	Site	MANAGEMENT UNITS									
		14	20-29	30-32	33-39	40-41	43-47	48-57	60-69	71-75	81-99
JP/SP	all sites	75	60	80	80	60	60	75	80	80	80
RP/WP	all sites		80								
BS	site 1	80	80	80	80	80	80	80	80	100	80
	site 2	140	140	140	140	140	140	140	140	140	140
	site 3	140	140	140	140	140	80	140	140	140	140
WS	all sites	120	80	100	100	80	80	100	100	100	100
BF	all sites	80	60	70	70	80	80	80	80		80
TL	site 1	90	90	90	90	90	90	90			
	site 2	140	140	140	140	140	140	140			
EC	site 1		80			80					
	site 2		140			140					
Hdwd.	all sites	60	60	60	70	60	60	60	80	80	80

Site- Habitat, or site is defined by Nichols (1917) "as any unit area in which the combined influence of the various external factors which determine the ecological aspect of the vegetation is such as to produce an essentially uniform environment". Three classes of sites are used in Forest Inventory. They depend on a variety of factors such as soil, slope, elevation, photoperiod, air temperature, and moisture.

Sub type- This term indicates the species composition in broad groups within the cover-type. Subtype is determined by the proportion of basal area of two or three main species in the stand as found on a sample plot to the total basal area of all species. To determine the subtype, the basal area of individual species must be computed and rounded off to the nearest one percent.

Type aggregate- This term is used in reference to all stands or potentially productive areas in a Management Unit or Forest Section which have common characteristics as to cover type, subtype, site, cutting class, and crown closure.

Abbreviations

Common name	Botantical name	Abbreviation
Ash	Fraxinus nigra	AS
Balsam fir	Abies balsamea	BF
Balsam poplar	Populus balsamifera	BA
Black spruce	Picea mariana	BS
Bur oak	Quercus macrocarpa	BO
Cedar	Thuja occidentalis	EC
Jackpine	Pinus banksiana	JP
Manitoba maple	Acer negundo	MM
Red pine	Pinus resinosa	RP
Scots pine	Pinus sylvestris	SP
Tamarach	Larix laricina	TL
Trembling aspen	Populus tremuloides	TA
White birch	Betula papyrifera	WB
White elm	Ulmus americana	E
White pine	Pinus strobus	WP
White spruce	Picea glauca	WS