AN ECONOMIC EVALUATION OF WINTER WHEAT

by

BRENT LLOYD DORNIAN

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ABSTRACT

During the 1970's a winter wheat variety was released which is better suited to Manitoba's climate. Winter wheat production requires specialized tillage and crop residue management techniques commonly refered to as minimum tillage as well as special fertilizer and chemical considerations which may differ from spring seeded crops.

The purpose of this study is to develop a framework capable of assessing cropping alternatives in terms of expected income and associated income variability. This framework was applied to evaluate minimum and conventional tillage of spring and winter wheat. A Monte-Carlo simulation process utilized an agronomic framework and an economic framework to evaluate the key components affecting the level and variation of income.

The agronomic framework draws upon agroclimatic models to establish the variables influencing yields. Variations in yields are explained by moisture stress, as influenced by temperature and precipitation, fertility and varietal variables. The statistical analysis provides for the simulation of annual wheat yields by utilizing historical daily weather events at different locations.

The economic framework involves simulating a farm business through a period of 10 years and evaluating the probability density functions for gross margin of simulated wheat production and net worth. Winter wheat and spring wheat cropping alternatives are compared for three different locations on the basis of simulated probability density functions for gross margin and net worth.

The simulations indicate that winter wheat production demonstrates a greater probability of attaining certain levels of yield than spring wheat. However, little difference in yields is probable between conventional tillage practices and minimum tillage practices. Minimum tillage presents an increase in operating expenses from conventional tillage yet winter wheat production presents reduced operating expenses from spring wheat production.

Spring wheat production under minimum tillage has the probability of contributing less revenue than conventional tillage. The simulation indicates that winter wheat production has the probability of contributing more revenue than spring wheat production and this result is linked primarily to the yield probability density function of each crop.

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I would like to dedicate this thesis to my parents and family for their unselfish support and encouragement throughout my years at University and would like to express my deepest gratitude to Cheryl for her patience and understanding.

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Chapter I

INTRODUCTION

According to Ruttan and Hayami (1971), new technology is induced by shifts in input prices or by changes in resource endowments and income distributions. In the case of winter wheat and minimum tillage, the impetus for considering this crop in Manitoba resulted from higher energy and land prices. Initial returns to the adoption of new technology are in the form of cost savings to the innovators. Future returns occur as cost savings to the industry and finally as price reductions to the consumer (Binswanger, et al., 1978).

The adoption of new technology is demonstrated in Manitoba's historical production of non-traditional crops. Acreages of crops other than spring wheat, oats and barley rose from 11 percent of total field crops in 1936 to 20 percent in 1956 before leveling at 30 percent during the 1960'S and 1970's. With the introduction of new crops, such as canola, and better management practices of other field crops, Manitoba's production of non-traditional crops reached an all time high of 33 percent in 1981.[1] To date, research in new crops, varieties and management techniques offers a greater diversification in production than has ever been available before.

Legget (1976) investigates this diversification and notes that;

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[1] Manitoba Agriculture, MDA Yearbook, (various issues).

> Producers tend to shift production resources from one commodity to another in response to market price and production costs.[2]

An objective of many farms is to obtain the highest revenue at the lowest cost. Given that commodity prices are determined independant of what the the farm prodeuces farmer's concentrate their choices on which commodity to produce and the method of production.

1.1 OBJECTIVES OF THE STUDY

One of the latest developments in agronomy has been the introduction of a winter wheat variety better suited to Manitoba's climate. Winter wheat production requires specialized tillage and crop residue management techniques, commonly refered to as minimum tillage, as well as fertilizer and chemical considerations which may differ from spring seeded crops.

The farmer must ask himself whether winter wheat is an economically viable alternative to the traditional spring wheat crop and how its attributes affect the year to year income variation. Given this problem of choice, the need of an economic framework arises whereby alternatives in crop production can be assessed.

The object of this study, therefore, is twofold:

1. To develop an efficient framework capable of assessing the economic viability of cropping alternatives in terms of expected income and income variability.

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[2] H.W. Legget, "Causes, Costs and Cases of Instability in Canadian Agriculture", <u>CJAE</u> March, 1976, pp. 30-52.

2. To apply this framework in evaluating minimum and conventional tillage of spring wheat relative to winter wheat production.

1.2 WINTER WHEAT

Winter wheat grown on the Prairies is labelled by the Canadian Wheat Board (CWB) as Canada Western Red Winter Wheat (CWRWW). It is a hard wheat variety which results in higher protein and better milling qualities than soft wheat varieties. Although hard winter wheat has slightly lower protein levels than hard spring wheat, it produces a highly desirable bread flour (Poor, 1987).

Winter Wheat production on the Prairies is predominantly in southwestern Alberta and, to a lesser extent southwestern Saskatchewan (Grant, et al. 1970). In these areas crop diseases are not a major problem and chinook winds moderate the harsh western winters (Stobbe and Evans, 1979). It was under this environment that M. N. Grant developed the latest and hardiest winter wheat cultivar (Poor, 1987).

Past attempts of winter wheat production in Manitoba proved less than satisfactory under traditional cropping practices due to its lack of winter hardiness and disease resistance to stem and leaf rusts.

Increased snow cover can keep winter kill to a minimum as snow insulates soil temperature from air temperature. This cover can be maintained through stubble management practices such as minimum and zero tillage (Stobbe and Rourke, 1981). Although current varieties are still susceptible to plant diseases, rust problems are now addressed with the use of Diathane M45, a new anti-rust fungicide (Vininsky, 1986). With these practices and the use of the hardier Norstar variety, the Manitoba Crop Insurance Corporation has begun insuring winter wheat through out southern Manitoba in the 1986-87 crop year (Poor, 1987).

There are a number of advantages associated with winter wheat. Yields of 15 to 20 percent over spring wheat have been demonstrated under similar growing conditions (Stobbe and Rourke, 1981). Vigorous growth in the early spring allows for better competition with weeds such as wild oat and green foxtail (Lyster, 1984). The extent of this competition is such that the need for chemical control of annual weeds occurs for the most part, on winter kill patches only (Stobbe and Evans, 1979).

Winter wheat grows for a period of about 145 days as compared with 90 to 100 days for spring wheat. The extended growing season allows for more extensive root development and vegetative growth. This, in turn, allows for better use of available moisture and nutrients in both the fall and early spring (Rourke and Stobbe, n.d.).

Early maturity dates make use of the dry summer for ripening while avoiding fall frost. Harvesting in the early fall reduces the risk of the crop weathering and sprouting in the swath. These conditions produce a better quality of grain (Stobbe and Evans, 1979).

There are also a variety of disadvantages associated with winter wheat. Its early spring growth leaves winter wheat more susceptible to late spring frost (Fowler, 1983). Even though competition with annual weeds is improved perennial weeds flourish in the reduced tillage conditions required for winter wheat production. Although hardier than its predecessors, Norstar is still susceptible to stem and leaf rusts. This can deflate any yield advantage otherwise associated with winter wheat (Stobbe and Evans, 1979). The variety, developed for Alberta's semiarid regions, also shows problems in lodging under Manitoba's subhumid climate (Stobbe and Evans, 1979).

Given the advantages and disadvantages of winter wheat production, the University of Manitoba's Plant Science Department has derived a set of recommended practices (Stobbe and Rourke, 1981). These are outlined as follows:

1. Tillage: The crop should be grown under conditions of minimum or zero tillage whereby snow trapping allows for adequate winter insulation.
2. Seeding: The seed should be placed shallow into moist soil at one to one and a half bushels per acre before September 15. Special zero till drills, hoe drills or air seeders, able to penetrate trash cover with a minimum of soil disturbance, are preferred.
3. Crop rotation and trash management: The previous crop should be early maturing to allow early fall seeding. The stubble should be cut high and the chaff spread evenly.
4. Variety: Norstar is the only recommended variety for Manitoba. Even though this variety is weak in all areas it has better yield, hardiness and disease, shattering and lodging resistance than other varieties.
5. Fertilizer: Adequate phosphorus and potassium are required for winter survival and maximum yield. The phosphorus should be

placed with the seed along with a small amount of nitrogen. Additional nitrogen should be applied in the spring.

6. Weed control: Fields relatively free of perennial weeds should be used for winter wheat. Annual weeds or volunteer crops, if present, can be controlled with low rates of herbicide in the fall or spot treatment on winter kill patches in the spring.

Tables 1.1 and 1.2 show Manitoba's winter wheat production has steadily increased with very little difference in yields when compared to spring wheat. In the 1984-85 crop year, MDA estimates close to 90 percent of the harvested acreage occurred in the southwest region of the province where conditions resemble those of southwestern Alberta and Saskatchewan (Poor, 1987).

Of the world's total wheat production, 75 percent is winter wheat. Canadian winter wheat enters this market on a small scale through the Canadian Wheat Board (CWB). Under the quota delivery system, varying grades and prices are placed on the crop based on quality and protien levels. Tables 1.3 and 1.4 compare the Board's delivery quotas and payments respectively, for grade number 1 CWRWW and CWRSW. Farmers have generally been able to market all of their production although prices have been 5 to 10 percent below spring wheat. With Canadian output of winter wheat expanding, the CWB has made efforts to expand its markets (Fowler, 1983).

Table I.1

Winter Wheat Production in Manitoba

Year	Production (tonnes)	Percent of Total Manitoba Wheat Production
1981-82	8,000	0.3
1982-83	9,000	0.3
1983-84	16,000	0.5
1984-85	28,000	0.8
1985-86	138,000	2.8

Source: Manitoba Department of Agriculture

Table I.2

Winter Wheat and Spring Yields in Manitoba

Year	Average Winter Wheat Yield (bu/acre)	Average Spring Wheat Yield (bu/acre)	
		Province	SW Region
1982-83	31.5	34.0	33.4
1983-84	26.5	27.3	27.3
1984-85	29.8	30.5	24.6

Source: Manitoba Department of Agriculture

Table I.3

CWB Delivery Quotas for CWRWW and CWRSW

Year	CWRWW (bu/acre)	CWRSW (bu/acre)
1977-78	15.4	25.6
1978-79	10.0	8.1
1979-80	open	20.0
1980-81	49.6	75.0
1981-82	53.5	52.2
1982-83	37.3	45.0
1983-84	21.6	open
1984-85	open	open
1985-86	34.3	124.8

Source: Canadian Wheat Board Annual Reports

Table I.4

Initial and Total Payments for No. 1 CWRWW and No. 1 CWRSW

Year	CWRWW ($/metric tonne) initial	CWRWW ($/metric tonne) total	CWRSW ($/metric tonne) intial	CWRSW ($/metric tonne) total
1977/78	104.35	107.17	110.23	120.30
1978-79	120.37	150.11	128.60	160.53
1979-80	145.56	179.18	156.16	196.43
1980-81	185.71	187.76	174.50	199.62
1982-83	185.71	180.39	174.50	192.34
1983-84	159.21	178.56	170.00	193.98
1984-85	159.21	171.51	170.00	186.37
1985-86	145.21	145.21	160.00	160.00
1986-87*	109.21		130.00	
1987-88*	89.21		110.00	

* includes initial payment only.

Source: Canadian Wheat Board Annual Reports

1.3 PROCEDURE OF THE STUDY

To obtain the objectives outlined, a Monte-Carlo simulation process incorporated an agronomic framework and an economic framework. The agronomic framework must accurately reflect annual wheat yields in relation to the agronomic system and weather conditions. Given the resulting yields, the economic framework must accurately reflect costs and returns.

The agronomic and economic systems are parts of an overall crop production system established by previous scientific investigation. The crop production system dictates the major biophysical and socioeconomic components of crop production and their interrelationship in the determination of yields and returns. The agronomic and economic frameworks used to represent the system are derived from a number of mathematical models developed in previous research. A brief outline of each framework is presented below to be followed by a summary of the study's experimental design.

Within the agronomic framework, an agroclimatic model simulates daily progression towards the stages of crop development. This is based on minimum and maximum temperatures and day length under Robertson's (1968) Biometeorlogical Time Scale (BMTS). The model then adopts Baier, et al's, (1979) Versatile Soil Moisture Budget (VSMB) to calculate available soil moisture. When this is compared to the moisture required by the crop, shortfalls in soil moisture are determined for each of the simulated crop stages. These shortfalls are used as an indicator of moisture stress.

The agronomic framework draws upon a statistical analysis to establish variables influencing yields. Variations in yields are explained by moisture stress, fertility and varietal variables. Variable parameters are .estimated using the ordinary least squares technique under a translog function of the independant variables. By holding the level of fertility and the variety of the wheat grown constant, annual wheat yields can be simulated by utilizing historical daily weather events on different locations. Given the historical daily weather, different levels of moisture stress occur for each year. Wheat yields unique to these conditions are estimated on the basis of annual simulated wheat yields. A probability density function is derived for each location which defines the likelihood that a given yield can be obtained. These probability density functions are then incorporated in the economic framework through the use of a Monte Carlo simulation.

The economic methodology involves simulating a farm business through a period of 10 years and evaluating the probability density function for gross margin of wheat production and net worth. Besides the variation in wheat yields developed in the agronomic analysis, the economic framework also has a probability density function for the price of wheat, delivery quotas and interest rates. cropping alternatives are compared for different locations on the basis of the simulated probability density functions for gross margin and net worth.

1.4 ORGANIZATION OF THE STUDY

The remainder of the study is organized into four chapters. Chapter II, the Literature Review, outlines the strengths of simulation as a method and discusses a number of successful applications of simulation that are relevant to the objectives of this study.

Chapter III, the System and Models chapter, presents the real world crop production system that the study attempts to simulate. The components and interrelations of the agronomic and economic systems are discussed followed by a presentation of the various computer models used to describe these systems.

Chapter IV, the Data Input and Results chapter, outlines the set of management assumptions and the data required by the models to simulate each scenario. The subsequent results are presented with an interpretation of their meaning and significance.

Chapter V, Conclusions and Recommendations, provides an overall assessment of the results with respect to the objectives of the study. It also outlines some of the limitations of the study and presents some recommendations for crop production and further research.

Chapter II

LITERATURE REVIEW OF SIMULATION METHODOLOGY

A system is defined as a collection of interrelated components or elements with a purpose. According to Martin (1977, p16) the synthetic representation of a system is the model. One method of experimenting with models or systems is that of simulation. The main use of simulations is to find out the consequences of different proposals over time (Dalton, 1982). More specifically Martin (1977, p183) defines a simulation as

> the method by which experimental information about systems, or models of systems is generated. It is used in formulating, evaluating and applying models of systems.

If the model depicts the relationships within the system as identities, the simulation is deterministic. When a high level of variablity is associated with specific variables of the system, the simulation becomes stochastic.

With respect to agriculture, Anderson (1978, p.4) notes

> with agriculture being characterized as it is by its biological and meteorological dependence ... simulation models presently and prospectively are the most feasible, most workable and probably most potentially useful types of models in this category.

The primary objective of stochastic simulation is to realistically reproduce the variability of the random variables in the system being studied (Lee, et al., 1986, p. 464).

When evaluating the results of a stochastic simulation one may compare the means and variances of decision variables as in means-variance analysis or compare the dominant decision function over another as in stochastic dominance analysis.

Mean-variance analysis is based on two possible assumptions. The first is that the decision makers utility function has a positive first derivative and a negative second derivative. The second is that the values or functions of uncertain variables is normally distributed. If both of these two assumptions hold, choosing between uncertain events based on the mean-variance analysis is consistant with the utility maximization model. If uncertain variables are not normally distributed or the utility functions are not twice differentiable, then a system of preference ordering or stochastic dominance becomes an alternative decision criteria (Porter and Gaumnitz, 1972, p. 438).

Interestingly enough, however, Porter and Gaumnitz (1972, p. 445) conclude that:

> except for the highly risk averse investor the choice between the more familiar means-variance model and the theoretically superior stochastic dominance model for selecting efficient portfolios is not critical.[3]

Zusman and Araid (1965) provide an early example of the strength of simulation as a tool for farm planning under conditions of weather uncertainty. Within the simulation model a series of state variables were related to state variables and farm decision variables in the previous period as well as weather variables and exogenous economic vari-

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[3] R.B. Porter and J.F. Gaumnitz, "Stochastic Dominance VS Mean Variance Portfolio Analysis: An Empirical Evaluation," American Economics Review, Vol. 62, 1972, p. 445.

ables. Decisions were then made based on preference relations or ranking of the values of the decision variables among different experiments of the model. The study demonstrated that:

> simulation techniques are a powerful tool in solving managerial problems arising under conditions of great weather variability and uncertainty. They provide a trial and error method to overcome the complexity of the situation, while the probabilistic structure of the problems is approached through sampling experiments.[4]

More recently, Zenter, et al. (1978) demonstrated the many uses of a simulation model apart from individual farm decisions. The farm firm system illustrated in Figure II.1 was modelled with a dry land cropping simulator under three basic components. These components were referred to as the systems model, the base-data block and the control-data block. The systems model portrayed the relationships within the biological and economic processes involved in production. The base-data block held the technical data, transformation coefficients and production alternatives for average farms in the region. The control-data block specified the information specific to an individual experiment.

Having read all input data, the model ran through a production planning stage, a resource allocation stage and a budgeting stage. Evaluation of the experiments was then made on the basis of the highest value of an objective function identified as terminal net worth.

The study highlighted the ability of simulation to be used in research, extension and policy and concluded;

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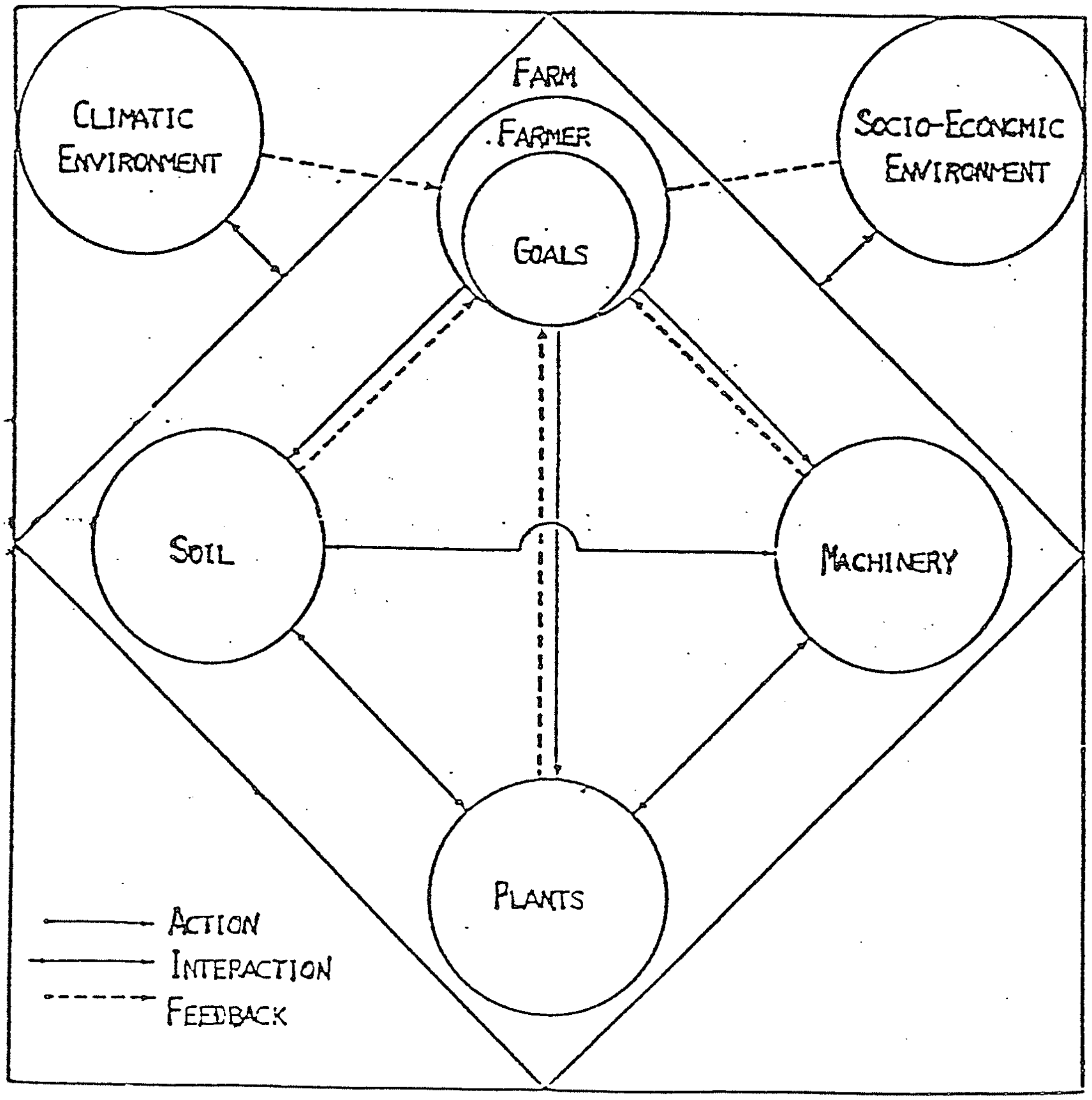
[4] P. Zusman and B.H. Amiad, "Simulation: A Tool for Farm Planning Under Conditions of Weather Uncertainty," Journal of Farm Economics, Vol. 47, No. 3, August (1965), pp. 574-594.

FIGURE II.1

Zentner's (1978) Schematic Representation of a Farm Cropping System



> In research, the system's model can assist in the economic evaluation of results from biological and engineering experiments. In extension, the system's model can be used to assist in establishing farm recomendations. In policy the system's model can be used to assist in identifying and quantifying farm level effects of alternative agricultural policies.[5]

2.1 RELEVANT APPLICATIONS OF SIMULATION

2.1.1 Evaluation of Soil Conservation Policies by Systems Analysis

Dumsday (1971) modelled soil conservation with a complex system of biophysical interactions and an external set of socioeconomic controls. The simulation model, illustrasted in Figure II.2, consisted of two sections, namely the biophysical aspects of the system and the economic aspects of the system.

The biophysical section was divided into three phases: the soil characteristics phase, the crop output phase and the soil loss phase. Input data concerning topographical factors, mechanical control practices, soil-plant relationships, plant-atmosphere relationships, physiological crop stages, soil loss ratios and yield weights for each crop stage make up the deterministic soil characteristics phase. Input data for the crop output phase was simply daily weather drawn from an historical sequence or generated from historical distributions. The soil loss phase then accumulated soil losses for each production period.

The economic section was initiated by fertilizer input and crop output prices as well as mechanical control costs and crop production costs. For each period the model produced discounted net revenues per acre, or total crop revenue less variable production and mechanical con-

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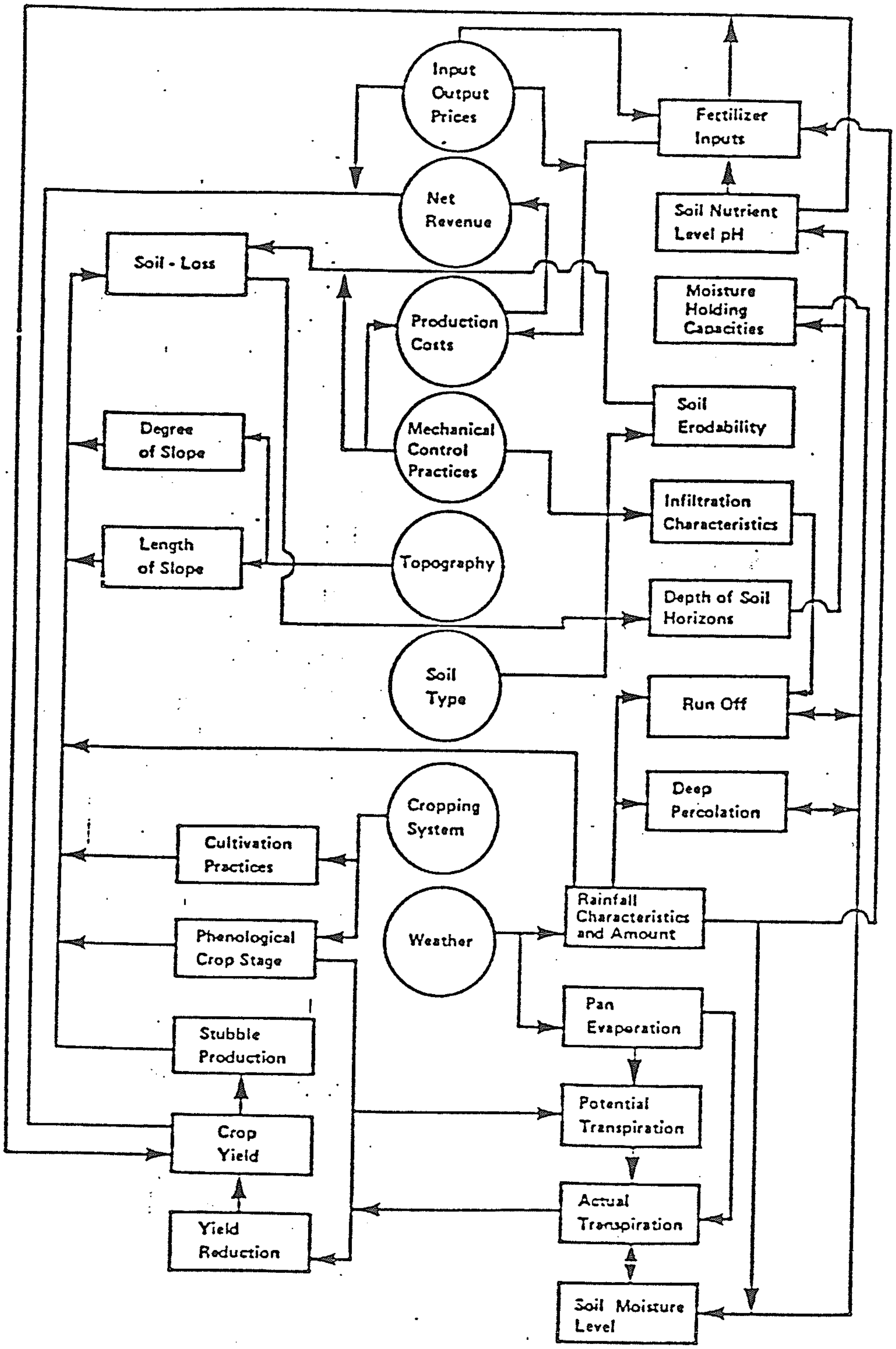
[5] Zentner and Sonntag, "Simulation Model for Dryland Crop Production in the Canadian Prairies," Agriculture Systems (3) 1978, p. 251.

FIGURE II.2

Dumsday's (1971) Interrelationships in the Soil Conservation System



trol costs, as the decision variable for a range of four discount rates.

2.1.2 The Simulation of Crop-Irrigation Systems

The system studied by Flinn (1971) was a crop-soil relationship influenced by climate, management and genotype with respect to irrigation. The system consisted of three major components.[6]

1. those factors determining the level of atmospheric demand for moisture;
2. those concerned with the availability of moisture for the crop; and
3. the interaction between the supply of, and demand for, water on economic yield.

The factor determining the level of atmospheric demand for moisture was potential transpiration, (Et). The relation of Et to free evaporation, (Eo), was dependent on climate, physiological stage of development and management via some function, (f). Within the system f had been empirically designated by previous scientific investigation.

Those factors within the system concerned with the availability of moisture for the crop were also previously empirically determined. They consisted of factors relating to soil moisture, soil type, soil tension, root development and crop extraction of water as influenced by climate, management and genotype.

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[6] J.C. Flinn, "The Simulation of Crop-Irrigation Systems" in Systems Analysis in Agricultural Management J.R. Anderson and J. Dent, editors, Wiley and Sons, Sydney, (1971) p. 127.

The relation between demand factors and supply factors was defined by the actual rate of moisture loss by the crop or actual transpiration, (Ea). This function, (P), was also empirically derived. Given the criteria of this relation, the degree of moisture stress on each physiological stage of development was defined. The economic yield was then determined via the sytems relation between moisture stress of crop stages and crop yield.

Under a set of assumptions, the system's simulation model set out to derive:[7]

1. a method of estimating Ea,
2. a method of estimating soil moisture levels in the root zone, and
3. a means of relating crop growth in each stage to the incidence and severity of moisture stress in that stage,

using the functions f, P and those functions concerned with the availability of moisture for the crop.

The operational processes of the model occurred as follows:

1. Actual rainfall, temperature and evaporation data were entered on a daily basis at the start of each period.
2. Daily temperature data from the starting day, forward, was summed to derive the number of days necessary for the physiological development of the crop (hence the f values over time).
3. The model operated in this crop growth mode, allowing for root extension until maximum root depth was reached. Daily values of soil moisture, Et and Ea were determined.

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[7] Ibid, p. 140.

4. By weighting the ratio of actual to potential growth in each stage of crop development, the economic yield of the crop was obtained as a function of irrigation inputs and weather variables.

The experiment consisted of running the model for a number of years of weather data and for different irrigation decisions. A frequency distribution of yields was derived under various irrigation strategies to be used for economic analysis.

Flinn (1971) concludes that if one is to attempt to predict crop response to changing weather patterns, irrigation development or management, the climate, soil type, and genotype suitable for the region of study may be such that anology of anticipated crop yield from distant emperical evidence is unsatisfactory. As such, he offers the notion that under such circumstances the possibility of developing a realistic simulation model of crop response in the new environment holds promise.

Chapter III

THE SYSTEM AND MODELS

3.1 THE CROP PRODUCTION SYSTEM

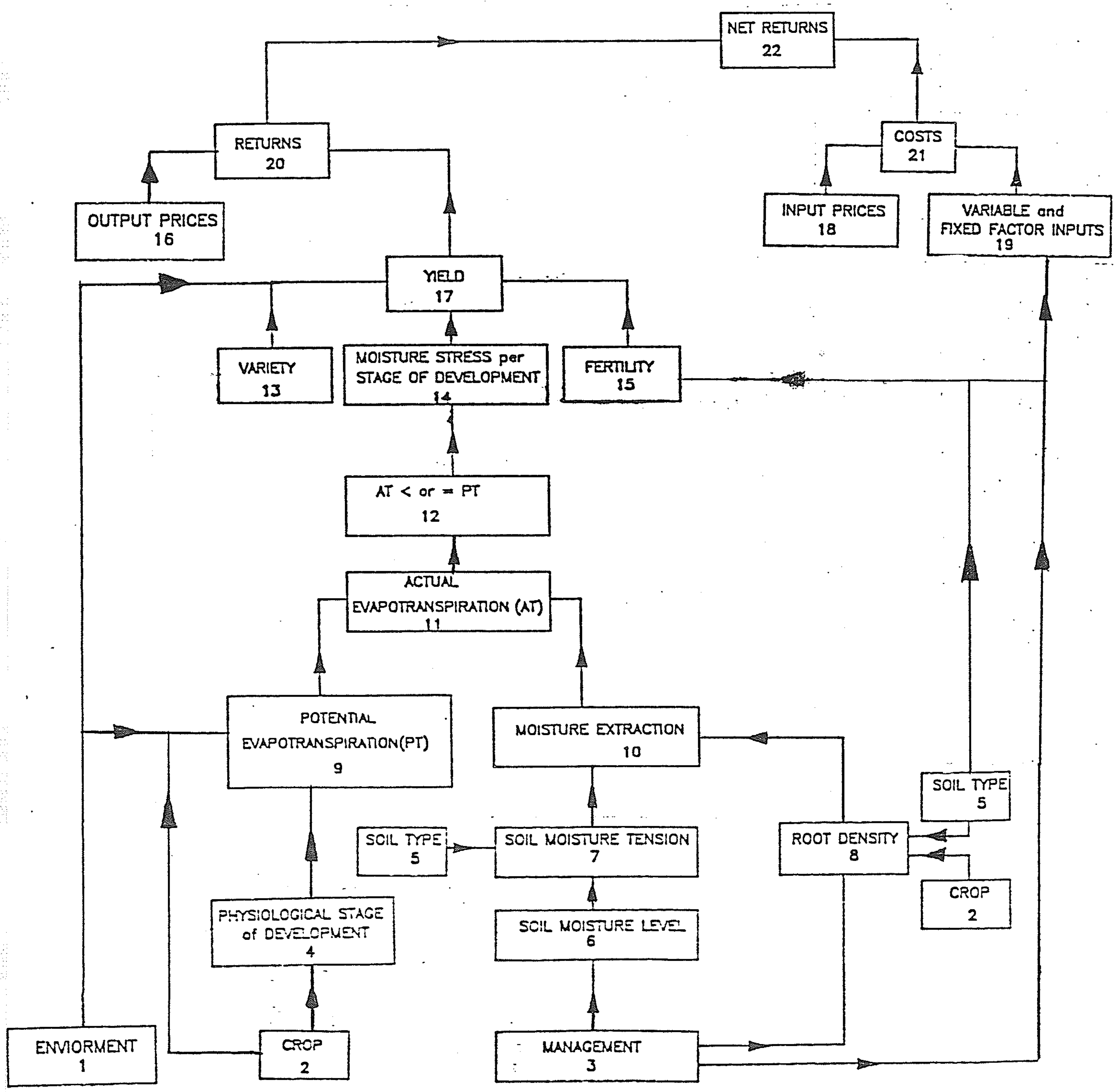
Extremely complex relationships are encountered in any system involving the interactions within biological/economic production. Due to the immense number and complexity of these interrelationships the system must be reduced to a workable number of parts, each representing a key group of biophyisical and socioeconomic parameters. Figure III.1 portrays some major components of the highly simplified system analyzed in this study.

3.1.1 The Agronomic System

The agronomic model takes a set of deterministic variables from the environment, crop and management aspects to establish crop yield. This is achieved by a series of relationships representing the biophysical growth processes involved in crop production. Because of the complexity of these relationships Flinn (1971, p.221) noted that an economic study should not attempt to interpret the established biophysical growth process but concentrate on the known relations of input to output. As such, when entering discussions of this nature, this study will simply refer to the appropriate scientific literature with a brief explanation of the system's components labelled in brackets.

FIGURE III.1

Agronomic and Economic Crop Production System



The agronomic section reflects the interpretation of Flinn (1971) of findings of research scientists. Figure III.1 illustrates that the water identity, which directly influenced plant growth was the magnitude of moisture stress (14, fig.III.1) as opposed to a direct measure of precipitation (1, fig.III.1). With this observation in mind, scientists suggested that yield be related to moisture tension and therefore, only indirectly related to water quantity, when formulating crop production functions or systems.

Other scientists went on to deduce that the moisture stress on the plant was the direct consequence of the transpiration process (11, fig.III.1). Scientists later defined a stress condition as the case when the water content (11, fig.III.1) falls below its fully turgid values (9, fig.III.1) under its present stage of development (4, fig.III.1). The case arises as a result of differences (12, fig.III.1) in the moisture uptake by the roots (10, fig.III.1) and the rate of moisture loss to the atmosphere from the crop cover (11, fig.III.1).

The supply of water to the crop therefore depends not only on soil water (4,7, fig.III.1) but, as pointed out by further research, on the density and depth of root penetration (8, fig.III.1) as well. The pattern of moisture extraction (10, fig.III.1) follows the pattern of root penetration (8, fig.III.1) which typically diminishes with depth. Moisture held by the soil and considered available to the plant becomes more significant in the region of root development (4,7, fig.III.1). Field capacity and permanent wilting point represent the maximum and minimum values of moisture availability and are determined by the type of soil (5, fig.III.1).

When a plant is under stress, that is when AT < PT (12, fig.III.1), the growth processes slow down and become identifiable when observing the physiological stage of development (14, fig.III.1). Hence, the yield (17,fig.III.1) falls short of its potential had the crop not experienced stress, that is when AT = PT (12, fig.III.1).

Environmental, management and crop factors can also apply themselves to yield variations outside of the moisture stress pathway. Wind, hail and dust storms (1, fig.III.1) for example, have their own environmental impacts on yield (17, fig.III.1). Crop factors reflecting quality as well as quantity influences on yield vary among varieties (13, fig.III.1). Management practices (3, fig.III.1) which influence the fertility levels (15, fig.III.1) of the different soil types (5, fig.III.1) add to the determination of yields (17, fig.III.1). More direct pathways of management (3, fig.III.1) to yields (17, fig.III.1) are identified as in the case of weed or disease control.

In summary, the agronomic system depicts the input/output relation between the crop, environment and management practices to yield. This relationship is based on the biophysical pathways of major components as defined by previous scientific investigation.

3.1.2 The Economic System

The economic system also depicts an input/output relation. As with the agronomic system, the interrelationships among major components can be very complex. Within an economic system these interrelationships are determined by theoretical economic identities and are generally specified as functions (Gould and Ferguson, 1980). This section will outline the functions involved following a description of the connection between the two systems.

All pathways of the agronomy system lend themselves to the determination of crop yield (17, fig.III.1). This component becomes the link to the pathways of the economic system. However, the common denominator which makes the two systems compatable is management (3, fig.III.1). Management (3, fig.III.1), through the biophysical pathways, is an input to yield (17, fig.III.1). Management (3, fig.III.1), through the socioeconomic pathways is also an input to yield (17, fig.III.1). This integration between the two systems allows for meaningful interpretation of the final decision variables derived from all pathways of the system.

The relation of management (3, fig.III.1) as an input, to yield (17, fig.III.1) as an output, is incorporated into an economic production function. A production function shows the output attainable from any specified set of factor inputs (21, fig.III.1) and is assumed to exist for every product.

The quantity (19, fig.III.1) and price (18, fig.3) of these factors of production dictates the economic cost (21, fig.III.1) for that unit of output (17, fig.III.1) according to the technology of production. A revenue function specifies the relation of output (17, fig.III.1) and economic return (20, fig.III.1) using price (16, fig.III.1) as an exogenous parameter. Net return (22, fig.III.1) then becomes the solution of a profit function with economic return (20, fig.III.1) and economic cost (21, fig.3) as its determinants (Gould and Ferguson, 1975).

In summary, the economic system relates the cost of inputs, as given by management, to the value of the output as given by the agronomy system, for the determination of some decision variable, namely income and net worth.

3.2 THE MODELS AND DATA REQUIREMENTS

The models used to simulate the crop production sytem occur as two major frameworks: the agronomic framework and the economic framework. Following the attributes of the system, the agronomic framework attempts to simulate yields while the economic framework attempts to simulate returns. The following sections discuss the structure of these frameworks. The agronomic framework is presented first with attention given to the specification of the models and their integration in simulating yield. A discussion of the models representing the economic system follows evaluating the specifications involved in simulating returns.

3.3 THE AGRONOMY FRAMEWORK

As presented, in the crop production system, yields are influenced by:

1. soil moisture;
2. fertility;
3. crop variety;
4. management; and
5. other environmental impacts.

The yield model attempts to qualify some of these influences using the techniques of regression. The factors considered to account for site to site variations in yields include soil moisture stress, fertilizer usage and technological advances attributed to genetic developments. Other factors such as management practices and extreme weather impacts are more difficult to quantify on a site to site basis of yield variation. These considerations will be assessed at a more appropriate point in the discussion.

The general form of the yield model is given in the equation:

$$Y_{ijkl} = f\,(M_{ijlt}\ ,\ F_{ijl},\ V_{ijkl}\ ) \tag{1}$$

where:

Y_{ijkl} = yield on the ith site in year, j, for crop, k, under tillage, l.

M_{ijklt} = soil moisture stress on the ith site in year, j, for crop, k, under tillage, l, for t crop development stages.

F_{ijkl} = Fertilizer application on the ith site in year, j, for crop, k, under tillage, l.

V_{ijkl} = Varietal improvement index on the ith site in year, j, fro crop, k, under tillage,l.

Crop yields can vary among sites not only because of differences in the three identified factors, but also because of intrinsic differences implicit to varying soil types and textures. If equal moisture stress, fertilizer applications and crop varieties occur in different locations, there is no reason to expect the same yields because of the influence of soil structure, pest control and management.

In spite of the many different types and textures of soil, similar characteristics are found in classifying the soil as either coarse, medium or fine textured. That is, similar drainage, moisture holding capacities and natural fertility characteristics are present in different types of coarse or sandy soil. The same is said for medium or loam soils and fine or clay soils. Based on this reasoning soil differences between fields are represented within the model with a dummy variable. The form of the model now becomes

$$Y_{ijkl} = f\,(M_{ijlt},\ F_{ijl},\ V_{ijk},\ S_i\ ) \qquad (2)$$

where:

S_i = a dummy variable representing the factors affecting yield which are attributed to the type of soil on site, i, where Si=1 for light textured soils, 2 for loam soils and 3 for heavy textured soils.

Management is a nonexclusive factor because many different determinants are grouped under the term, management. For instance, as portrayed in the crop production system, management influences on soil moisture stress via the choice, of tillage practice, and fertility via the choice of amount of fertilizer and method of incorporation. However, management practices reflecting disease, pest and weed control, and drainage and erosion control, are not easily identified independently. Therefore, it can be assumed that each site has its own set of management practices which distinguishes it against other sites with similar stress, fertility, variety and soil identities.

This assumption is incorporated into the model by a matrix of dummy variables. Each vector of the matrix distinquishes a site by setting the dummy variable associated with that vector equal to 'one' under the occurrence of management practices specific to that site under all other occurrences within that vector, the dummy variable is equal to 'zero'. In other words, it weights the yields from a site as unique to the management practices on that site in comparison to other sites. A site contains plots under the same management.

Adding this matrix of dummy variables to the model the yield function occurs as;

$$Y_{ijkl} = f\ (\ M_{ijlt},\ F_{ijl},\ V_{ijk},\ S_i,\ D_{ij}\ ) \tag{3}$$

where:

D_{ij} = A matrix of dummy variables such that D1 refers to the set of management practices applied to site, i, in year, j.

3.4 INPUT REQUIREMENTS TO THE AGRONOMY FRAMEWORK

Input used in the estimation of the variable coefficients for the yield regression is discussed in this section. The source of data for yield, fertilizer and soil variables is presented in the section immediatly following. The development of the varietal improvement index is then discussed before describing the estimation of a moisture stress indicator.

3.4.1 Fertility Trial Data

A number of fertility trials have been undertaken in Manitoba by various researchers over the last thirty years. These studies occur on a number of different soil types in many regions of the province. The specifications and results of these experiments are reported in the Proceedings of the Annual Manitoba Soil Science Meetings. A survey of these Proceedings was conducted and data was collected from 139 experiments.

The criteria for selection was that the experiment be a fertility study of wheat on stubble seed beds. Information was then collected on

1. the location
2. the soil type
3. the wheat variety used
4. the specific treatments of fertilizer
5. the specific yield results on a check treatment, and
6. the specific yield results on each fertilizer treatment and/or replicate.

Each experiment contained two or more observations per site, one of which being a check treatment. For each observation, the yield, rate of fertilizer, variety, soil type, year and location were recorded. The soil variable, S, was assigned a value of 3 for those experiments occurring on fine soil types, 2 for medium and 1 for coarse soil types. This accounts for any variation in yield attributed to the factors dictated by the type of soil of the experiment site. In cases where the location was given but not the soil type, the soil type was identified from Manitoba Soil Survey Reports.

Most experiments broadcasted the fertilizer applications in the spring. For the experiments that deviated from this procedure, the spring broadcast equivalent fertilizer rate was calculated using the efficiency criteria established by Manitoba Agriculture.

Every experimental site was assigned a dummy variable. This variable was set equal to 1 for all observations under that experiment and equal to 0 for all other observations, reflecting the management practices undertaken on that experiment. This accounts for any special pest, drainage or seeding bed preparations that went into the care and maintenance of one experimental site but not another.

Extreme weather events such as hail or flooding were not included in the specification of the model. Soil moisture stress was estimated from daily records of the weather station closest to the experiment site.

3.4.2 Varietal Improvement Index

Genetics has brought many improvements to the crop production system. The adoption of these developments has moved agriculture's technology frontier in a steady outward direction over time. The evidence of this is seen in the increasing yields experienced on the Prairie provinces over the last fifty years. A major contribution to this increase is the adoption of genetically superior crop varities. The effect of improved varieties on average yields is represented by a varietal yield improvement index and is the result of work by Dyck (1979) and the Expert Committee on Grain Breeding.[8]

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[8] Unpublished reports on cooperative test trials conducted by the Expert Committee on Grain Breeding provided by the Department of Plant Science, University of Manitoba, Winnipeg, 1960 - 1980.

Average yields of crop varieties were provided by a series of varietal test trials located at various research stations between 1960 and 1980. As noted previously, there is often an interdependence among the determining factors of yield. In this case, it was noted that average yields of specific varieties varied due to changing weather, fertility, weed control and other management practices over time. Although most of these interdependent impacts were unresolved, analysis concluded that little influence on the amount of yield advantage from genetic improvement occurred from these impacts. The exception was the impact that soil type had on the performance of crop varieties. As a result, average yields from the trials were examined in association with the three soil zones, brown, black and black-grey.

A base variety was selected as the variety tested over the entire time frame and was assigned a weight of 1. For each soil zone, the average yields for the base variety was then used as the denominator for average yields of other varieties to determine their relative weights. The resulting weights for wheat varieties are presented in Table III.1 and are relative to the Marquis variety. Because the proportion of wheat grown to durum and winter wheat varieties is usually recorded in aggregate, they are treated each as a single variety.

The crop variety reported from the experiment was assigned a value from the varietal index. Since the coefficient for the variety variable is restricted to 1, the varietal index acts as a weight relative to the average yields of Marquis wheat. For those cases in the earlier years where the crop variety was not reported, it was estimated by choosing the predominant variety in use at the time of the experiment.

Table III.1

Relative Varietal Yield Weights

	Soil Zones		
Wheat Variety	Brown	Black	Black-Grey
Apex	0.973	1.053	-
Canthatch	1.124	1.298	-
Canuck	1.080	1.275	-
Chinook	0.982	1.039	0.901
Durum	1.113	1.193	-
Glenlea	1.208	1.180	1.299
Lee	0.972	1.158	0.944
Manitou	1.117	1.191	1.080
Marquis	1.000	1.000	1.000
Napayo	1.095	1.212	1.118
Neepawa	1.160	1.247	1.105
Pembina	1.008	1.249	0.979
Redman	0.998	1.086	1.031
Rescue	1.007	1.009	0.926
Selkirk	1.063	1.255	1.058
Sinton	1.0596	1.173	-
Thatcher	1.092	1.136	1.091
Winter Wheat	1.310	1.496	1.309

Source: The varietal index value for winter wheat was estimated from various winter wheat yield trials conducted in comparison to Neepawa wheat by the University of Manitoba Department of Plant Science. Arthur, L.M. and D.F. Kraft, "Towards a Socio-economic Assessment of the Implication of Climate Change for Agriculture in Manitoba and the Prairie Provinces," Department of Agricultural Economics and Farm Management, University of Manitoba, March (1985), p. 28.

As demonstrated within the crop production system, soil moisture, or the lack thereof, plays an intricate role in the determination of crop yields. It becomes necessary therefore, to construct some means of indicating the occurrence of stress on the crop by the lack of adequate soil moisture.

Flinn (1971) noted that economists were first introduced to the use of soil moisture budgets research conducted by soil scientists. These budgets are used to trace available soil moisture in the rooting zone over time. Predictions of the occurrence of moisture stress can then be made by considering the level of soil moisture and the atmospheric demand for moisture from the crop (Flinn, 1971 p. 125).

A number of approaches to this concept have been undertaken. Flinn (1971) points out that researchers first related crop yields to soil moisture. Using actual weather and irrigation data as inputs to soil moisture and observed crop yields from experimental and farm data, they measured the effect of the incidence of moisture stress on the harvested yields (Flinn, 1971, p. 126). This approach becomes restrictive in that for studies of crop response in a new environment, an analogy of expected crop yield from distant empirical evidence is unconvincing.

A drought day index was later proposed whereby a critical soil moisture level occurred, below which a plant became stressed. It was then suggested that a magnitude of stress was more appropriate under the assumption that as moisture stress increased the effects of a moisture deficiency on the plant would increase.

Baier and Robertson (1966) adopted this assumption in the development of a versatile soil moisture budget (VSMB). The VSMB provides a very workable moisture stress indicator in the form of soil moisture shortfalls for different stages of plant development. The following is a general presentation of the VSMB and its operations.

3.4.3 The VSMB

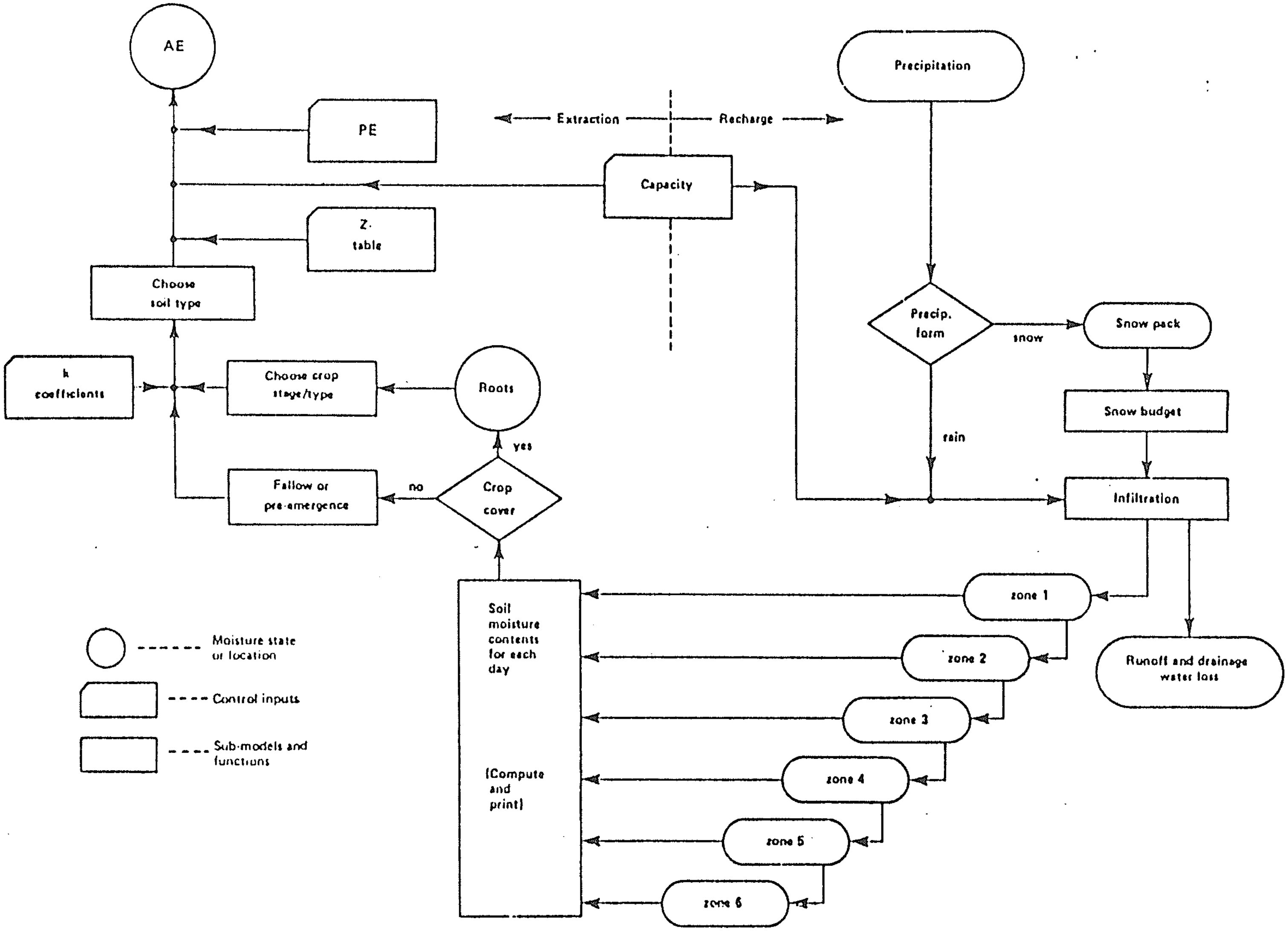
The VSMB is a computerized mathematical model originally developed by Baier and Robertson (1966). Three updated versions have been produced since by Baier, et al. (1972), Baier, et al. (1979) and Dyer and Mack (1984). The first two revisions have included refinements and subroutine additions to the original, while the last revision concentrated on the budget's application to a wider range of uses. The version adopted by this study is the VSMB version II (Baier, et al. 1979).

The VSMB estimates changes in soil moisture content from extractions of soil moisture in the form of evapotranspiration (AE). As displayed in Figure III.2, AE, on any day, is a function of potential evapotranspiration, rooting patterns, soil moisture release characteristics and the available soil moisture from the previous day. The available soil moisture is simply the difference between moisture extraction, or AE, and moisture recharge or precipitation for that day.

By taking the difference between the estimated available soil moisture and the estimated level of moisture reguired by the crop, the daily moisture shortfalls were simulated and summed in relation to the days of a particular growth stage. This provides a simulated soil moisture

FIGURE III.2

Soil-Root-Atmosphere Pathways for Water in the Versatile Soil Moisture Budget



shortfall for each stage of crop development to be used as the moisture stress indicator within the agronomic framework.

3.4.3.1 Soil Moisture Extraction

Water is extracted from varying depths of the soil profile simultaneously. This process is termed actual evapotranspiration, AE. AE is related to:

1. the rate of potential evapotranspiration
2. the rooting patterns of the crop
3. the soil's release characteristics of moisture, and
4. the available moisture within each soil zone of specified water holding capacity.

The VSMB estimates AE daily by the equation;

$$AE_i = \sum_{j=1}^{n} \left[K_j * S_{j(i-1)} / C_j * Z_j * PE_i \right] \qquad (4)$$

where:

AE_i = actual evapotranspiration for day, i.

$\sum_{j=1}^{n}$ = summation carried out from soil zone j=1 to j=n.

K_j = coefficient accounting for soil and plant characteristics in the jth zone.

$S_{j(i-1)}$ = available soil moisture in the jth zone at the end of day, i-1.

C_j = capacity for available water in the jth zone.

Z_j = adjustment factor for different types of soil dryness curves.

PE_i = potential evapotranspiration for day, i.

Estimates of PE occur as a subroutine within the VSMB based on daily maximum and minimum temperatures and radiation at the top of the atmosphere. The VSMB uses PE calculations as defined by Baier and Robertson (1965).

3.4.3.2 Soil Moisture Recharge

Within the VSMB, soil moisture recharge is entirely the result of precipitation. However, consideration is given to:

1. rainfall
2. snowmelt
3. surface runoff
4. infiltration
5. subsurface drainage, and
6. the precentage of soil moisture on the previous day.

Infiltration of water into the soil depends on precipitation, soil moisture and available water capacity. Distribution of moisture over the soil zones is a function of the amount of infiltration, the relative moisture content of each zone and the fraction of water infiltrating to the next zone. Infiltration cannot exceed the soils capacity to hold water and, therefore, any excess moisture to the first soil zone becomes runoff.

Infiltration is computed as:

$$\mathrm{INFL}_i = 0.9177 + 1.811 \log \mathrm{RR}_i - 0.97\ [S_{j(i-1)} / \log \mathrm{RR}_i] \tag{5}$$

where:

RR_i = rainfall on day, i.

$S_{j(i-1)}$ = soil moisture in the jth zone on day, i-1.

C_j = available water capacity of the jth zone.

j = 1 since any excess moisture to the first zone is runoff.

The distribution of moisture entering the first zone and infiltrating to the remaining zones is simulated by the function:

$$INFL_{ij} = [\ 1-S_{j(i-1)}/C_j\ b]\ [INFL_i - \sum_{n=1}^{j-1} INFL_{in}] \tag{6}$$

where:

$INFL_{ij}$ = new infiltration into each zone of soil.

b = fraction of water infiltrating to the next zone.

The deficit of soil moisture (DEF) or the amount of moisture the soil is able to take on above that which is already present is simply:

$$DEF_{ij} = C_j - S_{j(i-1)} + AE_{ji} \tag{7}$$

A snow budget and a snow melt subroutine also occurs in the VSMB. This accounts for that amount of infiltration in the soil from melting snow and is affected by the percentage of trash remaining on the field surface after fall tillage.

3.4.3.3 Input Requirements to the VSMB

Inputs to the VSMB's pathways and calculations as presented are required with respect to:

1. daily minimum and maximum temperature
2. daily precipitation
3. latitudinal locations as they correspond to radiation levels at the top of the atmosphere
4. coefficients accounting for the soil's moisture release characteristics
5. soil characteristics of zone depths and water holding capacities
6. coefficients accounting for the crops rooting patterns and extraction of water
7. dates of seeding and stages of crop development, and
8. a set of control parameters.

The following is a brief description of the VSMB input data.[9]

Meteorological data for temperature and precipitation was obtained from archived computer files of the Agrometeorological Section of Agriculture Canada. Data from 140 weather stations in Manitoba is continually collected, reported and stored on tape for daily minimum and maximum temperature and precipitation values. For any particular site of interest weather data from the closest available station is called from the files for that year.

Radiation levels at the top of the atmosphere are simply those values used by Baier, <u>et</u> <u>al</u>. (1979). These values were originally derived by Robertson and Russelo (1968) using a simple estimating technique based on the latitude of interest.

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[9] For a detailed explanation on the derivation and source of the variables and data refer to the various VSMB publications noted.

The characteristics of moisture release by different soil types are estimated by a set of coefficients for each type of soil. These coefficients describe the relation of available soil moisture to the ratio of AE to PE. This relation changes with different types of soil. Given the calculated level of soil moisture, the model chooses the appropriate coefficient from the set to be used in the moisture extraction equation for that day on that particular soil.

Other soil characteristics are required. These include the number and depth of soil zones to be considered and the water holding capacities of these zones. Information of this nature was obtained for a soil type from the Manitoba Soil Survey Branch of the Manitoba Department of Agriculture.

The rooting patterns and subsequent extraction of water by the roots depends on the type of crop and the stage of development. A set of coefficients representing this process has been determined by iterative comparison between computed and measured soil moisture for wheat by Baier, et al. (1979). A value reflecting water extraction by roots is available for each stage of crop development for soil zone. Because plants draw from the complete rooting zone, an adjustment must be made to these coefficients during periods of drought where plants draw comparatively more from the lower zones. This adjustment appears as a subroutine within the model depending on available soil water in each of the zones.

It then becomes necessary to estimate the date whereby the crop reaches the following stages of development:

1. seeding
2. emergence
3. jointing
4. heading
5. soft-dough, and
6. ripe.

These dates are obviously not deterministic and will vary by regional climate and yearly weather patterns. In considering these two factors, Robertson (1968) designed a biometeorological time scale (BMTS) for wheat. This approach was considered to be superior to the heat unit equations and photothermal concepts previously adopted (Baier, 1972). The BMTS simulates the daily progression towards the completion to each of the five stages of crop development based on daily maximum and minimum temperatures, photoperiod and an estimated seeding date. Temperature data is obtained from the same weather reporting stations. Photoperiod is simply the time of day light occurring at the appropriate site of longitude.

Seeding dates, however, must be estimated for each site and year of interest. In estimating corn planting dates, Flinn (1971) used a process of conditional criteria. That is once a set of criteria had been met conditions for planting were considered favourable. The criteria established for corn occurred as:

1. Seeding was assumed to take place after May 5th;
2. Rainfall in the previous five days must be less than 1 inch;

3. Rainfall in the previous three days must be less than one-half inch; and
4. Mean temperatures must exceed 55 degrees fahrenheit for 5 consecutive days.

A similar set of criteria for planting spring wheat was derived by Dunlop (1981) and occurred as:

1. The soil moisture must be at or below 90 percent of field capacity;
2. Daily precipitation must be less than 2.54 mm.; and
3. The maximum air temperature must be above 0 degrees celsius.

In consultation with the Plant Science Department at the University of Manitoba, these conditions were extended to include;

1. The minimum air temperature must be above -2 degress celsius to ensure no refreezing of the soil occurs; and
2. On any day there is recorded precipitation, maximum air temperature must be in excess of 5 degrees celcius to ensure this precipitation is not in the form of snow.

The above conditions must occur for three consecutive days to give earliest possible seeding conditions. Adding another seven days assumes general seeding operations are general for the area.

For spring wheat under conventional tillage, analysis commenced on April 20th and continued until conditions were met. If these conditions were not met on or before June 10th this date was used as the estimated seeding date.

Evans and Olson (n.d.) upon noting that soil temperature is a concern to planting dates conveys the notion that,

> Fields covered with plant residues from minimum tillage will tend to have lower soil temperatures....than fields without surface plant residues.[10]

They estimated a five day delay in reaching adequate temperature levels from sod to plowed surfaces. Gauer, et al. (1982), estimated a four day delay in crop development under zero tillage from conventional tillage on Manitoba's Osborne clay soils. With no estimation available on the delay of seeding due to reduced soil temperatures under minimum tillage, an assumed two day delay over conventional tillage seeding date estimates is used.

Seeding dates for winter wheat are assumed to occur before September 15th as recommended. However, the date of interest as input to the BMTS is the day in which the crop commences growth in the spring.

In consultation with the University of Saskatchewan, Crop Science Department, it was noted that winter wheat will break dormancy when soil surface temperatures reach 5 degrees celsius. Gupta, et al., (1983) estimated an equation relating soil surface temperature to air temperature under reduced tillage for the spring, summer and fall. The equation for reduced tillage in the spring was estimated as:

$$ST = 1.05 + 0.3591(AT) + 0.0462(AT)^2 + 0.00052(AT)^3 \qquad (8)$$

where:

ST = soil surface temperature (degrees celcius)

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[10] P. Evans, and Olson, T., "Implications of Soil Temperatures in May," Bulletin by South Dakota Agricultural Experiment Station, n.d., p. 14.

AT = maximum, minimum or mean air temperature

Using this equation, air temperatures of about 6.5 degrees celsius generates soil surface temperatures adequate for winter wheat to resume growth. Therefore, the criteria used to ensure favourable conditions for winter wheat to break dormancy was that mean air temperatures be greater than 6.5 degrees celsius for five consecutive days.

3.5 YIELD EQUATION FUNCTIONAL FORM

Given the common responses to climatic factors in crop development from emergence to heading and again from heading to harvest, the crop development stages M1, M2 and M3 are to be grouped together and referred to as M1 for the purposes of estimating regression coefficients. Similarly, the stages M4 and M5 are grouped together in the yield regression equation and referred to as M2.

From the factors determining crop yields it becomes evident that these variables are not necessarily independant of each other. For instance, the level of moisture stress may influence the efficiency of a fertilizer application, the efficiency of the crop variety or the effects of soil type and texture on yields. As such, an appropriate functional form for the equation would be a multiplicative format as shown in equation 9. A similiar functional form was used by Arthur and Kraft (1985) in deriving a yield equation to simulate the effects of long term climatic changes across the Canadian prairies and by Kraft (1985) in deriving a yield equation to assess the effects of technological change on grain operations.

$$Y = e^{(a+bS_i+cD_{ij})} F^d * M_1^f * M_2^k * e^{(gM_1+hM_2)} * V^n * E \qquad (9)$$

where:

E = an error term representing the difference between the yield predicted from the explanatory variables and the yield which actually occurred.

A number of characteristics become evident from the specification of the functional form of the equation. The form stipulates that except for the moisture stress variables, marginal products are positive and as fertilizer applications increase, yield will always increase but at a decreasing rate, i.e., $0 < d < 1$. The moisture stress variables are allowed to decline as well as to rise, i.e., $|f,k| > 0$ and $|g,h| > 0$.

As mentioned previously, a matrix of dummy variables is incorporated to account for the potential of yields to vary by site management. One site must be chosen as the base whereby the intercept, (a), reflects the base yield which may be expected under management conditions of that field when the influence of the other factors is held constant. All other fields have an intercept of 'a' plus the coefficient of the dummy variable (c) used to identify the set of management conditions associated with that observation. The dummy variable (b) used to identify variations due to soil type affects the intercept in the same manner.

Another characteristic of the function relating to its specification refers to the varietal improvement variable, V. This variable acts as an index representing a measure of the genetic potential of the crop variety grown.

A total of 1,013 observations of yield, soil type, site management, nitrogen fertilizer rates, early stage soil moisture stress, late stage soil moisture stress and crop variety were used to generate the yield regression parameters and are tabled in Appendix A. Data for the yield, soil type, site management, nitrogen fertilizer rates and crop variety observations was collected from a survey of fertility trial experiments as reported in the Manitoba Soil Science Proceedings. The parameters were estimated by taking the log of the functional form and using the ordinary least squares method of regression.

The resulting yield equation occurs as:

$$Y = e^{(a+bS_i+cD_{ij})} F^d * M_1^f * M_2^k * e^{(gM_1+hM_2)} * V^r \qquad (10)$$

where:

Regression Parameter	T value
a = 3.55	(15.90)
b = .09	(6.32)
c = varied by site and year	
d = .13	(24.37)
f = -.35	(5.13)
k = .11	(6.45)
g = .008	(7.39)
h = -.009	(11.92)
r = 1	

Equation (10) was used to estimate annual wheat yields for three sites in Manitoba. The sites were chosen on the basis of different weather patterns and soils. The Graysville location has coarse textured Almissippi fine sand while the Minnedosa and Pierson sites have Newdale clay loam and Oxbow loam, respectively. Fertility conditions and the variety of wheat and tillage operations were held constant while daily precipitation, temperature and solar radiation were the same as the historical record for each site. Each year, the simulated wheat yields differ because of the weather events even though management and technology were held constant. The simulated annual wheat yields were, in turn, utilized to estimate probability density functions of yields unique for each site, technology and historical weather. The probability density function became one of the components used to determine a representative farm's gross margin from wheat and net worth in the economic model.

3.6 THE ECONOMIC FRAMEWORK

As discussed in the crop production system, annual gross margins are derived from estimated expenditures and crop receipts for spring and winter wheat production. Gross margins vary from one year to the next not only because of differences in crop yields, but also because crop prices and are assumed to change from one year to the next. A stochastic model developed by Snitynsky (1983) and modified by Dzisiak (1987) was utilized to evaluate the cropping options. A similiar study by Hardin (1978) used a Monte-Carlo simulation in analysing farm investment alternatives.

The same argument used in applying Monte-Carlo simulation processes to assess risk in investment is used applying Monte-Carlo simulation to assess possible outcomes with different management alternatives. With the key economic variables of yield and price exhibiting a distribution of possible outcomes, Monte-Carlo simulation is able to incorporate a degree of uncertainty associated with alternate management practices. Analysis using Monte-Carlo simulation is then able to generate a probability distribution of outcomes by repeating the simulation many times over for each alternative.

The Risk Simulation Model (RSM) used in this study is a slightly modified version of the Dzisiak (1987) model. Financial, production and marketing information relevant to a particular crop production enterprise is included as an input summary. The data from the input summary must be sufficient to construct the budgets for the crop enterprise in question and to initialize the starting points for the stochastic and non-stochastic variables.

The process of internally generating uncertain variables consists of two distinct phases. The first phase involves computing the stochastic variables of farm crop yields, grain prices, interest rates and grain sales. The second phase involves generating non-stochastic variables such as operating expenditures.

The model calculates farm production costs, returns, annual cash flows, assets and liabilities. Debt payments on existing loans, capital investment for equipment, living and personal withdrawals and income taxes are then deducted. A predetermined number of replications are simulated to determine annual cash flow and net worth probability distributions of a particular management alternative.

A brief description of the operations of the RSM relevant to this study is provided. The input data requirements are discussed followed by an outline of the stochastic processes.[11]

3.6.1 Input Requirements to the RSM

The input data requirements as described in Table III.2 allows the model to:

1. develope a budget for the management alternative to be simulated;
2. initialize the starting points for the stochastic and non-stochastic trend variables; and
3. construct the financial state of affairs of the farm being simulated.

3.6.2 Stochastic Processes

Given the input data requirements specific to a particular management alternative, the model is able to introduce a stochastic element into those variables demonstrating a high degree of uncertainty. This is accomplished by generating random numbers which are used in the context of a probability density function.

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[11] For a detailed presentation of the Risk Simulation Model and its various applications see Dzisiak (1987) and Snitynsky (1983).

TABLE III.2

RSM Input Data Summary

1. The beginning year and quarter of the analysis:
2. The number of productive acres purchased:
3. The price paid/acre:
4. The average price/acre from recent sales of comparable land:
5. The current price of wheat ($/bushel):
6. The expected annual increase in yields (%):
7. The percentage of land in summerfallow:
8. The average quota expected per year (bu/acre):
9. The expected annual increase in quota (%):
10. The total operating expenses/acre:
11. The expected inflation rate for operating expenses (%):
12. The present cost of fertilizer/acre:
13. The present cost of herbicide/acre:
14. The basic living and personal expenditures/year:
15. The expected inflation rate for living expenses (%):
16. The present non-farming income:
17. The expected annual increase in non-farming income (%):
18. The total value of cash, near cash and operating supplies:
19. The beginning wheat and wheat equivalent inventory (bu):
20. The market value of machinery:
21. The average replacement frequency of machinery (yrs):
22. The total number of rented productive acres:
23. The total amount owing on accounts payable:
24. The Canadian/U.S. exchange rate:
25. The expected Can./U.S. exchange rate in 10 years:
26. The total number of owned pasture land (acres):
27. The total number of owned hay, crop and fallow acres:
28. The average price/acre of improved farmland (excl. bldgs):
29. The total value of farm buildings (excl. livestock barns):
30. The present pasture land taxes/acre:
31. The present improved land taxes/acre:
32. The current operating loan interest rate (%):
33. The operating loan outstanding:
34. The average % of cultivated cropped land/qtr. section:
35. The proportion of the generated wheat price to be used:

The variables to which the random number applies for the purposes of the this study include Canadian wheat prices, as determined by U.S. wheat prices and Canadian/U.S. exchange rates, wheat yields, interest rates and wheat sales (delivery quotas). A brief description of the process in determining these variables is presented below.

3.6.3 Randomly Generated Wheat Prices

The RSM assumes that Canadian wheat prices are a function of the U.S. wheat prices. Dzisiak (1987) adopted the technique of Spectral Analysis to determine a six year cycle for wheat prices.[12] Canadian wheat prices are then generated via the following equation.

$$P_t = (INF * M_{t-1}) \tag{11}$$

$$W_t = P_k + at \tag{12}$$

$$\text{If } (W_t < LOAN_t) \text{ Then } (W_t = LOAN_t) \tag{13}$$

$$CANWHT = (W_t * EX_t) \tag{14}$$

where:

C = Cycle value of quarters being simulated

P = Wheat cycle price adjusted for the inflation rate and the mean value

K = Quarter in the cycle (k=1 to 24)

INF = Quarterly inflation rate

M = Mean price of wheat series (MO = 143.69)

t = Time in quarters

W = Average quarterly price of U.S. wheat ($/tonne)

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[12] The historical U.S. price series and the resulting 24 (six year) individual cycle values are presented in Dysiak (1987), p 28.

a = Normally distributed random error term

LOAN = U.S. loan rate for wheat for quarter being simulated

CANWHT = Average quarterly price of Canadian wheat (\$/tonne)

EX = Canadian/U.S. quarterly exchange rate

This process is initialized by the beginning year and quarter of the analysis, the expected inflation rate and the current price of wheat in \$/tonne as specified in the input data requirements. The initial mean value for the U.S. wheat price series is added to the appropriate cycle value for the quarter being simulated. For each quarter the mean value is increased by an inflation factor and once the last value of the cycle has been used, the model reverts back to the first value defined in the cycle. A randomly generated error term is added to the wheat cycle value to determine the U.S. price for wheat.[13] If this value falls below the floor price for U.S. wheat specified by the loan rate, the wheat price is set equal to the loan rate. The Canadian hard red spring wheat price is then calculated by multiplying the U.S. price by the Canadian/ U.S. exchange rate. Winter wheat prices are determined by taking some specified proportion of the generated wheat price reflecting the traditional spread in price between the two classes.

The exchange rate is a randomly generated value initialized from values specified in the input data requirements using a functional relationship between the two countries' historical price series and exchange rates.[14] Given the input data, the model calculates the yearly incremen-

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[13] The characteristics of the randomly generated error term are presented in Dzisiak(1987), p. 35.

[14] Specification of this functional form is found in Dzisiak (1987) p. 23.

tal increase or decrease in the base exchange rate value for a period of 10 years. This increment is added to the base value and upper and lower bounds are specified for this value. The equation then calls for a random number to determine a stochastic value between the bounds. This value is used in year one of the simulation run. The process is repeated for each year of the ten-year simulation.

3.6.4 Randomly Generated Yield

Yields are generated from the specification of the cumulative yield distributions derived from the agronomic framework for each management alternative. Each distribution is specified in the input data requirements as the cumulative percent probability of producing yields from 0 to 7.40 tonnes per hectare acre in increments of 0.33 mt/ha. For each year of the simulation run, the random number generator assigns a value from the specified distribution.

3.6.5 Financial Calculations

The RSM financial calculations pertinent to this study include

1. replacement of capital inputs,
2. capital cost allowances,
3. living and personal withdrawals,
4. income tax, annual equity and annual cash flow.

Yearly capital replacement requirements, income taxes, annual equity and annual cash flow of a particular management enterprise will vary depending on the management alternative being considered.

The RSM determines the yearly capital replacement requirement based on present market value of machinery and the average turnaround of machinery as specified from the input data requirements, age of equipment and the required machinery investment per acre.

The capital cost allowance deductions for machinery investment is also required for the determination of yearly taxable income. It is equal to the value of the undepreciated cost of capital for that year, multiplied by the yearly depreciation rate. The model allows for the payment of income tax whenever the yearly taxable income is positive.

The net worth position of the farm is determined in the initial and final year of the simulation. The beginning net worth equity calculation depends on initial assets and liabilities. The equity position during successive years of the simulation depends on the financial considerations generated through the simulation process. The final net worth calculation occurs in year ten of the simulation.

Specification for the capital replacement requirement, capital cost allowances, income tax and annual equity is taken directly from Dzisiak (1987). The RSM calculates cash flows for the particular enterprise by deducting total operating expenses from total revenues annually. Crop budget costs are determined using the Crop Production Simulator as presented by Longmuir, et al. (1983). The Crop Production Simulator is designed to compute the total costs, both fixed and variable, associated with a particular crop management enterprise.

Input requirements for the Crop Production Simulator are of two types; price and amounts of inputs. Values of inputs are dictated by the market place and are, therefore, exogenous to the crop production system. This includes prices for the variable input factors of:

1. fertilizer,
2. chemicals,
3. fuel,
4. lubricant,
5. repairs,
6. seed,
7. seed cleaning and treatment,
8. labour and
9. custom work

the fixed input factors of:

1. land taxes or rent
2. machinery insurance
3. miscellaneous overhead

The model's input requirements relating to the physical components of production are dictated by the specific management practices adopted and are therefore endogenous to the system. These inputs include information relating to:

1. tillage and seeding practices
2. crop and variety grown
3. types and rates of fertilizers and chemicals and

4. machinery and land inventory.

Given the input information the Crop Production Simulator computes the total operating budget for a particular management alternative for a particular year. This value is then used in the annual cash flow calculations of the RSM.

Positive annual cash flows are added to a cash surplus reserve over the course of the simulation. If for any year of a simulation run net cash flow is negative, an operating loan is applied to cover the shortfall. For any case arising where the shortfall is greater in absolute value than the total amount of operating expenses, loan consolidation takes place if there is sufficient equity in the business.

The ten year simulation obtained from the input data requirements, stochastic process and financial caluclations is replicated 300 times.

Following the replications the model determines probability distributions for:

1. gross margins of wheat production and
2. the probability of an annual increase in net worth.

The probability distributions become the economic decision variables used to compare each management alternative.

Chapter IV

DATA INPUT AND RESULTS

The simulation experiment was divided into three sites; Graysville, Minnedosa and Pierson, which where chosen on the basis of:

1. availability of historical weather data,
2. differences in climatic characteristics, and
3. differences in soil type.

On each of these sites, three management scenarios were simulated. These occur as:

1. Canadian Western Hard Red Spring Wheat (CWRS) grown under conventional continuous cropping tillage (denoted as SPCT);
2. CWRS grown under minimum tillage (denoted as SPMT),
3. Canadian Western Red Winter (CWRW) grown under minimum tillage (denoted as WWMT).

The remainder of this chapter will identify the specific data inputs used in each model of the agronomic and economic frameworks for each scenario and then outline the subsequent results. The data and results of the agronomic models will be discussed first with respect to the input components of the yield regression model for each site and scenario. The operations assumed for each management scenario are outlined in Table IV.1.

Table IV.1

Assumed Management Operations

SPCT	SPMT	WWMT
Spring		
1) Apply granual herb.	1) Broadcast N fert.	1) Broadcast N fertilizer
2) Broadcast N fert.	2) Cultivate	2) Spot spray winter kill patches
3) Cultivate	3) Harrow	
4) Harrow	4) Seed & apply P205 fert.	
5) Seed & apply P205 fert.	5) Harrow	
6) Harrow		
Summer		
7) Spray	6) Spray for narrow leaved weeds	3) Spray for rust
	7) Spray for broad leaved weeds	
Fall		
8) Swath	8) Swath	4) Swath
9) Combine	9) Combine	5) Combine
10)Truck to farm	10)Truck to farm	6) Truck to farm
11)Auger to storage	11)Auger to storage	7) Auger to storage
12)Disc	12)Spray for perennial weeds	8) Spot spray for perennial weeds
13)Cultivate		9) Cultivate
14)Harrow		10)Harrow
		11)Seed & apply P205 fertilizer
		12)Harrow
Winter		
15)Auger to truck	13) Auger to truck	13) Auger to truck
16)Truck to market	14) Truck to market	14) Truck to market

Attention is then focused on the data input values used for the economic models and the subsequent results. This includes a description of the management practices adopted under each scenario and the associated operating expenses. The variable components adopted in the risk simulation model are then presented along with the resulting probability distributions of the decision variables.

4.1 DATA INPUT AND RESULTS FROM THE AGRONOMY MODELS

Yields were simulated for each scenario by using equation 10 and specifying the values of the model variables. The derivation of values for the soil type variable, the varietal index variable, the moisture stress variables and the nitrogen fertility variable are discussed in the following sections.

4.1.1 Soil Type

The soil type dummy variable values were specified based on the type of soil found at each of the three locations. The dominant soil in the Graysville area is a coarse textured Almissippi fine sand and therefore the variable Si was assigned a value of 1. For Minnedosa, the dominant soil is a fine textured Newdale clay loam and thus a value of 3 was assigned. The Si values for the Pierson scenarios was 2 since the soil in this area is a medium textured Oxbow Loam.

The specification of the yield equation is such that the soil type dummy variable contributes to the intercept of the yield function only. Therefore, the soil characteristics relating to this variable, such as intrinsic fertility or erosion, will cause a shift in the yield functions between sites. Those soil characteristics that have an effect on the shape of the function are captured in the soil moisture stress variables.

4.1.2 Varietal index

For each of the SPCT, SPMT and WWMT scenarios the varietal improvement variable was defined simply from the varietal improvement index defined in table III.1. The SPCT and SPMT scenarios adopted the Neepawa variety index value of 1.25. The WWMT scenario adopted the winter wheat variety index value of 1.5.

4.1.3 Soil Moisture Stress

As discussed previously, input requirements for the VSMB include:

1. daily minimum and maximum temperatures,
2. daily precipitation,
3. latitudinal location,
4. soil moisture release characteristics,
5. soil zone depths,
6. soil water holding capacities,
7. rooting and water extraction coefficients,
8. seeding and stage dates,
9. control parameters.

Each scenario for each site held a different set of values for these input requirements. As such, a different set of moisture stress values were simulated for each case. The values for these variables are presented in Appendix B and the resulting frequency distributions of moisture stress are diagramed in figures IV.1 to IV.6.

The frequency distributions are expressed as the probability of occurrence of different levels of soil moisture stress and are presented for both early and late crop development stages. The cumulative distribution probability curves portray the differences in soil moisture stress for each scenario on each site. Figure IV.4 shows that the probability of experiencing a soil moisture stress of no more than 50 mm is between 16% and 20%. In other words about one year in every five or six the soil moisture stress does not exceed 50 mm. A stress of less than 100mm is likely to occur approximately 80% of the time. Alternatively, stress in excess of 100 mm will happen 20% of the time.

The probability of, say, 100 mm of moisture stress occurring during the early or late stages of crop development should be different for each management scenario on a particular site. Using the SPCT scenario as the base curve in figure IV.1 to IV.6, a shift to the left of SPCT represents a reduction in the level of soil moisture stress for a specific level of likelihood of occurrence. A shift to the right of SPCT is interpreted conversely as an increase in the level of soil moisture stress that is likely to occur. From discussion of the crop production system, an increase in moisture stress is expected to translate in to reduced yields.

The SPMT scenario produced a minor shift in the cumulative probability of early stage moisture stress curve to the left of SPCT in each of

FIGURE IV.1

GRAYSVILLE CUMULATIVE SIMULATED
EARLY STAGE SOIL MOISTURE STRESS

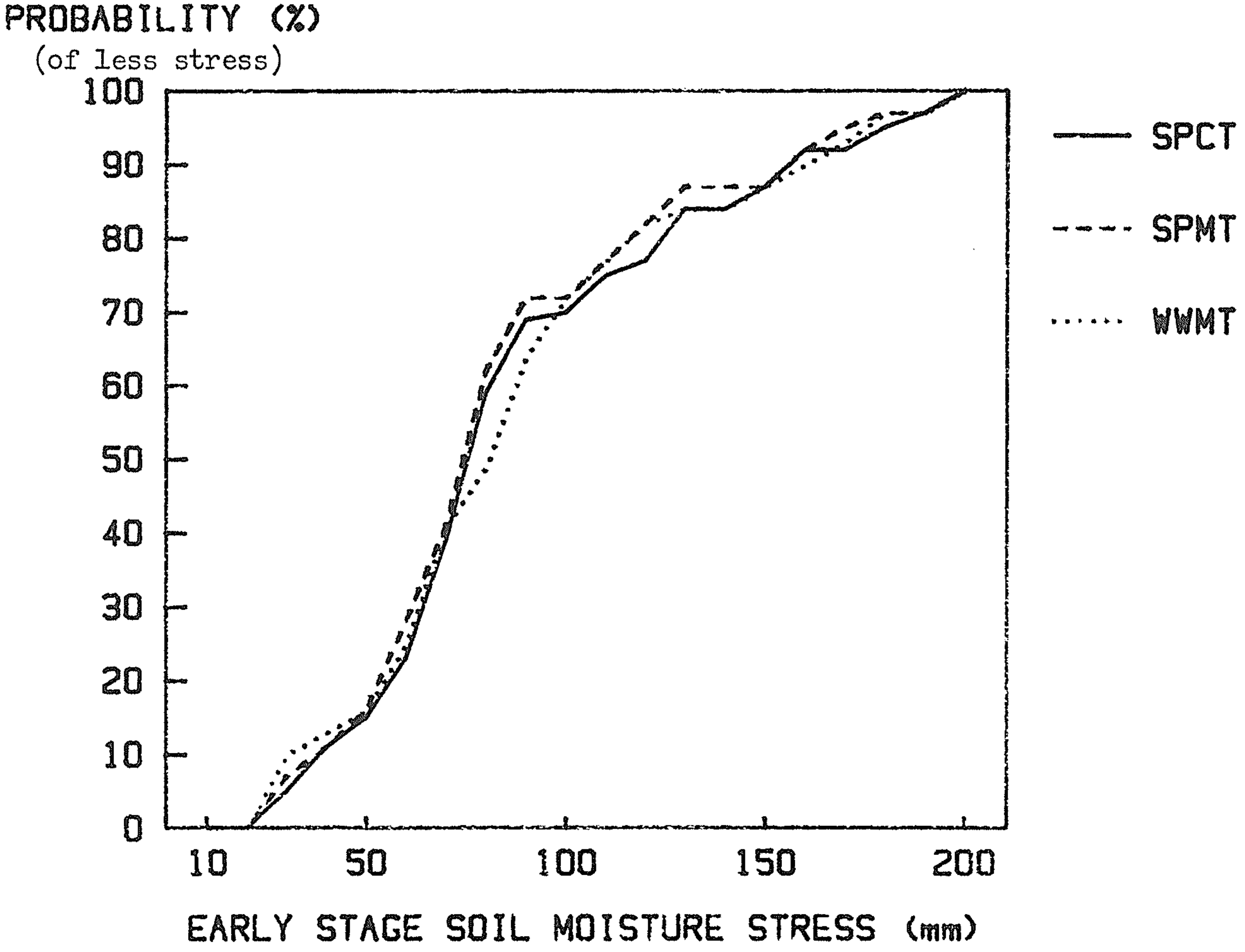


FIGURE IV.2

MINNEDOSA CUMULATIVE SIMULATED
EARLY STAGE SOIL MOISTURE STRESS

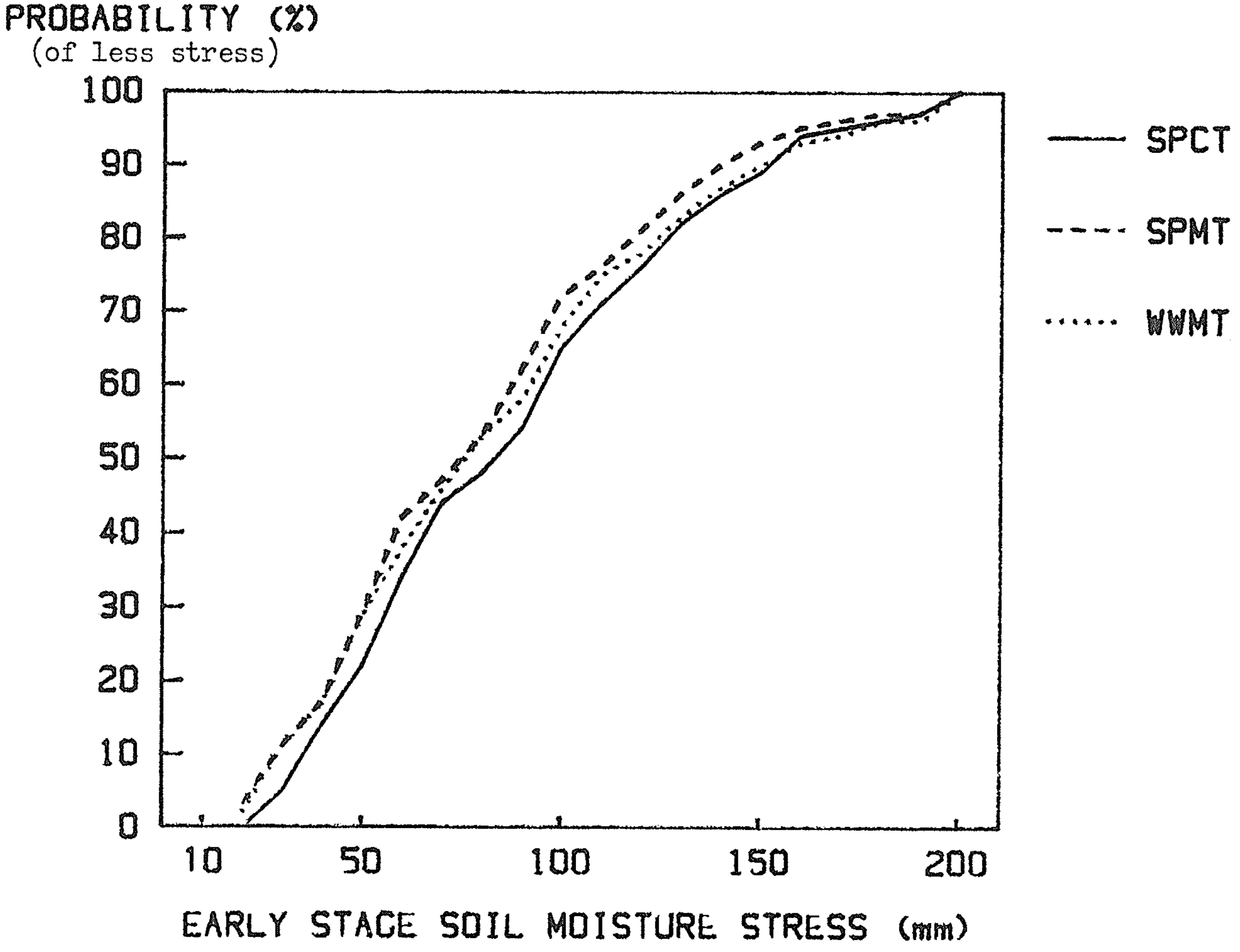


FIGURE IV.3

PIERSON CUMULATIVE SIMULATED
EARLY STAGE SOIL MOISTURE STRESS

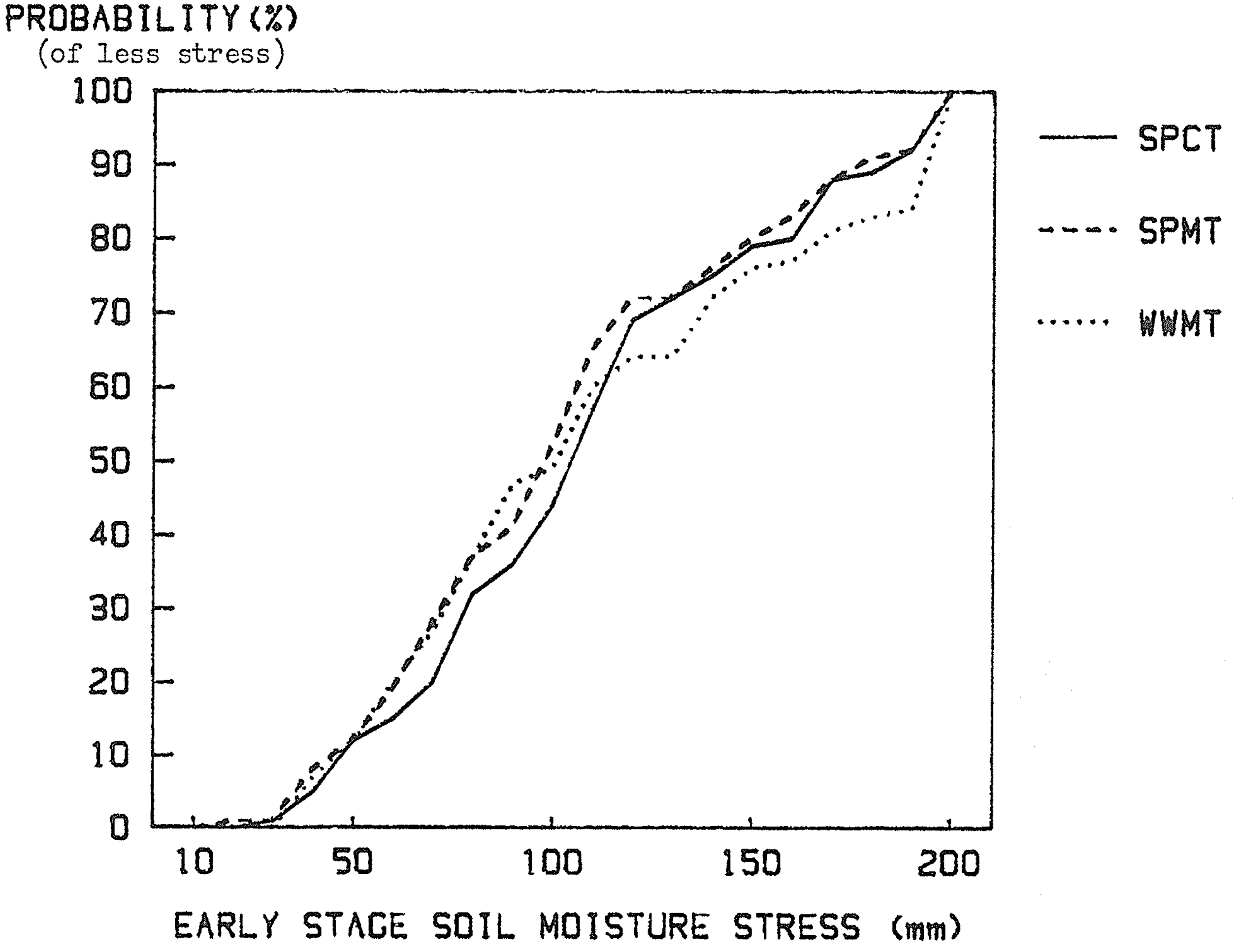


FIGURE IV.4

GRAYSVILLE CUMULATIVE SIMULATED
LATE STAGE SOIL MOISTURE STRESS

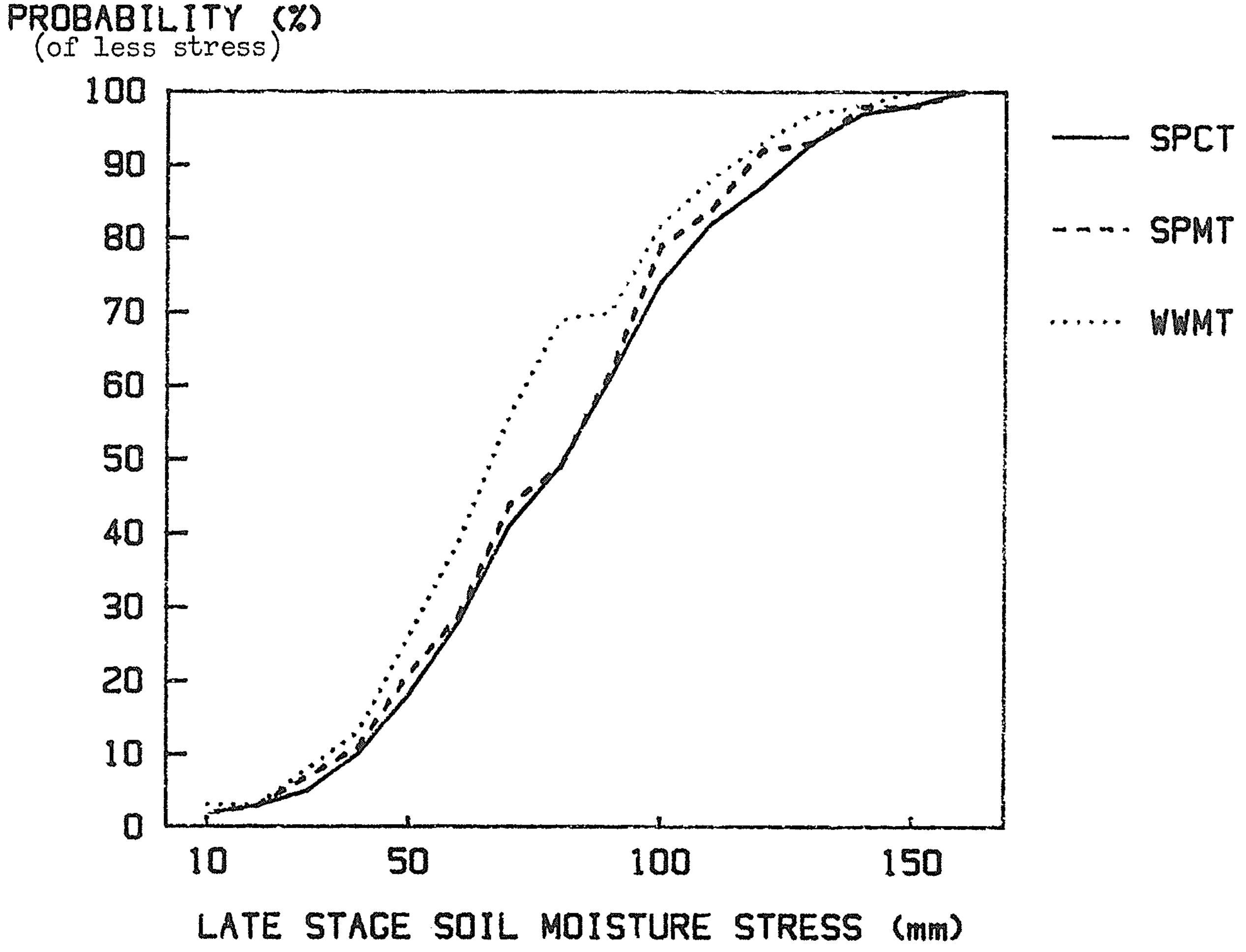


FIGURE IV.5

MINNEDOSA CUMULATIVE SIMULATED
LATE STAGE SOIL MOISTURE STRESS

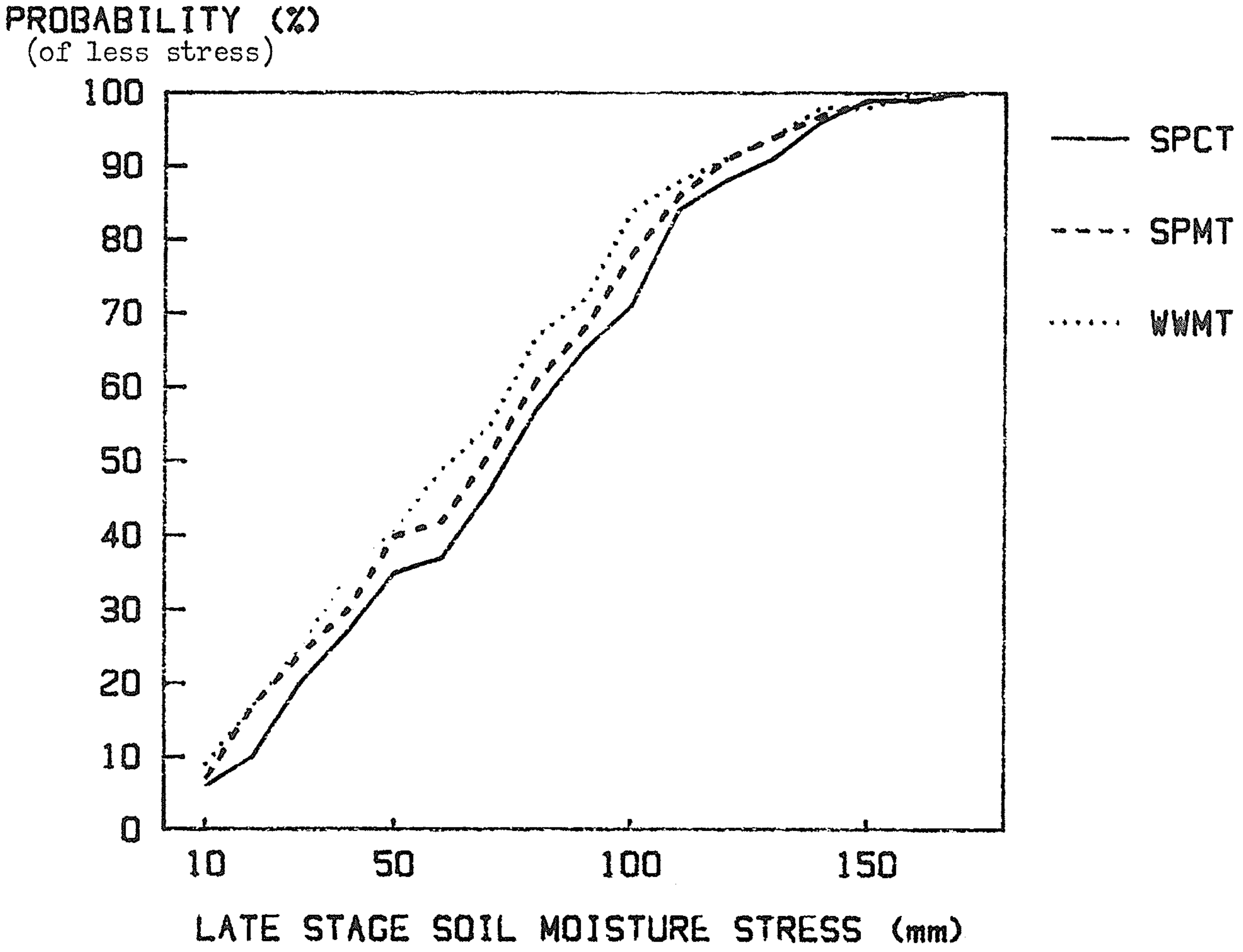
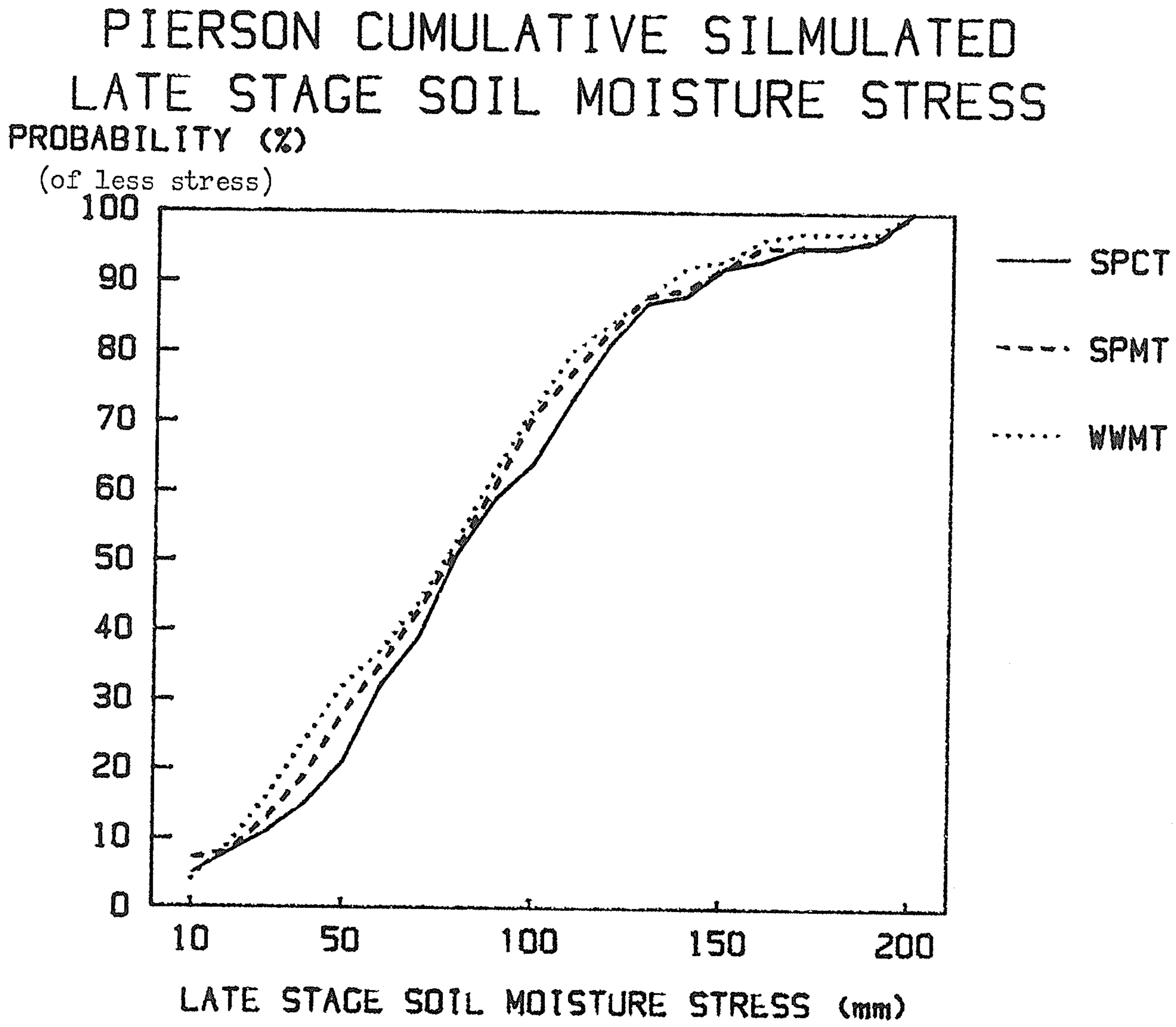


FIGURE IV.6


PIERSON CUMULATIVE SILMULATED
LATE STAGE SOIL MOISTURE STRESS
PROBABILITY (%)
(of less stress)
100
90
80
70
60
50
40
30
20
10
0
10
50
100
150
200
LATE STAGE SOIL MOISTURE STRESS (mm)
SPCT
SPMT
WWMT

the three locations. This is interpreted to mean that spring wheat produced under minimum tillage offers a slight reduction in moisture stress during the early stages of crop development when compared to production under conventional tillage. This result meets expectations in that a reduction of tillage is expected to increase soil moisture, thereby reducing stress, via increased snow accumulation and reduced evaporation and runoff. Since the yield equation coefficient for early stage stress is negative (i.e., a decrease in soil moisture stress in the early stages of crop development produces an increase in yields), this shift is expected to have a positive impact on simulated yields.

A similar situation arises during the later stages of development. Again, this meets with expectations in that the positive attributes of SPMT over SPCT would be expected to diminish as the crop develops towards maturity. The advantages of increased snow cover and decreased evaporation under SPMT occur in the spring, with the positive impact on soil moisture carrying over throughout the crop year.

In the case of winter wheat, the distribution of moisture stress is not quite as consistent. During the early stages, the WWMT curve is positioned to the right of the SPCT curve at some points and to the left at others. This situation is presumed to be indicative of the fact that crop development in winter wheat can occur at different rates than spring wheat under conventional tillage and spring wheat under minimum tillage throughout the same crop year. The pattern in spring resumption of winter wheat growth over the years, as opposed to the seeding date of spring wheat, may not necessarily coincide. Therefore, the ultimate effect on simulated yields of winter wheat due to the levels of early stage soil moisture stress is uncertain in comparison to the SPCT levels.

During the later stages of development, the WWMT curve is more consistently to the left of the SPCT and SPMT curves. This protrays the fact that winter wheat can more readily take advantage of the higher levels of precipitation during the early portions of the growing season and the drier conditions required for ripening in the later portions of the season. Thus, the ultimate effect of winter wheat yield simulations due to soil moisture stress in the last stages should be positive.

In site-to-site comparisons the position of all three scenarios on a site occurs as Minnedosa to the extreme left, Graysville and Pierson to the extreme right. This coincides with both the climatic and soil characteristics of the sites. Minnedosa, while having a similar annual level of precipitation as Graysville, is of a clay loam texture, while Graysville is a sandy loam. Pierson, with a loam soil complex, receives a substantially smaller amount of precipitation than Minnedosa, and Graysville has the highest soil moisture deficit.

4.1.4 Nitrogen Fertility

The values for the nitrogen fertility variable, F, were estimated by solving the yield regression equation for the optimal value given the average moisture stress (50 percent probability) and varietal index for each crop. For example, given the yield equation (10), the optimal value of Nitrogen occurs when

$$\partial Y/\partial F = e^{(a+bS_i+cD_{ij})} * M_1^f * M_2^k * e^{(gM_1+hM_2)} * V^r * dF^{d-1} = \frac{\text{price N}}{\text{price Y}} \tag{15}$$

From equation (15), it is noted that the marginal product for N fertilzer is continually increasing but at a decreasing rate. The optimal point therefore, occurs when the rate of increase equals the 1986 input/output price ratio. In order to calculate optimal F values, values are needed for the M1, M2 and V variables. Therefore, the 50% probability soil moisture stress values are used for M1 and M2 and the varietal index values for V. For each scenario on each site these values are outlined in Table IV.2.

The optimal fertility levels demonstrate a reduced requirement of nitrogen fertilizer in the SPMT scenarios when compared to SPCT at all sites. The WWMT scenario demonstrates an increased requirement from the SPMT scenarios on all sites and increased requirement from the SPCT scenarios except in Minnedosa where the requirements are similar.

4.1.5 Results of the Agronomy Models

All the data for the yield model variables in terms of soil type, nitrogen fertility, soil moisture stress and variety for each of the SPCT, SPMT and WWMT scenearios on the Graysville, Minnedosa and Pierson sites are outlined in Appendix B. This data when incorporated with the previously estimated parameters of the yield regression (equation 10) generated a series of yields. For the Graysville site, yields over the past 61 years of weather conditions were simulated, for Minnedosa, 100 years were simulated and for Pierson, 75 years. From these simulations, cumulative wheat yield frequency distributions were derived for each scenario and are outlined in Figures IV.7 to IV.9

Table IV.2

Optimal Nitrogen Fertility Levels for 1986 Wheat Fertilizer Prices with 50 % Soil Moisture Stress

Site/ Scenario	50% Early Stage Moisture Stress	50% Late Stage Moisture Stress	Varietal Index	Nitrogen Fertility
	mm	mm		kg/ha
Graysville				
SPCT	75	86	1.25	37
SPMT	75	87	1.25	36
WWMT	80	72	1.50	52
Minnedosa				
SPCT	68	77	1.25	47
SPMT	73	77	1.25	36
WWMT	73	72	1.45	46
Pierson				
SPCT	102	85	1.25	38
SPMT	95	89	1.25	36
WWMT	100	93	1.50	44

FIGURE IV.7

GRAYSVILLE CUMULATED SIMULATED YIELD

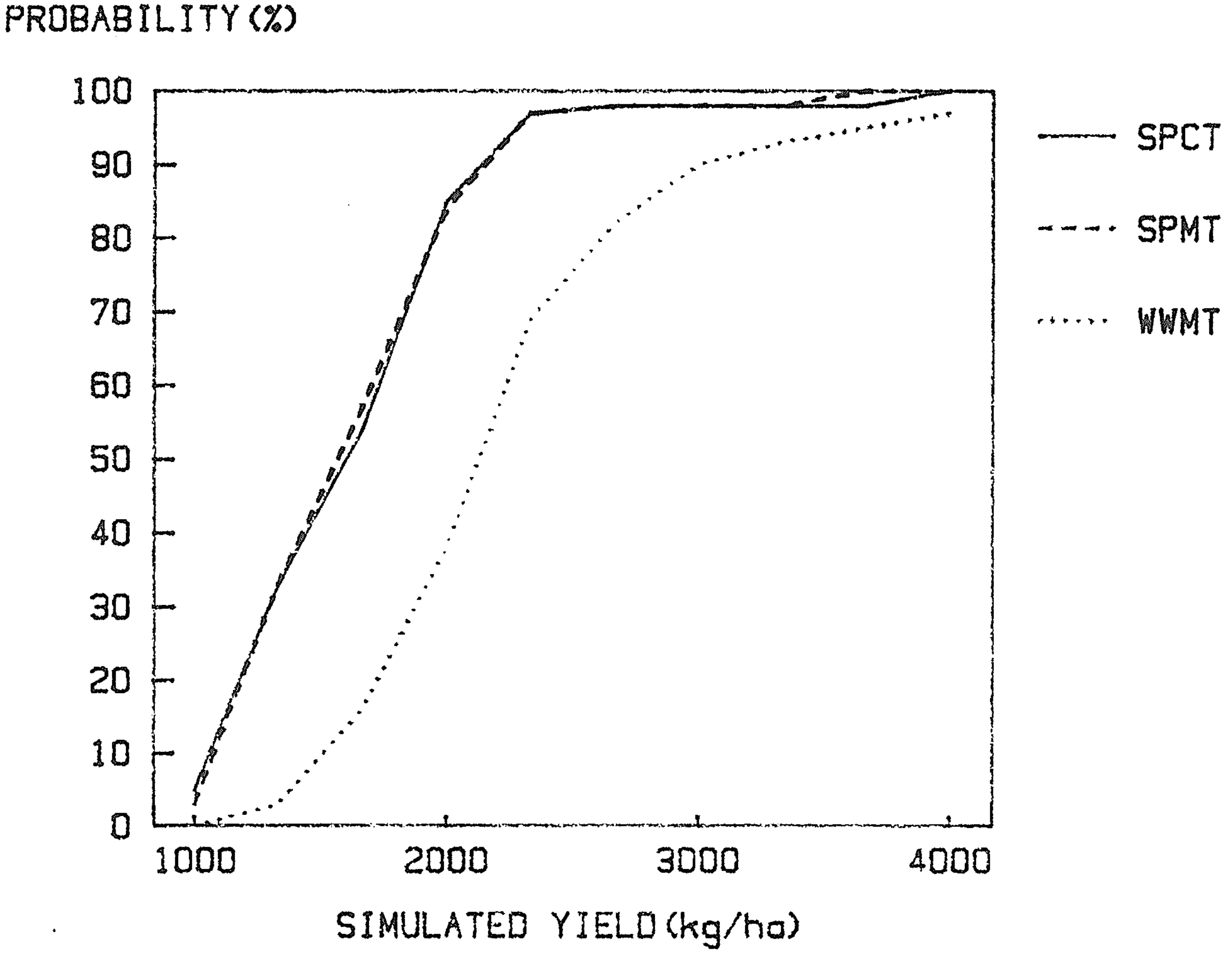


FIGURE IV.8

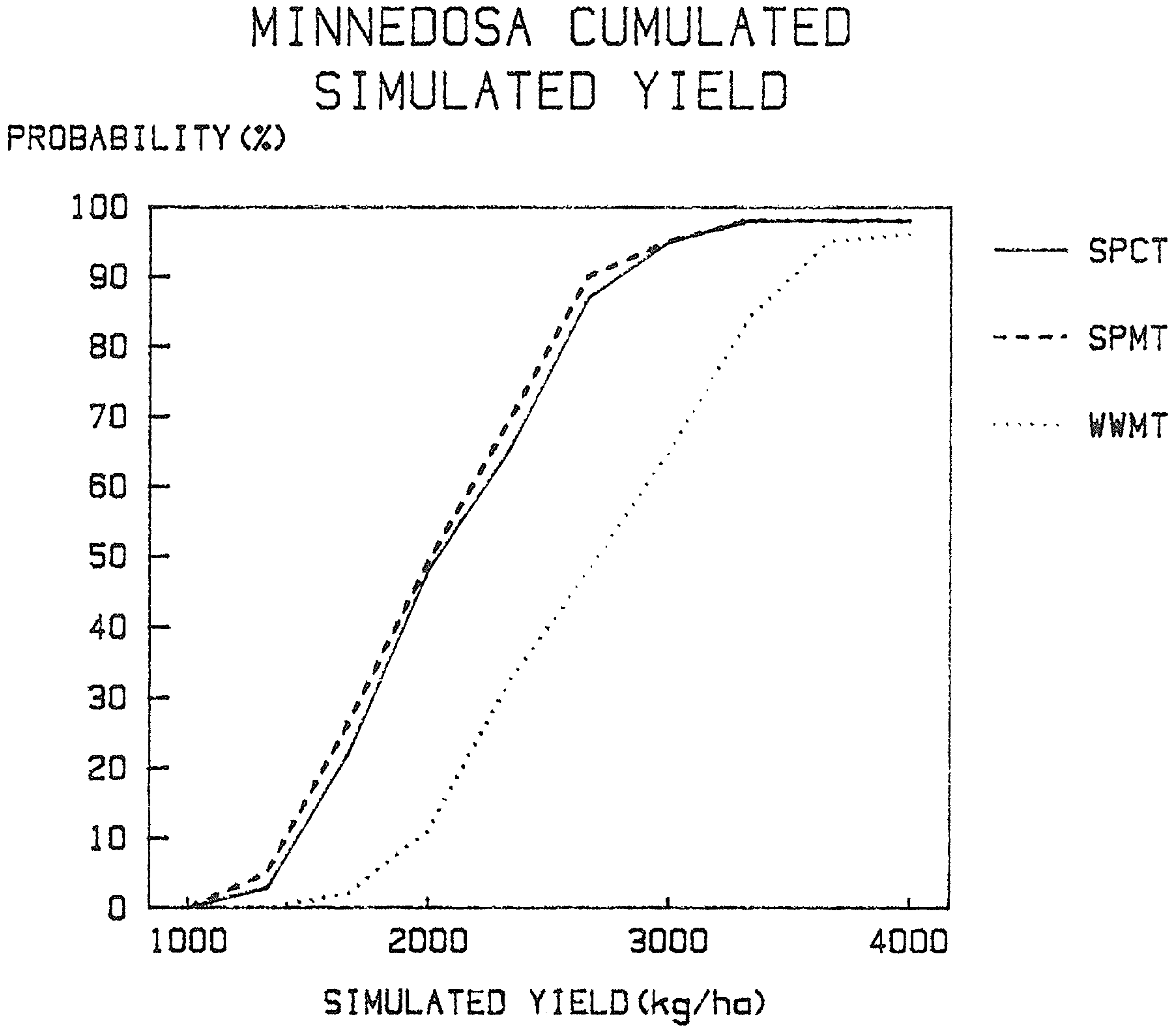
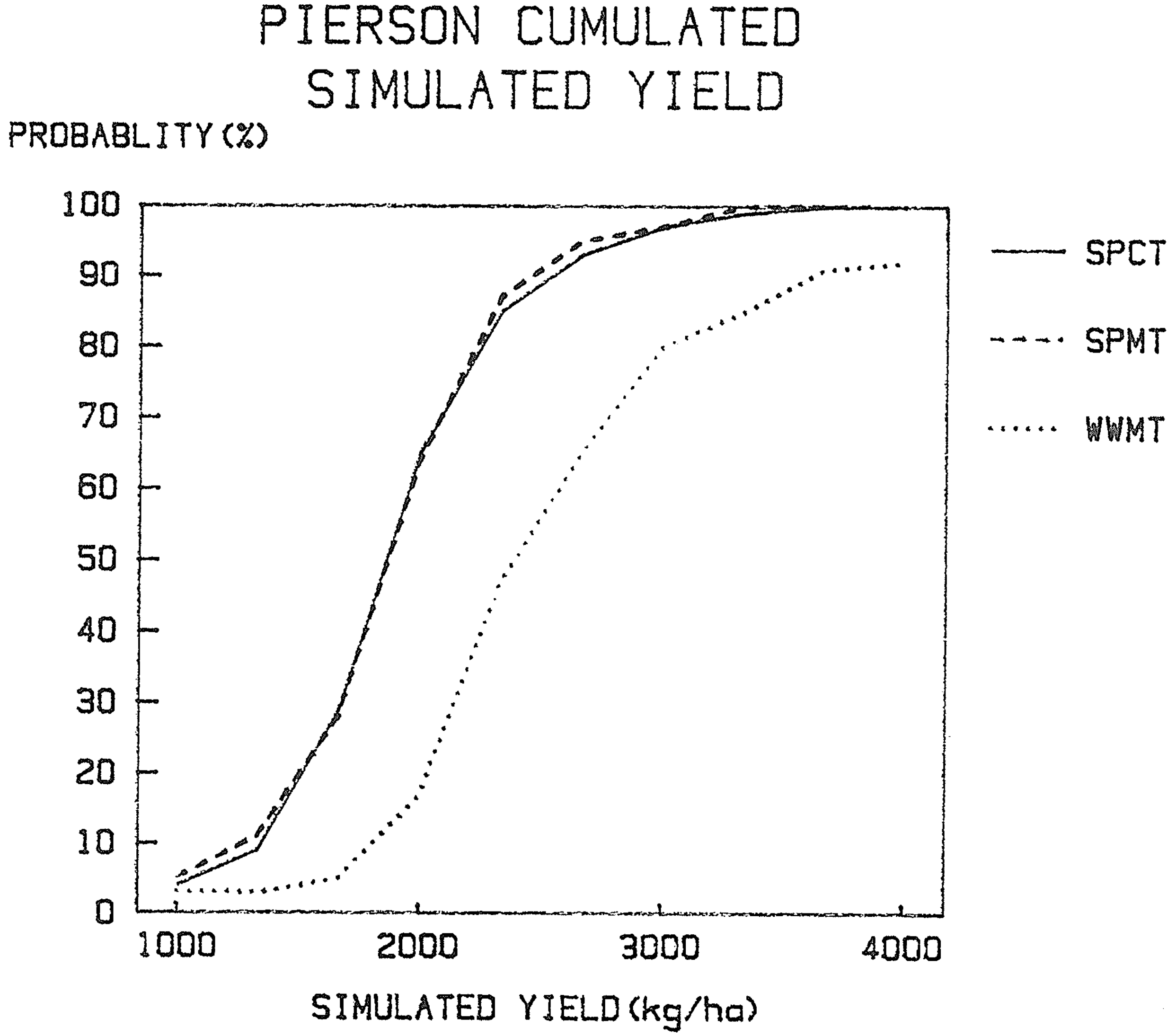

MINNEDOSA CUMULATED
SIMULATED YIELD
PROBABILITY (%)
100
90
80
70
60
50
40
30
20
10
0
1000
2000
3000
4000
SIMULATED YIELD (kg/ha)
SPCT
SPMT
WWMT

FIGURE IV.9


PIERSON CUMULATED
SIMULATED YIELD
PROBABLITY (%)
100
90
80
70
60
50
40
30
20
10
0
1000
2000
3000
4000
SIMULATED YIELD (kg/ha)
SPCT
SPMT
WWMT

These curves represent the cumulative probability of obtaining a certain yield on each site for each scenario. For example, the probability of obtaining a winter wheat yield of 2000 hg/ha, or less, at Minnedosa (figure IV.8) is about 10 percent. The probability of the same yield, or less, under both conventional and minimum tillage is about 40 percent. As such, if the SPCT curve is used as a base curve, a parallel shift to the left of SPCT represents an increase in the probability of getting a lower yield. A parallel shift to the right corresponds to an increase in the probability of getting a higher yield.

The figures demonstrate little, if any, change in yields between conventional tillage practice to minimum tillage for all three locations. The expected increase in simulated yields with the reduced moisture stress of minimum tillage in the early stages of development was equally offset by the disadvantage applied to yields with the reduced moisture stress in the last stages.

A distinct yield advantage was demonstrated under the production of winter wheat with a rightward shift of the WWMT curve compared to the SPCT and SPMT curves on all locations. Since very little distinction can be made on the influence of early stage stress on winter wheat yields when compared to spring wheat, this shift is indicative of the leftward shift of late stage stress in WWMT, the increased fertilizer requirements and the positive impact associated with varietal traits.

A comparison of the expected yields between sites in table IV.3 shows the probability of realizing less than 2000 kg/ha of spring wheat in Minnedosa is 48 percent, while the more arid area around Pierson is only

Table IV.3

Cumulative Probability of Wheat Yields (%)

Yield	Graysville			Minnedosa			Pierson		
Kg/ha	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT	SPCT	SEMT	WWMT
1,000	5	4	0	0	0	0	4	5	3
2,000	85	84	38	48	49	11	65	64	17
3,000	98	98	90	95	95	65	97	97	80
4,000	100	100	97	98	98	96	99	100	92
5,000	100	100	100	99	100	98	100	100	99

65 percent. Graysville has a probability of annual spring wheat yields falling below 2000 kg/ha of 85 percent. The lower yield potential of the Graysville location is primarily due to the effect of sandy loam soils in the yield equation for wheat. In both the Graysville and Pierson sites, the probability that spring wheat yields would fall below 1000 kg/ha was between 4 percent and 5 percent, while the likelihood they would exceed 3000 kg/ha was between 2 percent and 3 percent (100% less 98%). The probability of realizing less than 2000 kg/ha of winter wheat in each site is substantially lower. For example, the more drought prone Pierson area was simulated to have winter wheat yields fall below 2000 kg/ha 17 percent of the time, while spring wheat yield would fall below 2000 kg/ha in two years out of three years. The greater yield potential of winter wheat is primarily responsible for the higher yields (see table III.1) as it was assumed to yield 20 percent more than the spring wheat variety (Neepawa) chosen. Any incidence of winter kill or rust would reduce the simulated yield difference in winter wheat. The probability of either event was not included in estimating the annual winter wheat yields with equation 10 and the weather events for each site.

4.2 DATA INPUT AND RESULTS FROM THE ECONOMIC MODELS

Input for the economic models was based on the results of agronomic models and the set of assumed management operations. Given no significant difference in yield between conventional and minimum tillage of spring wheat production and the distinct yield advantage of winter wheat production, the economic models attempt to ascertain whether the yield results translate into differences in returns given the different cost structure of each practice.

The conventional tillage and minimum tillage operations required a different inventory of equipment. Information on the machinery inventory, the management practices associated with each scenario and the cost of the required inputs make up the set of input data for the Crop Production Simulator. The resulting operating expenses, along with the yield distributions and other financial data make up the set of input data for the Risk Simulation Model. This section outlines the input and results of both the Crop Production Simulator and the Risk Simulation Model.

4.2.1 Crop Production Simulator

Given the machinery inventory, management operations and cost of inputs for each site and scenario as outlined in Appendix C, the resulting operating expenses are presented in Table IV.4 For each site, SPMT demonstrated an increase in operating expenses from three percent at Minnedosa to seven percent at Graysville and Pierson when compared to SPCT. This increase is due for the most part to the additional cost of herbicide. Therefore, the 73 percent increase in the cost of chemical weed control in reduced tillage proved greater than the 18 percent average decline in tillage costs. In order for the operating expenses of minimum tillage to come in line with conventional tillage the price of chemicals must fall by 22%.

Table IV.4

1986 Operating Expenses ($/Ac)

Input	Graysville			Minnedosa			Pierson		
	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT
Fuel+Lub.	16.96	13.01	12.38	17.96	13.46	12.81	17.46	13.23	12.15
Repair	15.94	13.94	12.98	15.94	13.94	12.98	15.94	13.94	12.85
Fert.	18.59	17.91	23.37	22.00	17.91	21.32	18.59	17.91	20.64
Chem.	19.25	33.36	18.05	19.25	33.36	18.05	19.25	33.36	18.05
Seed	8.63	8.63	7.50	8.63	8.63	7.50	8.63	8.63	8.63
Equip.rent.	1.29	1.04	1.04	1.29	1.04	1.04	1.29	1.04	7.50
Mach.Ins.	0.44	0.43	0.43	0.44	0.43	0.43	0.44	0.43	0.43
Overhead	7.85	7.85	7.85	5.35	5.35	5.35	5.87	5.87	5.87
Total Exp.	88.96	96.16	83.59	90.88	94.11	79.47	87.48	94.40	78.83

Operating expenses under the WWMT scenario were lower than SPCT by six percent for Graysville, 13 percent for Minnedosa and 10 percent for Pierson. This was due mainly to reductions in tillage costs by an average of 24 percent and chemical costs by six percent. Fertilizer costs were higher for WWMT than either of the spring wheat scenarios.

In summary, for each site, minimum tillage production of spring wheat required greater operating expenses than does conventional tillage, while winter wheat production required the least direct costs.

Table IV.5 outlines the distribution of labour for the spring (April 1 to June 1); summer (June 1 to July 15); fall (July 15 to November 1); and, winter (November 1 to April 1) working seasons.

While the spring and fall requirements for SPCT exceed available hours, SPMT seasonal requirements are within the hours available. SPMT labour requirements are 90 percent of those for conventional tillage while WWMT requirements are 84 percent. Much of the work for winter wheat production is needed in the fall. This represents a 13 percent increase from SPCT fall requirements.

4.2.2 Risk Simulation Model

A number of the input requirements used by the RSM to construct the financial state of affairs of the enterprises being simulated are held constant over the course of the experiment. The values associated with these variables are given in Table IV.6.

Table IV.5

Estimated Distribution of Labour Requirements for 1,000 Acres of Wheat

	SPCT	SPMT		WWMT	
Season	Hours Spent	Hours Spent	% of SPCT	Hours Spent	% of SPCT
Apr 1-Jun 1	509	348	68	89	17
Jun 1-July 15	82	163	50	82	0
July 15-Nov 1	818	723	88	925	113
Nov 1-Apr 1	299	299	100	330	110
Total	1,707	1,533	90	1,426	84

Table IV.6

RSM Input Data Summary
Variable Held Constant

1.	The beginning year and quarter of the analysis:	1986
2.	The number of productive acres purchased:	0.00
3.	The price paid/acre:	400.00
4.	The average price/acre from recent sales of comparable land:	400.00
5.	The current price of wheat ($/bushel):	4.00
6.	The expected annual increase in yields (%):	1.00
7.	The percentage of land in summerfallow:	0.00
8.	The average quota expected per year (bu/acre):	35.00
9.	The expected annual increase in quota (%):	1.00
10.	The total operating expenses/acre:	
11.	The expected inflation rate for operating expenses (%):	4.00
12.	The present cost of fertilizer/acre:	
13.	The present cost of herbicide/acre:	
14.	The basic living and personal expenditures/year:	15,000
15.	The expected inflation rate for living expenses (%):	4.00
16.	The present nonfarming income:	0.00
17.	The expected annual increase in nonfarming income (%):	0.00
18.	The tot.val.of cash, near cash and operat.supp.:	50.000.00
19:	The beginning wheat and wheat equivalent inventory (bu):	2,500.00
20.	The market value of machinery:	
21.	The average replacement frequency of machinery (yrs.):	15.00
22.	The total number of rented productive acres:	0.00
23.	The total amount owing on accounts payable:	0.00
24:	The Canadian/U.S. exchange rate:	1.36
25.	The expected Can./U.S. exchange rate in 10 years:	1.25
26.	The total number of owned pasture land (acres):	0.00
27.	The total number of owned hay, crop and fallow acres:	1.000.00
28.	The average price/acre of improved farmland (excl. bldgs.):	400.00
29.	The total value of farm buildings (excl. livestock barns):	6,000.00
30.	The present pasture land taxes/acre:	1.00
31.	The present improved land taxes/acre:	
32.	The current operating loan interest rate (%):	12.00
33.	The operating loan outstanding:	10,000.00
34.	The average % of cultivated cropped land/qtr. section:	100.00
35.	The proportion of the generated wheat price to be used:	

The remaining input requirements vary by site and scenario. These values, along with the yield distributions generated from the agronomy models (table IV.7), provide an economic description of the management alternative to be simulated and initialize the starting points for the stochastic and nonstochastic trend variables.

Table IV.7

Input Data to the Risk Simulation Model
which varies by Location and Crop

Data	Graysville			Minnedosa			Pierson		
	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT
Wheat Price (% of Spring Wheat)	1	1	.9	1	1	.9	1	1	.9
Quota (bu/acre)	35	35	45	35	35	45	35	35	45
Operating Cost ($/acre)	88.96	96.16	83.59	90.88	94.11	79.49	87.48	94.40	78.53
Machinery ($/acre)	156	152	152	156	152	152	156	152	152
Taxes ($/acre)	5.10	5.10	5.10	5.27	5.27	5.27	3.58	3.58	3.58
Fertilizer ($/acre)	18.59	17.91	23.37	22.01	17.91	21.32	18.59	17.91	20.64
Herbicide ($/acre)	19.26	33.36	18.05	19.26	33.36	18.05	19.26	33.36	19.26

Tables IV.8 to IV.10 provide samples of one replication of the ten year simulation for the three scenarios at Pierson. Values in each year for the stochastic variables of wheat yield, price and sales along with interest rates vary for each of the 300 replications. The remaining columns are calculated based on these randomly generated data and the information defined in the input data. The annual cash flow and the equity position is then tabled for comparison.

Table IV.8 shows the computer printout from SPCT where the upper portion of the tables is the simulated revenue from wheat sales and direct operating costs. The difference between revenue and direct costs is the gross cash flow from wheat production and it is combined with other sources of revenue (livestock and off-farm income) in the lower half of the table to represent total receipts available to meet debt obligations, purchase equipment, pay income taxes and contribute to household living expenditures. The financial variable tabulated for each replication is the crop gross cash flow which appears in both sections of the table. It represents the income contributed by the crop enterprise to the farm business. A negative amount indicates the farm had to borrow money or cross subsidize the cropping operation from another income source. The simulated crop cash flow registered for 300 replications was tabulated and reported as cumulative probability distribution for the second and tenth year of the simulation. Besides simulating the ten-year crop cash flow, the balance sheet of the business is estimated at the beginning of the ten-year interm and at the end. The growth or decline in equity for each ten-year period is tabulated and reported as a cumulative probability distribution.

Table IV.8

Risk Analysis of Spring Wheat Production in Pierson, Manitoba with Conventional Tillage

CROP ENTERPRISE

Year	Sales (bus)	Carry -over (bus)	Yield (bus/ Acre)	Price ($/ Bus)	Total Revenue ($)	Total Operating Expenses	Gross Cash Flow
1	30363	0	27.8	3.83	116318	94702	21615
2	26509	0	26.5	3.87	102651	98490	4160
3	20085	0	20.0	3.85	77437	102429	-24992
4	29871	1569	31.4	4.86	145355	106526	38828
5	27971	5830	32.2	6.39	178924	110787	68136
6	21654	0	15.8	6.63	143784	115219	28565
7	30592	3039	33.6	6.42	196463	119828	76635
8	29864	1467	28.2	6.01	179524	124621	54903
9	39080	3578	41.1	5.63	220191	129605	90585
10	29614	0	26.0	6.13	181663	134790	46872

Summary of Annual Net Cash Flows from All Enterprises

Year	Stocker Gross Cash Flow($)	Cow-Calf Gross Cash Flow($)	Farrow-Finish Gross Cash ($)	Crop Gross Cash Flow$	Non-Farm Income ($)	Total Gross Cash Flow($)	Interest Rate (%)	Begin Cash Assets ($)	Cash Reserve ($)	Debt Pay-ments ($)	Total Operate Expense ($)	Replace Capital Inputs ($)	Living & Personal Withdraw ($)	Income Tax ($)	Net Cash Flow Before Loan ($)
1	0	0	0	21615	0	21615	0.11	40000	61615	0	94702	25674	15000	0	20941
2	0	0	0	4160	0	4160	0.10	23405	27565	0	98490	11965	15599	0	0
3	0	0	0	-24992	0	-24992	0.13	0	-24992	0	102429	0	16223	0	-41216
4	0	0	0	38828	0	38828	0.15	-45176	-6347	0	106526	0	16872	0	-23220
5	0	0	0	68136	0	68136	0.10	-25866	42269	0	110787	15119	17547	766	8835
6	0	0	0	28565	0	28565	0.11	9781	38346	0	115219	20777	18249	11162	-11843
7	0	0	0	76635	0	76635	0.09	-12870	63764	0	119828	22079	18979	118	22587
8	0	0	0	54903	0	54903	0.07	24746	79650	0	124621	23005	19738	15108	21796
9	0	0	0	90585	0	90585	0.07	23382	113968	0	129605	23930	20528	5599	63910
10	0	0	0	46872	0	46872	0.05	68761	115634	0	134790	24887	21349	18925	50471

Note: An * beside the Debt Payments means the outstanding debt has been refinanced

SIMULATED SUMMARY BALANCE SHEET

Year	Current Assets	Term Assets	Total Assets	Liabilities	Equity
0	+60,000	+615,534	+675,534	+10,000	+665,534
10	+53,396	+568,841	+622,238	+2,612	+619,625

Table IV.9

Risk Analysis of Spring Wheat Production in Pierson, Manitoba
With Minimum Tillage

CROP ENTERPRISE

Year	Sales (bus)	Carry -over (bus)	Yield (bus/ Acre)	Price ($/ Bus)	Total Revenue ($)	Total Operating Expenses	Gross Cash Flow
1	30915	3878	32.2	3.87	119799	101899	17900
2	15154	0	11.2	4.10	62241	105974	-43733
3	25163	0	25.1	4.88	123002	110213	12788
4	24509	0	24.5	5.38	131913	114622	17290
5	29880	0	29.8	6.06	181196	119207	61989
6	39033	410	39.4	5.77	225518	123975	101542
7	22215	0	21.8	5.40	120113	128934	-8820
8	26501	0	26.5	5.27	139904	134091	5812
9	29021	0	29.0	6.02	174796	139455	35341
10	35331	0	35.3	7.05	249276	145033	104242

Summary of Annual Net Cash Flows from All Enterprises

Year	Stocker Gross Cash Flow($)	Cow-Calf Gross Cash Flow($)	Farrow-Finish Gross Cash ($)	Crop Gross Cash Flow$	Non-Farm Income ($)	Total Gross Cash Flow($)	Interest Rate (%)	Begin Cash Assets ($)	Cash Reserve ($)	Debt Pay-ments ($)	Total Operate Expense ($)	Replace Capital Inputs ($)	Living & Personal Withdraw ($)	Income Tax ($)	Net Cash Flow Before Loan ($)
1	0	0	0	17900	0	17900	0.14	40000	57900	0	101899	25028	15000	0	17872
2	0	0	0	-43733	0	-43733	0.15	20439	-23293	0	105974	0	15599	0	-38893
3	0	0	0	12788	0	12788	0.14	-43393	-30604	0	110213	0	16223	0	-46828
4	0	0	0	17290	0	17290	0.15	-51895	-34604	0	114622	4539	16872	0	-56016
5	0	0	0	61989	0	61989	0.15	-62352	-363	0	119207	18577	17547	0	-36489
6	0	0	0	101542	0	101542	0.09	-40705	60837	0	123975	20611	18249	6719	15257
7	0	0	0	-8820	0	-8820	0.10	16767	7947	0	128934	21556	18979	21453	-54041
8	0	0	0	5812	0	5812	0.08	-58334	-52521	0	134091	22429	19738	0	-94689
9	0	0	0	35341	0	35341	0.07	-100598	-65257	0	139455	23327	20528	0	-109113
10	0	0	0	104242	0	104242	0.08	-115145	-10903	0	145033	24260	21349	79	-56592

Note: An * beside the Debt Payments means the outstanding debt has been refinanced

SIMULATED SUMMARY BALANCE SHEET

Year	Current Assets	Term Assets	Total Assets	Liabilities	Equity
0	+60,000	+611,606	+671,606	+10,000	+661,606
10	+0	+565,389	+565,389	+77,575	+487,814

Table IV.10

Risk Analysis of Winter Wheat Production in Pierson, Manitoba

CROP ENTERPRISE

Year	Sales (bus)	Carry -over (bus)	Yield (bus/ Acre)	Price ($/ Bus)	Total Revenue ($)	Total Operating Expenses	Gross Cash Flow
1	27750	0	25.2	3.24	100095	85394	14701
2	35639	0	35.6	3.08	122175	88809	33365
3	46029	0	46.0	3.19	163363	92362	71001
4	8022	0	8.0	3.19	28443	96056	-67613
5	37795	1319	39.1	3.86	162273	99898	62374
6	34376	0	33.0	4.68	178847	103894	74952
7	30906	0	30.9	5.58	191932	108050	83881
8	35348	0	35.3	5.84	229509	112372	117137
9	30134	0	30.1	5.67	189907	116867	73040
10	40690	10671	51.3	5.18	234453	121542	112911

Summary of Annual Net Cash Flows from All Enterprises

Year	Stocker Gross Cash Flow($)	Cow-Calf Gross Cash Flow($)	Farrow-Finish Gross Cash ($)	Crop Gross Cash Flow$	Non-Farm Income ($)	Total Gross Cash Flow($)	Interest Rate (%)	Begin Cash Assets ($)	Cash Reserve ($)	Debt Pay-ments ($)	Total Operate Expense ($)	Replace Capital Inputs ($)	Living & Personal Withdraw ($)	Income Tax ($)	Net Cash Flow Before Loan ($)
1	0	0	0	14701	0	14701	0.14	40000	54701	0	85394	25028	15000	0	14673
2	0	0	0	33365	0	33365	0.15	16738	50103	0	88809	27161	15599	0	7342
3	0	0	0	71001	0	71001	0.11	8449	79450	0	92362	28353	16223	0	34873
4	0	0	0	-67613	0	-67613	0.11	38906	-28707	0	96056	0	16872	9252	-54832
5	0	0	0	62374	0	62374	0.10	-59477	2897	0	99898	0	17547	0	-14650
6	0	0	0	74952	0	74952	0.08	-15793	59159	0	103894	5005	18249	6664	29239
7	0	0	0	83881	0	83881	0.10	31825	115707	0	108050	20102	18979	14997	61626
8	0	0	0	117137	0	117137	0.12	68118	185255	0	112372	22293	19738	17698	125524
9	0	0	0	73040	0	73040	0.12	141761	214802	0	116867	23314	20528	26815	144143
10	0	0	0	112911	0	112911	0.11	161637	274549	0	121542	24259	21349	14260	214679

Note: An * beside the Debt Payments means the outstanding debt has been refinanced

SIMULATED SUMMARY BALANCE SHEET

Year	Current Assets	Term Assets	Total Assets	Liabilities	Equity
0	+60,000	+611,606	+671,606	+10,000	+661,606
10	+300,415	+565,390	+865,806	+25,208	+840,598

Table IV.8 represents one ten-year replication of SPCT for the Pierson site. Year 1 in the analysis is 1986 and wheat prices were lower than the specified 1985 starting price of $4.00 per bushel (table IV.6). Whereas the simulated prices in the replication presented in table IV.8 did not fall as low as the actual prices received by farmers in 1986 and 1987, the prices simulated in other replications approached these levels (see table IV.10). Given that the model does not estimate government payments to the representative farm, the net cash flow is often negative in the first three years (see table IV.9). For example, in year 3 in table IV.8, the farm operating expenditure for wheat production exceeds revenue because of a relatively lower yield and price. This results in an outstanding operating loan of $41,216 at the end of the year. Wheat prices tended to increase after years 3 and 4. Wheat yields in table IV.8 were estimated to range between 15.8 bu/acre and 41.1 bu/acre. The spring wheat probability density function for Pierson (figure IV.9,table IV.2) indicated that a yield of 15 bushels per acre would occur no more than once every 20 years. Table IV.8 also shows that in five of the ten years, the farm could not sell all the wheat produced and carried some inventory into the next crop year. The variability of cash flow from wheat production for a 1,000 acre farm is exhibited in table IV.8 as it ranges form $-24,992 to $90,585. Figures IV.10 through IV.15 display the cumulative probability density functions for each scenario and site for the second and tenth year.

The simulated cash flow contributed by 1,000 acres of spring wheat production in the second year (1987) shows there is a 50 percent probability the enterprise will not return sufficient revenue to pay the

FIGURE IV.10

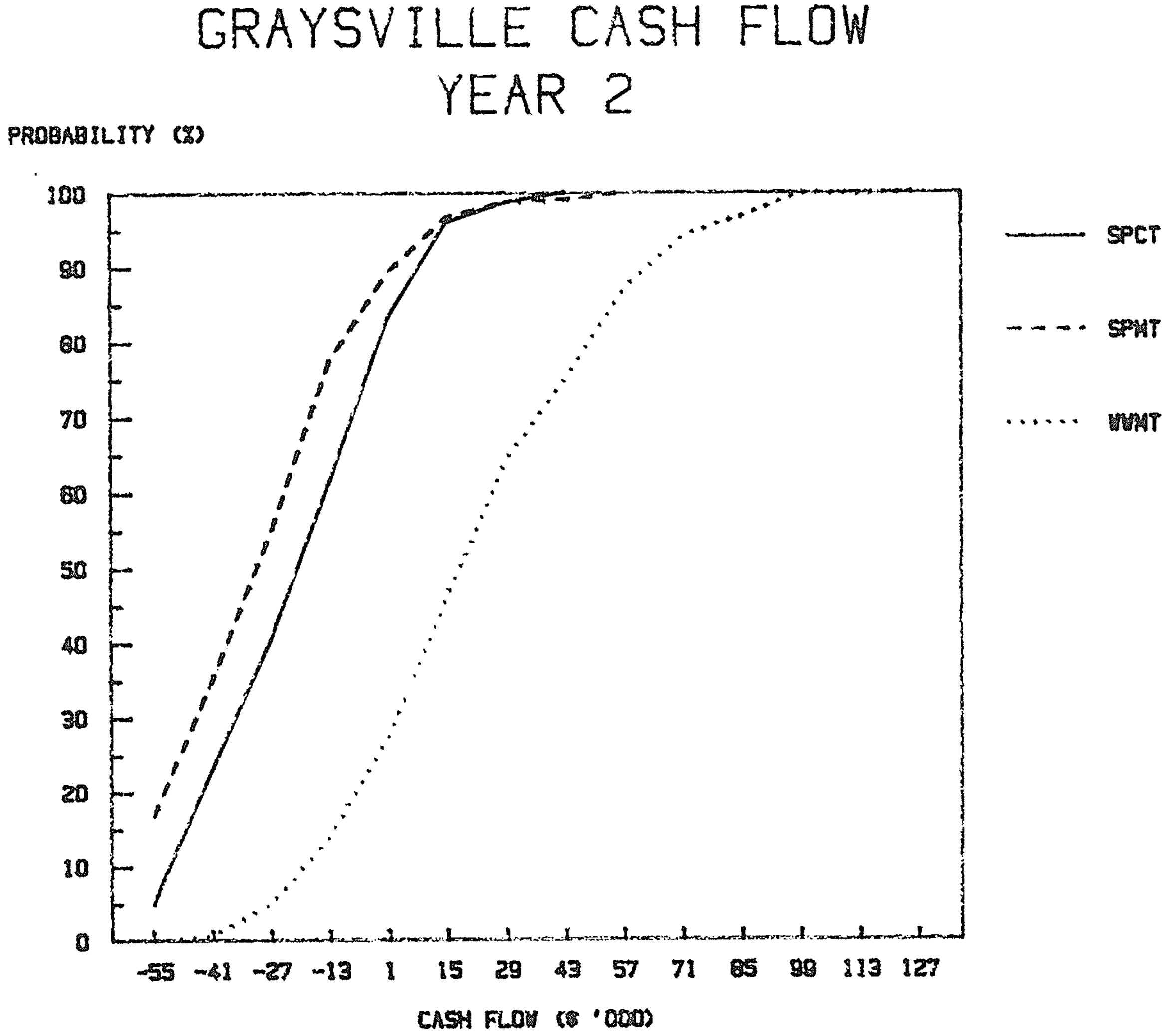

GRAYSVILLE CASH FLOW
YEAR 2

FIGURE IV.11

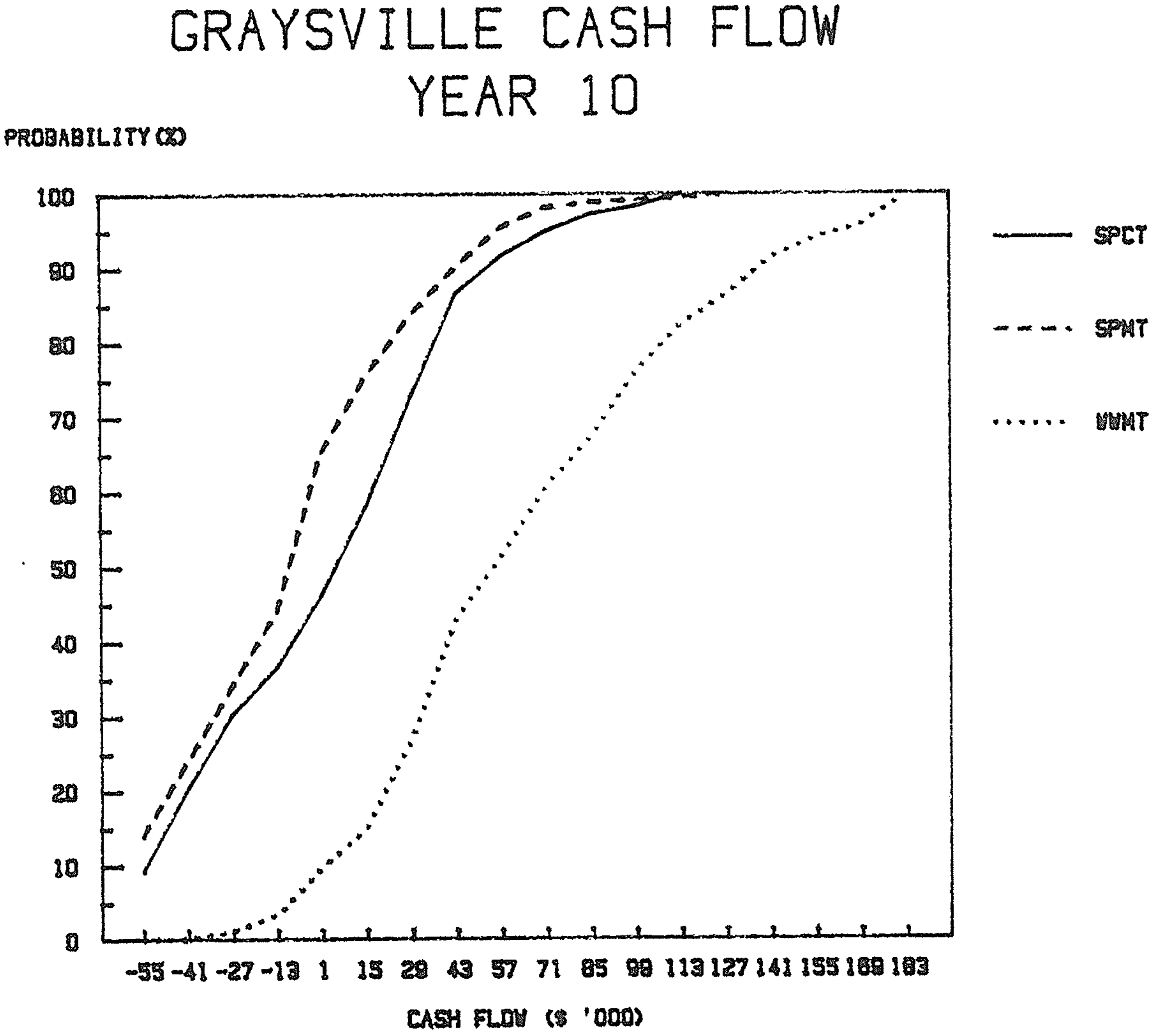

GRAYSVILLE CASH FLOW
YEAR 10
PROBABILITY (%)
100
90
80
70
60
50
40
30
20
10
0
-55
-41
-27
-13
1
15
29
43
57
71
85
99
113
127
141
155
169
183
CASH FLOW ($ '000)
SPCT
SPNT
WWMT

FIGURE IV.12

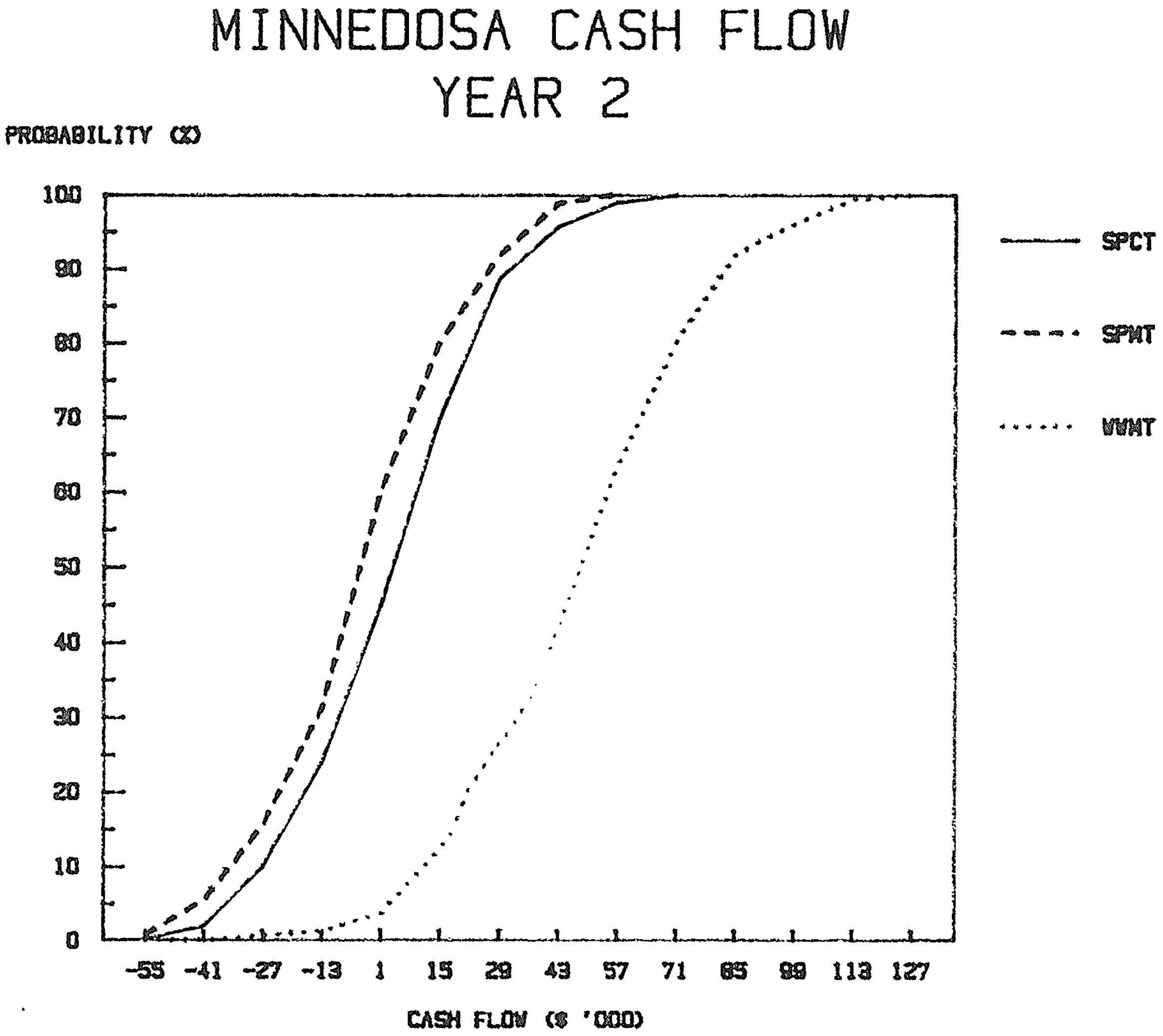

MINNEDOSA CASH FLOW
YEAR 2
PROBABILITY (%)
100
90
80
70
60
50
40
30
20
10
0
-55
-41
-27
-13
1
15
29
43
57
71
85
99
113
127
CASH FLOW ($ '000)
SPCT
SPMT
WWMT

FIGURE IV.13

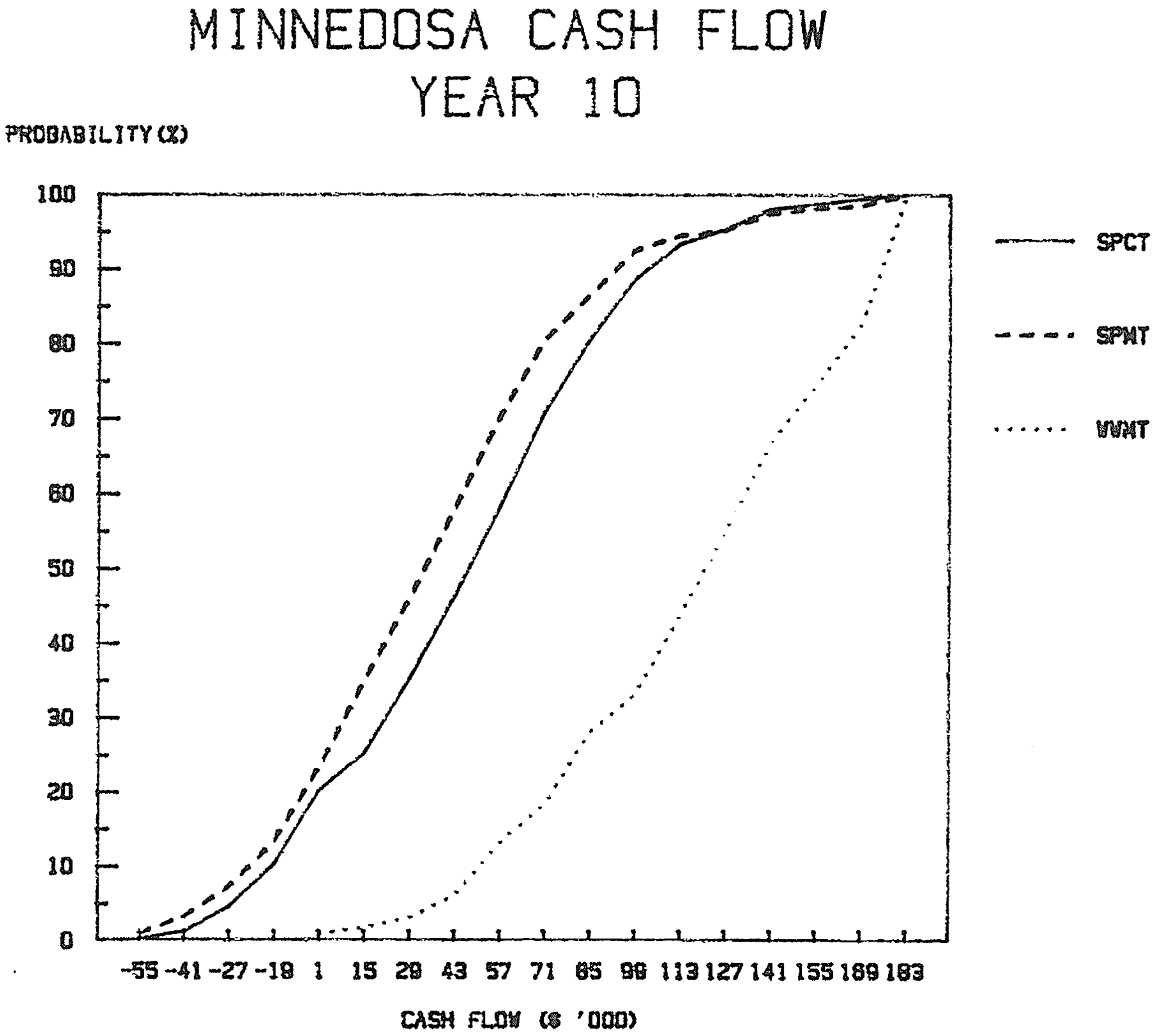

MINNEDOSA CASH FLOW
YEAR 10
PROBABILITY (%)
100
90
80
70
60
50
40
30
20
10
0
-55 -41 -27 -13 1 15 29 43 57 71 85 99 113 127 141 155 169 183
CASH FLOW ($ '000)
SPCT
SPMT
WWMT

FIGURE IV.14

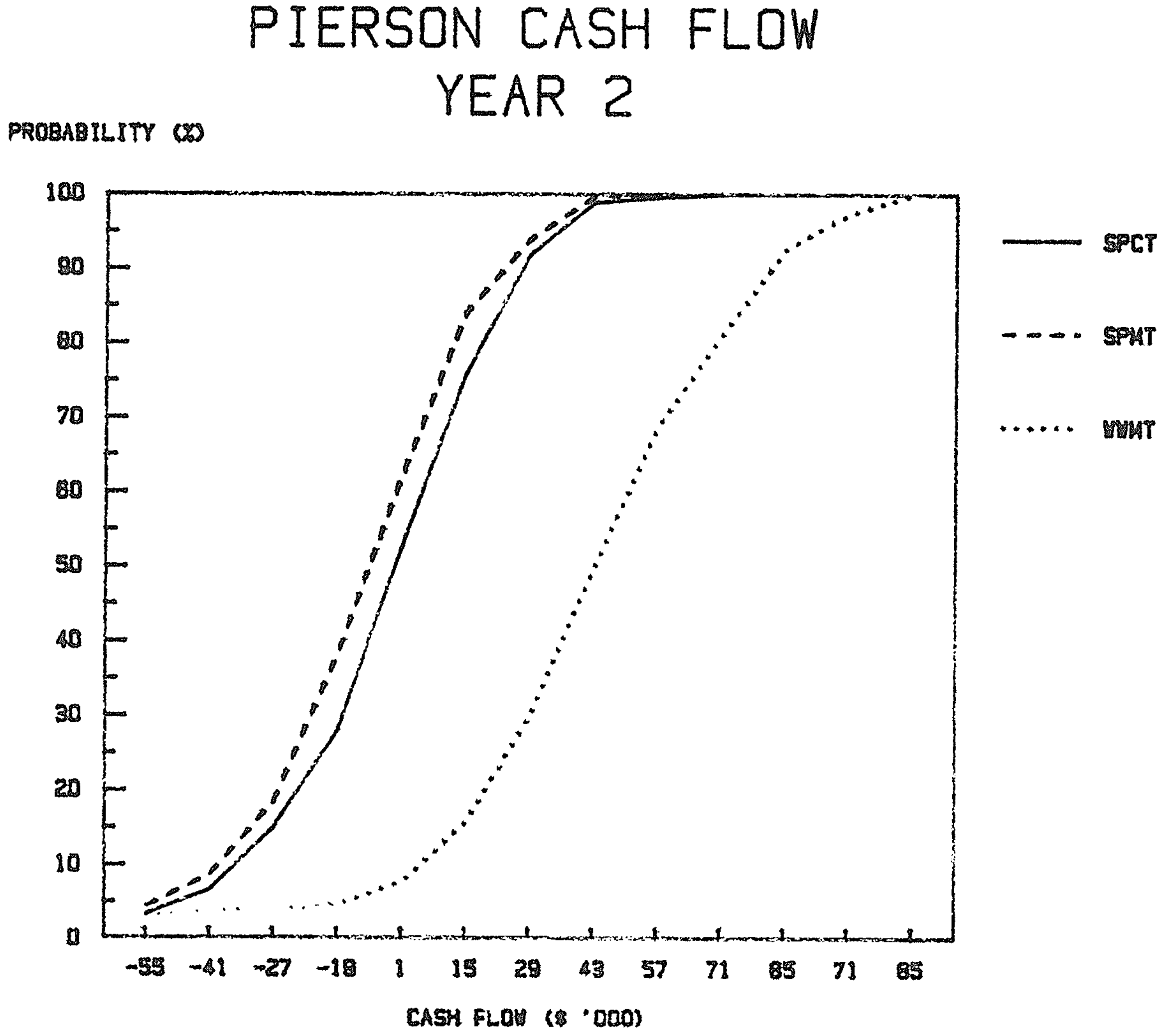
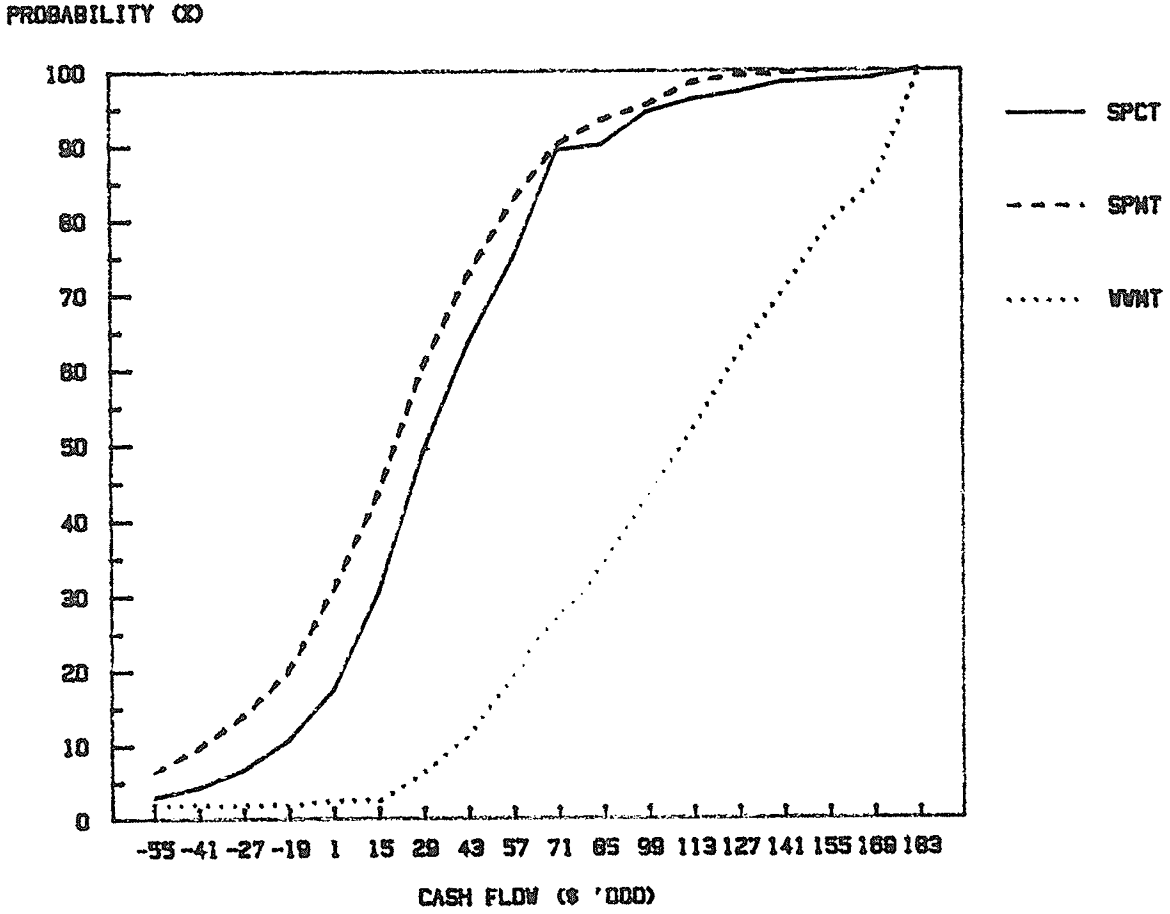

PIERSON CASH FLOW
YEAR 2
PROBABILITY (%)
100
90
80
70
60
50
40
30
20
10
0
-55
-41
-27
-18
1
15
29
43
57
71
85
71
85
CASH FLOW ($ '000)
SPCT
SPMT
WWMT

FIGURE IV.15

PIERSON CASH FLOW
YEAR 10



operating costs. Minimum tillage spring wheat contributes less revenue to the farm than conventional tillage. Winter wheat displays a substantially higher potential as loss is expected only 5 percent of the time. The cash flow difference between spring wheat and winter wheat is linked primarily to the yield probability density function. Spring wheat has a 65 percent probability of falling below 30 bu/acre (2000 kg/ha) while winter wheat has only a 17 percent chance of yielding less than this amount. Given year 2 wheat prices (1987), a yield of approximately 30 bu/acre (2000 kg/ha) is required to meet operating costs. The simulation indicates that winter wheat has a greater probability of achieving this level of production than spring wheat. However, it must be noted that the analysis of winter wheat yields did not account for any yield loss due to winter kill or rust. Whereas the derived yield potential is about 20 percent higher for winter wheat, this difference could be eroded with crop loss from winter kill and rust. Therefore, the relative economic superiority of winter wheat in relationship to spring wheat may be considerably less once the probable incidence of rust and frost damage is taken into account.

The tenth year of the simulated wheat cash flows show a much lower probability of deficits from crop production. Future wheat prices are projected to increase the likelihood a grain farm will meet the operating costs. However, the simulation suggests that annual spring wheat produced with conventional tillage still has a 15 percent chance of not meeting all operating costs in year 10. The farm has a 50 percent chance of receiving more than $30,000 ($30/acre) and a 10 percent chance that the wheat crop will contribute more than $65,000 ($65/acre) to the business in 1990. No negative net cash flows were projected for winter wheat in the tenth year. The cumulative probability density function of each site for winter wheat in the tenth year shows tha variance in cash flow exceeds spring wheat. The higher variance is likely attributed to realizing the relatively higher yield potential when soil moisture is less limiting. If the probability of winter kill and rust were included, this would increase the net cash flow variance even more. Winter wheat likely has a higher income potential but exhibits more variability than spring wheat.

Figures IV.10 to IV.13 show the comparable cumulative probability gross margin functions for the Minnedosa and Graysville site. Minnedosa has a comparable gross margin variance with Pierson with a modest increase in expected gross margin for the same probability. Graysville has a substantially lower level of gross margin. For example, in figure IV.10, the probability of a negative gross margin in the tenth year for spring wheat conventional tillage is 45 percent in Graysville while both Minnedosa and Pierson were in the 15 percent range. Given the cost structure (tables IV.4 and IV.6) and the wheat yield probability density functions specified for Graysville, the simulation suggests that wheat production would not be economically viable. Given the historical weather at Graysville and the wheat yield functions specified to represent a sandy loam soil, either the cost structure for continuous cropping is too high for the soil and climate conditions or the yield estimates (equation 10) are too low when adjusted for sandy loam soils. Wheat is grown on the sandy loam soils in the Graysville area and most farms continue to be viable businesses. Therefore, the gross margin simulations are too low. The cumulative density yield function (figure IV.7) for Graysville shows an average yield of 1600 kg/ha while the average yield noted by the Manitoba Crop Insurance Corporation is 1900 kg/ha. Simulated wheat yields are probably under estimated for the Graysville site.

The growth or decline in net worth for each site and scenario is presented in table IV.11. Simulated growth in farm net worth at the Minnedosa and Pierson sites with spring wheat production shows a stable business environment. After ten years of producing spring wheat with conventional tillage, the simulated farm in Minnedosa had shown no real accumulation of wealth 68 percent of the time. Year 10 found 12 percent of the time farmers could expect to increase their real net worth between 2 percent to 8 percent each year while 17 percent of the time, the business had shown a decline of 2 to 8 percent.

A decline in net worth was most often associated with a combination of relatively low crop yields in the first two to three years of the simulation when wheat prices were depressed (1986 to 1988). The simulation required the farm to borrow added monies and the liabilities were not paid off by year 10. The model did not account for transfer payments in the form of stabilization or the Canadian Special Grains Programs which have contributed substantially to farm income in 1986 and 1987. Clearly the model suggests a winter wheat rotation will allow the farm to accumulate more wealth than either spring wheat management systems. However, this result assumes no rust infestations or winter kill over the ten years the business was simulated.

Table IV.11

Simulated Probability of the Annual Growth (Decline) in New Worth

Growth Rate (%)	Graysville			Minnedosa			Pierson		
	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT
< -8	65	86	4	4	9	7	9	28	5
-2 to -8	23	12	1	9	17	0	17	23	0
-2 to +2	12	2	45	68	62	0	71	48	4
2 to 8	0	0	48	19	12	52	3	1	67
8+	0	0	2	0	0	41	0	0	24

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Various models derived from previous research were linked to develope a Monte-Carlo simulation as an approach to evaluate cropping alternatives. This approach proved to be effective and the models used lent themselves very well to the objectives of the study.

The accuracy and acceptability of the method chosen is based on the accuracy of the input data, each model's ability to simulate the real world and the acceptability of each model when originally introduced. The exogenous input data for each model is highly accurate since it is derived from observations of the real world. Since the accuracy and acceptability of each model was assessed by previous researchers when developed, this study is more interested in the trends of the outcomes when compared to a base scenario.

The ability of the BMTS, VSMB, yield regression, CPS and RSM models to accept data from a previous model, simulate one component of the crop production system and generate data for a subsequent model provides for a very workable and flexible alternative to costly field plot research or management surveys. Since each model is the result of previous agronomic research or defined economic identities, they may be applied to a very wide range of management alternatives in crop production simply by specifying the appropriate data at any step in the simulation process.

The ability of the models as a working group to capture the stochastic nature of weather, yields, price, interest rates and deliveries and to generate outcomes with a probabilistic degree of certainty allows for further flexibility in drawing conclusions about a particular management or cropping system. As such, recommendations on management alternatives can be scaled to fit either the risk taking or risk averse entrepeneur.

In summary, Monte-Carlo simulation is a very useful and highly adaptable approach to assess the economics of management alternatives in crop production.

The cropping alternatives that were economically assessed by the Monte-Carlo simulation included minimum tillage production of spring and winter wheat using spring wheat production under conventional tillage as a base comparison. The results indicate that very little difference in yield occurs whether adopting conventional or minimum tillage practices for the production of spring wheat. A distinct yield advantage occurs when adopting minimum tillage practices for the production of winter wheat due to the better utilization of seasonal climatic conditions as well as increased returns to fertilizer and the positive impact associated with varietal traits of winter wheat.

Minimum tillage production of spring wheat requires greater operating expenses than conventional tillage practices since the additional chemical costs proved greater than the savings realized from reduced tillage. Minimum tillage production of winter wheat requires less operating expenses than spring wheat since the chemical requirements are significantly reduced. Therefore, the reduced expenses, when compared to conventional tillage, are mainly the result of reduced tillage costs.

Minimum tillage production of spring wheat requires less labour, overall, than conventional tillage and is also more evenly distributed throughout the year. Minimum tillage production of winter wheat requires less labour, overall, than both minimum and conventional tillage of spring wheat. However, labour requirements are more concentrated in the fall and during this time more labour is required than the other cases.

The combination of increased operating costs and no difference in yield translates into reduced annual cash flow when growing spring wheat under minimum tillage rather than conventional tillage. Since equity was being eroded over time in the conventional tillage enterprise, the probability of reduced annual cash flow meant an even greater degree of erosion in equity for minimum tillage production of spring wheat.

The yield advantage and reduced operating expenses of winter wheat more than offset the lower price per unit and generate the probability of greater annual cash flow. The probability of growth in net worth is much greater for winter wheat production than spring wheat production.

In summary, the production of spring wheat under minimum tillage has the probability of lower economic returns than those realized from the production of spring wheat under conventional tillage practices. This is mainly the result of the high cost of chemicals compared to the cost of tillage. The production of winter wheat under minimum tillage has the probability of greater economic returns than those realized from the production of spring wheat under both conventional and minimum tillage. This is the result of minimal chemical and tillage requirements and distinct yield advantages, despite lower output prices.

5.2 LIMITATIONS

The series of models used proved to be well suited for the simulation of crop production and may be easily adapted to a wide variety of cropping alternatives and changes to the crop production system. However, when assessed individualy, each model has its limitations.

The parameters for the agronomic yield equation were developed to best explain historical events and were then used to generate a probabilistic frequency of occurrences under slightly different circumstances. Although the model was adjusted for these circumstances, one can never be sure if the effect of the new circumstances was completely accounted for short of lengthy and costly field work verification.

The VSMB was used to provide an indicator of moisture stress which, in turn was a determining factor in crop yields. Although its validity has been successfully assessed a number of times, less attention has been focused on its sensitivity to a number of components. Therefore, some implications may be lost when analyzing the results of a change in one component when compared the base experiment if more than one component is altered.

For the purposes of this study, the RSM was used under the acceptance of limitations inherent with its application. For instance, the price forecasting model's ability to define, in a probabilistic sense, an uncertain event of the future based on historical data. As such, events of the future must resemble those of the past if the results are to be deemed valid (Dzisiak, 1987).

The study assumes a distinct relation between spring wheat and winter wheat prices within the RSM. If significant evidence suggests that the two varieties of wheat operate within unrelated market's and market forces, then modifications must be made to the model to more adequately generate forecasts of winter wheat prices.

Other assumptions that warrant consideration include the assumption that the possible damage to crops from rust infestation is controlled with the application of Diathane M45 and that the possible damage to crops from winter kill is controlled with adequate snow trapping from minimum tillage practices. In some years both these assumptions may not hold true. However, avenues required to completely account for such occurrences are complex and may not significantly alter the resulting trends.

The study failed to account for opportunity costs or extenuating liabilities of intensified erosion under conventional tillage practices. Again, the complexities involved in accounting for erosion as well as the lack of knowledge of the long run impacts are reasons for its omission. Furthermore, the time frame and outlook is different for each entreprenuer in their assessment of risk whereby the degree of significance of incorporating such costs is uncertain.

5.3 RECOMMENDATIONS

In light of the conclusions and limitations of the study, further research into the topic of economic assessment of cropping alternatives is recommended. This should include some means of ground truthing the trends revealed from simulation techniques. With respect to the comparisons between minimum tillage and conventional tillage and the production of winter wheat, sensitivity analysis applied to key economic variables is recommended. This would provide a better determination of the point at which each variable becomes a limiting factor and would provide insight into policy directives required to bring about necessary changes.

The recent stress placed on the crop production sector has brought an even greater need to effectively manage choices in production alternatives. It is recommended that further study be conducted into fine tuning the ability of the simulation process to evaluate any change in the crop production system as well as broadening the application of the various models used.

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Appendix A

INPUT AND RESULTS OF THE YIELD REGRESSION

Parameters for the yield regression equation (10) were estimated by taking the log of the functional form applying the ordinary least squares method of regression to the data as presented in Table A.1. This data was generated from a survey of fertility field trials at various locations across Manitoba as reported in the annual of the Manitoba Soil Science Proceedings. The was model was first estimated by applying each trial site with its own dummy variable, Dn, and setting its value equal to 1 for those observations occurring on that site and 0 for all other observations. The parameters for this matrix of variables that did not prove statistically significant were then eliminated under the assumption that no specific management activities occurred on these trials that were significantly different from the other trials. Those parameters for Dn that proved significant remained and a final estimate of the variable parameters was achieved as outlined in equation (10).

Table A.1

Yield Regression Data

Observation	Year	Weather Station	Yield	Nitrogen Fertilizer	Early Stage Moisture Stress	Late Stage Moisture Stress	Variety Index	Soil Type
7	1956	5010480	11.9	0.0	47.16	42.55	1.255	1
8	1956	5010480	32.8	3.3	47.16	42.55	1.255	1
9	1956	5023160	29.0	0.0	28.81	10.50	1.255	3
10	1956	5023160	38.4	43.2	28.81	10.50	1.255	3
11	1957	5011760	23.8	0.0	82.62	31.30	1.255	1
12	1957	5011760	35.0	3.3	82.62	31.30	1.255	1
13	1957	5011760	9.8	0.0	59.44	9.86	1.255	2
14	1957	5011760	11.1	4.4	59.44	9.86	1.255	2
15	1957	5011760	12.2	7.7	59.44	9.86	1.255	2
16	1957	5011760	18.7	15.4	59.44	9.86	1.255	2
17	1957	5011760	18.7	15.4	59.44	9.86	1.255	2
18	1957	5011760	24.0	0.0	59.44	9.86	1.255	2
19	1957	5011760	28.9	39.6	59.44	9.86	1.255	2
20	1957	5011760	24.5	4.4	59.44	9.86	1.255	2
21	1957	5011760	27.3	7.7	59.44	9.86	1.255	2
22	1957	5011760	39.9	15.4	59.44	9.86	1.255	2
23	1957	5011760	30.6	15.4	59.44	9.86	1.255	2
24	1957	5011760	35.3	25.9	59.44	9.86	1.255	2
25	1957	5011760	32.0	44.0	59.44	9.86	1.255	2
26	1957	5012400	24.8	0.0	83.84	49.77	1.255	2
27	1957	5012400	26.2	4.4	83.84	49.77	1.255	2
28	1957	5012400	21.7	7.7	83.84	49.77	1.255	2
29	1957	5012400	26.8	15.4	83.84	49.77	1.255	2
30	1957	5012400	24.4	15.4	83.84	49.77	1.255	2
31	1957	5020320	15.0	0.0	36.42	19.91	1.255	2
32	1957	5020320	18.6	4.4	36.42	19.91	1.255	2
33	1957	5020320	20.0	7.7	36.42	19.91	1.255	2
34	1957	5020320	21.1	15.4	36.42	19.91	1.255	2
35	1957	5020320	22.6	15.4	36.42	19.91	1.255	2
36	1957	5020320	20.9	25.9	36.42	19.91	1.255	2
37	1957	5022120	25.3	0.0	60.79	10.09	1.255	2
38	1957	5022120	25.4	4.4	60.79	10.09	1.255	2
39	1957	5022120	26.7	7.7	60.79	10.09	1.255	2
40	1957	5022120	32.9	15.4	60.79	10.09	1.255	2
41	1957	5022120	28.4	15.4	60.79	10.09	1.255	2
42	1957	5022120	21.0	25.9	60.79	10.09	1.255	2
43	1957	5022780	14.4	0.0	39.34	16.09	1.255	3
44	1957	5022780	16.6	4.4	39.34	16.09	1.255	3
45	1957	5022780	21.1	7.7	39.34	16.09	1.255	3
46	1957	5022780	23.0	15.4	39.34	16.09	1.255	3
47	1957	5022780	25.8	15.4	39.34	16.09	1.255	3
48	1957	5022780	24.7	25.9	39.34	16.09	1.255	3
49	1957	5022780	18.9	14.1	39.34	16.09	1.255	3
50	1957	5022780	24.3	33.5	39.34	16.09	1.255	3
51	1957	5023160	22.6	0.0	31.03	9.50	1.255	3

52	1957	5023160	38.7	43.2	31.03	9.50	1.255	3
53	1957	5031040	32.7	0.0	33.86	7.55	1.255	3
54	1957	5031040	36.1	37.6	33.86	7.55	1.255	3
55	1957	5031040	58.2	4.4	33.86	7.55	1.255	3
56	1957	5031040	47.7	7.7	33.86	7.55	1.255	3
57	1957	5031040	38.1	15.4	33.86	7.55	1.255	3
58	1957	5031040	33.6	15.4	33.86	7.55	1.255	3
59	1957	5031040	37.4	25.9	33.86	7.55	1.255	3
60	1957	5031040	49.8	44.0	33.86	7.55	1.255	3
61	1958	5010480	15.0	0.0	138.94	108.93	1.255	1
62	1958	5010480	32.4	3.3	138.94	108.93	1.255	1
63	1958	5012080	15.3	0.0	164.74	123.94	1.255	1
64	1958	5012080	14.8	3.6	164.74	123.94	1.255	1
65	1958	5012080	16.7	6.7	164.74	123.94	1.255	1
66	1958	5012080	13.5	13.4	164.74	123.94	1.255	1
67	1958	5012080	17.9	26.8	164.74	123.94	1.255	1
68	1958	5012080	17.8	4.5	164.74	123.94	1.255	1
69	1958	5012080	17.5	7.8	164.74	123.94	1.255	1
70	1958	5012080	17.7	14.5	164.74	123.94	1.255	1
71	1958	5012080	17.6	27.9	164.74	123.94	1.255	1
72	1958	5012080	18.6	5.6	164.74	123.94	1.255	1
73	1958	5012080	20.9	8.9	164.74	123.94	1.255	1
74	1958	5012080	15.4	15.6	164.74	123.94	1.255	1
75	1958	5012080	15.3	29.0	164.74	123.94	1.255	1
76	1958	5012080	15.8	7.8	164.74	123.94	1.255	1
77	1958	5012080	14.0	11.1	164.74	123.94	1.255	1
78	1958	5012080	17.9	17.8	164.74	123.94	1.255	1
79	1958	5012080	18.3	31.2	164.74	123.94	1.255	1
80	1958	5012280	44.4	0.0	103.24	6.20	1.255	1
81	1958	5012280	42.7	3.6	103.24	6.20	1.255	1
82	1958	5012280	51.2	6.7	103.24	6.20	1.255	1
83	1958	5012280	63.7	13.4	103.24	6.20	1.255	1
84	1958	5012280	70.3	26.8	103.24	6.20	1.255	1
85	1958	5012280	45.4	4.5	103.24	6.20	1.255	1
86	1958	5012280	46.4	7.8	103.24	6.20	1.255	1
87	1958	5012280	59.7	14.5	103.24	6.20	1.255	1
88	1958	5012280	74.2	27.9	103.24	6.20	1.255	1
89	1958	5012280	39.3	5.6	103.24	6.20	1.255	1
90	1958	5012280	53.9	8.9	103.24	6.20	1.255	1
91	1958	5012280	62.6	15.6	103.24	6.20	1.255	1
92	1958	5012280	74.8	29.0	103.24	6.20	1.255	1
93	1958	5012280	44.9	7.8	103.24	6.20	1.255	1
94	1958	5012280	54.0	11.1	103.24	6.20	1.255	1
95	1958	5012280	56.4	17.8	103.24	6.20	1.255	1
96	1958	5012280	75.3	31.2	103.24	6.20	1.255	1
97	1958	5012500	26.5	0.0	106.94	71.44	1.255	2
98	1958	5012500	34.7	3.6	106.94	71.44	1.255	2
99	1958	5012500	30.8	6.7	106.94	71.44	1.255	2
100	1958	5012500	31.8	13.4	106.94	71.44	1.255	2
101	1958	5012500	38.1	26.8	106.94	71.44	1.255	2
102	1958	5012500	30.4	4.5	106.94	71.44	1.255	2
103	1958	5012500	34.4	7.8	106.94	71.44	1.255	2
104	1958	5012500	37.1	14.5	106.94	71.44	1.255	2
105	1958	5012500	37.2	27.9	106.94	71.44	1.255	2
106	1958	5012500	33.5	5.6	106.94	71.44	1.255	2

107	1958	5012500	33.6	8.9	106.94	71.44	1.255	2
108	1958	5012500	41.5	15.6	106.94	71.44	1.255	2
109	1958	5012500	44.5	29.0	106.94	71.44	1.255	2
110	1958	5012500	33.1	7.8	106.94	71.44	1.255	2
111	1958	5012500	38.5	11.1	106.94	71.44	1.255	2
112	1958	5012500	45.4	17.8	106.94	71.44	1.255	2
113	1958	5012500	43.3	31.2	106.94	71.44	1.255	2
114	1958	5012960	28.5	0.0	134.32	67.01	1.255	1
115	1958	5012960	33.3	3.6	134.32	67.01	1.255	1
116	1958	5012960	27.9	6.7	134.32	67.01	1.255	1
117	1958	5012960	33.7	13.4	134.32	67.01	1.255	1
118	1958	5012960	24.4	26.8	134.32	67.01	1.255	1
119	1958	5012960	30.6	4.5	134.32	67.01	1.255	1
120	1958	5012960	28.3	7.8	134.32	67.01	1.255	1
121	1958	5012960	36.1	14.5	134.32	67.01	1.255	1
122	1958	5012960	37.5	27.9	134.32	67.01	1.255	1
123	1958	5012960	31.5	5.6	134.32	67.01	1.255	1
124	1958	5012960	36.0	8.9	134.32	67.01	1.255	1
125	1958	5012960	35.5	15.6	134.32	67.01	1.255	1
126	1958	5012960	39.2	29.0	134.32	67.01	1.255	1
127	1958	5012960	41.8	7.8	134.32	67.01	1.255	1
128	1958	5012960	39.4	11.1	134.32	67.01	1.255	1
129	1958	5012960	37.7	17.8	134.32	67.01	1.255	1
130	1958	5012960	50.4	31.2	134.32	67.01	1.255	1
131	1958	5020320	19.5	0.0	119.99	64.60	1.255	2
132	1958	5020320	24.0	3.6	119.99	64.60	1.255	2
133	1958	5020320	31.3	6.7	119.99	64.60	1.255	2
134	1958	5020320	26.8	13.4	119.99	64.60	1.255	2
135	1958	5020320	19.5	26.8	119.99	64.60	1.255	2
136	1958	5020320	24.1	4.5	119.99	64.60	1.255	2
137	1958	5020320	23.5	7.8	119.99	64.60	1.255	2
138	1958	5020320	23.7	14.5	119.99	64.60	1.255	2
139	1958	5020320	23.4	27.9	119.99	64.60	1.255	2
140	1958	5020320	20.1	5.6	119.99	64.60	1.255	2
141	1958	5020320	24.9	8.9	119.99	64.60	1.255	2
142	1958	5020320	22.7	15.6	119.99	64.60	1.255	2
143	1958	5020320	25.4	29.0	119.99	64.60	1.255	2
144	1958	5020320	30.2	7.8	119.99	64.60	1.255	2
145	1958	5020320	24.0	11.1	119.99	64.60	1.255	2
146	1958	5020320	27.2	17.8	119.99	64.60	1.255	2
147	1958	5020320	24.0	31.2	119.99	64.60	1.255	2
148	1958	5021920	33.0	0.0	91.25	31.71	1.255	3
149	1958	5021920	32.6	3.6	91.25	31.71	1.255	3
150	1958	5021920	28.6	6.7	91.25	31.71	1.255	3
151	1958	5021920	35.5	13.4	91.25	31.71	1.255	3
152	1958	5021920	30.9	26.8	91.25	31.71	1.255	3
153	1958	5021920	39.6	4.5	91.25	31.71	1.255	3
154	1958	5021920	39.9	7.8	91.25	31.71	1.255	3
155	1958	5021920	39.8	14.5	91.25	31.71	1.255	3
156	1958	5021920	33.3	27.9	91.25	31.71	1.255	3
157	1958	5021920	43.8	5.6	91.25	31.71	1.255	3
158	1958	5021920	36.5	8.9	91.25	31.71	1.255	3
159	1958	5021920	36.1	15.6	91.25	31.71	1.255	3
160	1958	5021920	40.4	29.0	91.25	31.71	1.255	3
161	1958	5021920	35.9	7.8	91.25	31.71	1.255	3

162	1958	5021920	41.9	11.1	91.25	31.71	1.255	3
163	1958	5021920	39.5	17.8	91.25	31.71	1.255	3
164	1958	5021920	39.3	31.2	91.25	31.71	1.255	3
165	1958	5031040	44.5	0.0	58.07	15.49	1.255	2
166	1958	5031040	42.3	3.6	58.07	15.49	1.255	2
167	1958	5031040	39.1	6.7	58.07	15.49	1.255	2
168	1958	5031040	45.9	13.4	58.07	15.49	1.255	2
169	1958	5031040	39.2	26.8	58.07	15.49	1.255	2
170	1958	5031040	43.0	4.5	58.07	15.49	1.255	2
171	1958	5031040	45.3	7.8	58.07	15.49	1.255	2
172	1958	5031040	44.0	14.5	58.07	15.49	1.255	2
173	1958	5031040	40.9	27.9	58.07	15.49	1.255	2
174	1958	5031040	42.0	5.6	58.07	15.49	1.255	2
175	1958	5031040	40.0	8.9	58.07	15.49	1.255	2
176	1958	5031040	43.3	15.6	58.07	15.49	1.255	2
177	1958	5031040	48.4	29.0	58.07	15.49	1.255	2
178	1958	5031040	47.4	7.8	58.07	15.49	1.255	2
179	1958	5031040	51.1	11.1	58.07	15.49	1.255	2
180	1958	5031040	42.5	17.8	58.07	15.49	1.255	2
181	1958	5031040	49.0	31.2	58.07	15.49	1.255	2
182	1958	5040680	31.2	0.0	86.73	81.43	1.255	2
183	1958	5040680	32.5	3.6	86.73	81.43	1.255	2
184	1958	5040680	32.4	6.7	86.73	81.43	1.255	2
185	1958	5040680	29.5	13.4	86.73	81.43	1.255	2
186	1958	5040680	33.6	26.8	86.73	81.43	1.255	2
187	1958	5040680	26.2	4.5	86.73	81.43	1.255	2
188	1958	5040680	34.4	7.8	86.73	81.43	1.255	2
189	1958	5040680	40.3	14.5	86.73	81.43	1.255	2
190	1958	5040680	38.1	27.9	86.73	81.43	1.255	2
191	1958	5040680	34.6	5.6	86.73	81.43	1.255	2
192	1958	5040680	36.4	8.9	86.73	81.43	1.255	2
193	1958	5040680	36.6	15.6	86.73	81.43	1.255	2
194	1958	5040680	37.5	29.0	86.73	81.43	1.255	2
195	1958	5040680	37.7	7.8	86.73	81.43	1.255	2
196	1958	5040680	35.5	11.1	86.73	81.43	1.255	2
197	1958	5040680	43.0	17.8	86.73	81.43	1.255	2
198	1958	5040680	43.1	31.2	86.73	81.43	1.255	2
199	1958	5042800	52.1	0.0	98.61	91.33	1.255	2
200	1958	5042800	58.0	3.6	98.61	91.33	1.255	2
201	1958	5042800	50.3	6.7	98.61	91.33	1.255	2
202	1958	5042800	47.5	13.4	98.61	91.33	1.255	2
203	1958	5042800	41.2	26.4	98.61	91.33	1.255	2
204	1958	5042800	50.0	4.5	98.61	91.33	1.255	2
205	1958	5042800	47.1	7.8	98.61	91.33	1.255	2
206	1958	5042800	53.4	14.5	98.61	91.33	1.255	2
207	1958	5042800	50.2	27.9	98.61	91.33	1.255	2
208	1958	5042800	51.8	5.6	98.61	91q.33	1.255	2
209	1958	5042800	42.8	8.9	98.61	91.33	1.255	2
210	1958	5042800	58.5	15.6	98.61	91.33	1.255	2
211	1958	5042800	50.7	29.0	98.61	91.33	1.255	2
212	1958	5042800	38.8	7.8	98.61	91.33	1.255	2
213	1958	5042800	59.7	11.1	98.61	91.33	1.255	2
214	1958	5042800	41.6	17.8	98.61	91.33	1.255	2
215	1958	5042800	65.8	31.2	98.61	91.33	1.255	2
216	1958	5042800	29.9	0.0	98.61	91.33	1.255	1

217	1958	5042800	35.8	3.6	98.61	91.33	1.255	1
218	1958	5042800	36.3	6.7	98.61	91.33	1.255	1
219	1958	5042800	37.4	13.4	98.61	91.33	1.255	1
220	1958	5042800	42.3	26.8	98.61	91.33	1.255	1
221	1958	5042800	28.9	4.5	98.61	91.33	1.255	1
222	1958	5042800	37.4	7.8	98.61	91.33	1.255	1
223	1958	5042800	43.2	14.5	98.61	91.33	1.255	1
224	1958	5042800	45.2	27.9	98.61	91.33	1.255	1
225	1958	5042800	34.4	5.6	98.61	91.33	1.255	1
226	1958	5042800	34.5	8.9	98.61	91.33	1.255	1
227	1958	5042800	41.4	15.6	98.61	91.33	1.255	1
228	1958	5042800	42.4	29.0	98.61	91.33	1.255	1
229	1958	5042800	37.7	7.8	98.61	91.33	1.255	1
230	1958	5042800	38.7	11.1	98.61	91.33	1.255	1
231	1958	5042800	46.0	17.8	98.61	91.33	1.255	1
232	1958	5042800	43.8	31.2	98.61	91.33	1.255	1
233	1958	5052060	15.3	0.0	161.93	87.00	1.255	1
234	1958	5052060	20.0	3.6	161.93	87.00	1.255	1
235	1958	5052060	22.0	6.7	161.93	87.00	1.255	1
236	1958	5052060	34.1	13.4	161.93	87.00	1.255	1
237	1958	5052060	46.5	26.8	161.93	87.00	1.255	1
238	1958	5052060	16.8	4.5	161.93	87.00	1.255	1
239	1958	5052060	23.8	7.8	161.93	87.00	1.255	1
240	1958	5052060	38.6	14.5	161.93	87.00	1.255	1
241	1958	5052060	47.9	27.9	161.93	87.00	1.255	1
242	1959	5052060	20.3	5.6	161.93	87.00	1.255	1
243	1958	5052060	22.2	8.9	161.93	87.00	1.255	1
244	1958	5052060	43.2	15.6	161.93	87.00	1.255	1
245	1958	5052060	54.6	29.0	161.93	87.00	1.255	1
246	1958	5052060	20.7	7.8	161.93	87.00	1.255	1
247	1958	5052060	27.0	11.1	161.93	87.00	1.255	1
248	1958	5052060	35.4	17.8	161.93	87.00	1.255	1
249	1958	5052060	47.9	31.2	161.93	87.00	1.255	1
250	1959	5010480	22.5	0.0	92.19	53.86	1.255	1
251	1959	5010480	31.5	3.3	92.19	53.86	1.255	1
252	1959	5011080	13.2	0.0	52.85	73.83	1.255	2
253	1959	5011080	13.2	3.6	52.85	73.83	1.255	2
254	1959	5011080	12.5	6.7	52.85	73.83	1.255	2
255	1959	5011080	10.6	13.4	52.85	73.83	1.255	2
256	1959	5011080	9.4	26.8	52.85	73.83	1.255	2
257	1959	5011080	11.9	4.5	52.85	73.83	1.255	2
258	1959	5011080	14.3	7.8	52.85	73.83	1.255	2
259	1959	5011080	11.7	14.5	52.85	73.83	1.255	2
260	1959	5011080	11.7	27.9	52.85	73.83	1.255	2
261	1959	5011080	11.4	5.6	52.85	73.83	1.255	2
262	1959	5011080	10.0	8.9	52.85	73.83	1.255	2
263	1959	5011080	14.6	15.6	52.85	73.83	1.255	2
264	1959	5011080	13.8	29.0	52.85	73.83	1.255	2
265	1959	5011080	16.2	7.8	52.85	73.83	1.255	2
266	1959	5011080	12.9	11.1	52.85	73.83	1.255	2
267	1959	5011080	11.2	17.8	52.85	73.83	1.255	2
268	1959	5011080	11.8	31.2	52.85	73.83	1.255	2
269	1959	5012080	22.3	0.0	98.00	81.04	1.255	1
270	1959	5012080	22.1	3.6	98.00	81.04	1.255	1
271	1959	5012080	18.4	6.7	98.00	81.04	1.255	1

272	1959	5012080	18.5	13.4	98.00	81.04	1.255	1
273	1959	5012080	17.0	26.8	98.00	81.04	1.255	1
274	1959	5012080	21.1	4.5	98.00	81.04	1.255	1
275	1959	5012080	21.8	7.8	98.00	81.04	1.255	1
276	1959	5012080	19.7	14.5	98.00	81.04	1.255	1
277	1959	5012080	22.5	27.9	98.00	81.04	1.255	1
278	1959	5012080	24.7	5.6	98.00	81.04	1.255	1
279	1959	5012080	25.8	8.9	98.00	81.04	1.255	1
280	1959	5012080	20.8	15.6	98.00	81.04	1.255	1
281	1959	5012080	20.0	29.0	98.00	81.04	1.255	1
282	1959	5012080	24.3	7.8	98.00	81.04	1.255	1
283	1959	5012080	19.4	11.1	98.00	81.04	1.255	1
284	1959	5012080	25.9	17.8	98.00	81.04	1.255	1
285	1959	5012080	24.9	31.2	98.00	81.04	1.255	1
286	1959	5012280	8.9	0.0	42.76	27.08	1.255	1
287	1959	5012280	13.2	3.6	42.76	27.08	1.255	1
288	1959	5012280	11.6	6.7	42.76	27.08	1.255	1
289	1959	5012280	9.3	13.4	42.76	27.08	1.255	1
290	1959	5012280	12.5	26.8	42.76	27.08	1.255	1
291	1959	5012280	9.8	4.5	42.76	27.08	1.255	1
292	1959	5012280	12.3	7.8	42.76	27.08	1.255	1
293	1959	5012280	13.0	14.5	42.76	27.08	1.255	1
294	1959	5012280	15.7	27.9	42.76	27.08	1.255	1
295	1959	5012280	9.3	5.6	42.76	27.08	1.255	1
296	1959	5012280	13.8	8.9	42.76	27.08	1.255	1
297	1959	5012280	15.1	15.6	42.76	27.08	1.255	1
298	1959	5012280	17.2	29.0	42.76	27.08	1.255	1
299	1959	5012280	11.1	7.8	42.76	27.08	1.255	1
300	1959	5012280	10.5	11.1	42.76	27.08	1.255	1
301	1959	5012280	17.3	17.8	42.76	27.08	1.255	1
302	1959	5012280	15.8	31.2	42.76	27.08	1.255	1
303	1959	5012320	33.6	0.0	40.55	18.35	1.255	1
304	1959	5012320	39.6	18.4	40.55	18.35	1.255	1
305	1959	5012320	40.5	37.0	40.55	18.35	1.255	1
306	1959	5012320	42.4	15.4	40.55	18.35	1.255	1
307	1959	5012320	39.2	4.4	40.55	18.35	1.255	1
308	1959	5012320	18.0	0.0	40.55	18.35	1.255	1
309	1959	5012320	9.5	20.1	40.55	18.35	1.255	1
310	1959	5012320	14.7	21.2	40.55	18.35	1.255	1
311	1959	5012320	14.9	22.3	40.55	18.35	1.255	1
312	1959	5012320	13.3	24.5	40.55	18.35	1.255	1
313	1959	5012320	14.4	26.7	40.55	18.35	1.255	1
314	1959	5012320	16.0	7.8	40.55	18.35	1.255	1
315	1959	5012320	14.5	11.1	40.55	18.35	1.255	1
316	1959	5012320	14.0	17.8	40.55	18.35	1.255	1
317	1959	5012320	14.4	31.2	40.55	18.35	1.255	1
318	1959	5012960	15.8	0.0	98.48	53.39	1.255	2
319	1959	5012960	16.1	3.6	98.48	53.39	1.255	2
320	1959	5012960	13.8	6.7	98.48	53.39	1.255	2
321	1959	5012960	14.7	13.4	98.48	53.39	1.255	2
322	1959	5012960	12.3	26.8	98.48	53.39	1.255	2
323	1959	5012960	16.7	4.5	98.48	53.39	1.255	2
324	1959	5012960	15.6	7.8	98.48	53.39	1.255	2
325	1959	5012960	14.6	14.5	98.48	53.39	1.255	2
326	1959	5012960	15.0	27.9	98.48	53.39	1.255	2

327	1959	5012960	18.9	5.6	98.48	53.39	1.255	2
328	1959	5012960	13.3	8.9	98.48	53.39	1.255	2
329	1959	5012960	17.8	15.6	98.48	53.39	1.255	2
330	1959	5012960	15.2	29.0	98.48	53.39	1.255	2
331	1959	5012960	16.1	7.8	98.48	53.39	1.255	2
332	1959	5012960	17.8	11.1	98.48	53.39	1.255	2
333	1959	5012960	14.8	17.8	98.48	53.39	1.255	2
334	1959	5012960	16.3	31.2	98.48	53.39	1.255	2
335	1959	5021160	27.1	0.0	63.20	58.91	1.255	2
336	1959	5021160	30.0	18.4	63.20	58.91	1.255	2
337	1959	5021160	31.0	37.0	63.20	58.91	1.255	2
338	1959	5021160	33.7	15.4	63.20	58.91	1.255	2
339	1959	5021160	35.7	4.4	63.20	58.91	1.255	2
340	1959	5040680	18.8	0.0	29.30	19.15	1.255	2
341	1959	5040680	24.6	3.6	29.30	19.15	1.255	2
342	1959	5040680	25.0	6.7	29.30	19.15	1.255	2
343	1959	5040680	25.7	13.4	29.30	19.15	1.255	2
344	1959	5040680	29.3	26.8	29.30	19.15	1.255	2
345	1959	5040680	37.7	4.5	29.30	19.15	1.255	2
346	1959	5040680	28.3	7.8	29.30	19.15	1.255	2
347	1959	5040680	30.3	14.5	29.30	19.15	1.255	2
348	1959	5040680	26.3	27.9	29.30	19.15	1.255	2
349	1959	5040680	25.4	5.6	29.30	19.15	1.255	2
350	1959	5040680	27.4	8.9	29.30	19.15	1.255	2
351	1959	5040680	32.0	15.6	29.30	19.15	1.255	2
352	1959	5040680	32.1	29.0	29.30	19.15	1.255	2
353	1959	5040680	25.2	7.8	29.30	19.15	1.255	2
354	1959	5040680	31.0	11.1	29.30	19.15	1.255	2
355	1959	5040680	29.3	17.8	29.30	19.15	1.255	2
356	1959	5040680	31.5	31.2	29.30	19.15	1.255	2
357	1959	5042000	16.8	0.0	74.81	62.02	1.255	2
358	1959	5042000	20.2	18.4	74.81	62.02	1.255	2
359	1959	5042000	24.5	37.0	74.81	62.03	1.255	2
360	1959	5042000	18.6	15.4	74.81	62.02	1.255	2
361	1959	5042000	14.8	4.4	74.81	62.02	1.255	2
362	1959	5042240	27.6	0.0	77.99	61.04	1.255	1
363	1959	5042240	30.5	20.1	77.99	61.04	1.255	1
364	1959	5042240	28.1	21.2	77.99	61.04	1.255	1
365	1959	5042240	29.3	22.3	77.99	61.04	1.255	1
366	1959	5042240	29.9	24.5	77.99	61.04	1.255	1
367	1959	5042240	30.0	26.7	77.99	61.04	1.255	1
368	1959	5042240	29.4	7.8	77.99	61.04	1.255	1
369	1959	5042240	29.7	11.1	77.99	61.04	1.255	1
370	1959	5042240	29.3	17.8	77.99	61.04	1.255	1
371	1959	5042240	29.5	31.2	77.99	61.04	1.255	1
372	1959	5042800	13.3	0.0	51.95	38.75	1.255	2
373	1959	5042800	15.3	3.6	51.95	38.75	1.255	2
374	1959	5042800	15.3	6.7	51.95	38.75	1.255	2
375	1959	5042800	13.8	13.4	51.95	38.75	1.255	2
376	1959	5042800	12.5	26.8	51.95	38.75	1.255	2
377	1959	5042800	16.7	4.5	51.95	38.75	1.255	2
378	1959	5042800	13.3	7.8	51.95	38.75	1.255	2
379	1959	5042800	19.5	14.5	51.95	38.75	1.255	2
380	1959	5042800	15.5	27.9	51.95	38.75	1.255	2
381	1959	5042800	14.6	5.6	51.95	38.75	1.255	2

382	1959	5042800	17.0	8.9	51.95	38.75	1.255	2
383	1959	5042800	19.7	15.6	51.95	38.75	1.255	2
384	1959	5042800	14.4	29.0	51.95	38.75	1.255	2
385	1959	5042800	18.4	7.8	51.95	38.75	1.255	2
386	1959	5042800	16.7	11.1	51.95	38.75	1.255	2
387	1959	5042800	21.1	17.8	51.95	38.75	1.255	2
388	1959	5042800	16.1	31.2	51.95	38.75	1.255	2
389	1959	5052060	10.3	0.0	117.20	80.05	1.255	3
390	1959	5052060	15.5	3.6	117.20	80.05	1.255	3
391	1959	5052060	18.5	6.7	117.20	80.05	1.255	3
392	1959	5052060	23.2	13.4	117.20	80.05	1.255	3
393	1959	5052060	44.4	26.8	117.20	80.05	1.255	3
394	1959	5052060	14.3	4.5	117.20	80.05	1.255	3
395	1959	5052060	15.1	7.8	117.20	80.05	1.255	3
396	1959	5052060	29.1	14.5	117.20	80.05	1.255	3
397	1959	5052060	43.6	27.9	117.20	80.05	1.255	3
398	1959	5052060	12.8	5.6	117.20	80.05	1.255	3
399	1959	5052060	18.2	8.9	117.20	80.05	1.255	3
400	1959	5052060	27.7	15.6	117.20	80.05	1.255	3
401	1959	5052060	40.9	29.0	117.20	80.05	1.255	3
402	1959	5052060	12.5	7.8	117.20	80.05	1.255	3
403	1959	5052060	16.3	11.1	117.20	80.05	1.255	3
404	1959	5052060	27.2	17.8	117.20	80.05	1.255	3
405	1959	5052060	50.3	31.2	117.20	80.05	1.255	3
406	1960	5010480	14.2	0.0	67.86	82.57	1.255	1
407	1960	5010480	14.7	0.0	67.86	82.57	1.255	1
408	1960	5010480	20.0	6.6	67.86	82.57	1.255	1
409	1960	5010480	20.6	13.2	67.86	82.57	1.255	1
410	1960	5010480	20.7	19.8	67.86	82.57	1.255	1
411	1960	5010480	9.1	0.0	67.86	82.57	1.255	1
412	1960	5010480	8.9	0.0	67.86	82.57	1.255	1
413	1960	5010480	13.4	6.6	67.86	82.57	1.255	1
414	1960	5010480	17.2	13.2	67.86	82.57	1.255	1
415	1960	5010480	16.9	19.8	67.86	82.57	1.255	1
416	1960	5011080	14.4	0.0	65.60	65.08	1.255	2
417	1960	5011080	16.1	0.0	65.60	65.08	1.255	2
418	1960	5011080	15.9	6.6	65.60	65.08	1.255	2
419	1960	5011080	17.9	13.2	65.60	65.08	1.255	2
420	1960	5011080	19.8	19.8	65.60	65.08	1.255	2
421	1960	5052060	18.5	3.6	113.58	116.55	1.255	2
422	1960	5052060	20.2	6.7	113.58	116.55	1.255	2
423	1960	5052060	25.1	13.4	113.58	116.55	1.255	2
424	1960	5052060	29.6	26.8	113.58	116.55	1.255	2
425	1960	5052060	18.4	4.5	113.58	116.55	1.255	2
426	1960	5052060	21.8	7.8	113.58	116.55	1.255	2
427	1960	5052060	28.5	14.5	113.58	116.55	1.255	2
428	1960	5052060	42.9	27.9	113.58	116.55	1.255	2
429	1960	5052060	15.8	5.6	113.58	116.55	1.255	2
430	1960	5052060	21.9	8.9	113.58	116.55	1.255	2
431	1960	5052060	28.7	15.6	113.58	116.55	1.255	2
432	1960	5052060	39.7	29.0	113.58	116.55	1.255	2
433	1960	5052060	16.7	7.8	113.58	116.55	1.255	2
434	1960	5052060	23.2	11.1	113.58	116.55	1.255	2
435	1960	5052060	35.4	17.8	113.58	116.55	1.255	2
436	1963	5052060	44.0	31.2	113.58	116.55	1.255	2

437	1963	5012280	54.5	0.0	40.85	32.30	1.255	1
438	1963	5012280	53.2	0.0	40.85	32.30	1.255	1
439	1963	5012280	56.3	20.1	40.85	32.30	1.255	1
440	1963	5012280	65.8	20.1	40.85	32.30	1.255	1
441	1963	5020040	13.7	0.0	38.44	8.27	1.255	1
442	1963	5020040	19.7	0.0	38.44	8.27	1.255	1
443	1963	5020040	21.7	60.0	38.44	8.27	1.255	1
444	1963	5020040	22.0	60.0	38.44	8.27	1.255	1
445	1963	5022480	15.7	0.0	19.75	4.50	1.255	3
446	1963	5022480	17.3	0.0	19.75	4.50	1.255	3
447	1963	5022480	24.3	60.0	19.75	4.50	1.255	3
448	1963	5022480	23.8	60.0	19.75	4.50	1.255	3
449	1964	5010140	27.0	0.0	48.08	14.13	1.193	3
450	1964	5010140	36.0	11.0	48.08	14.13	1.193	3
451	1964	5010140	36.3	8.0	48.08	14.13	1.193	3
452	1964	5010485	27.7	0.0	68.24	41.08	1.255	2
453	1964	5010485	33.0	4.4	68.24	41.08	1.255	2
454	1964	5010485	30.5	19.8	68.24	41.08	1.255	2
455	1964	5010485	26.8	0.0	68.24	41.08	1.255	2
456	1964	5010485	33.2	11.2	68.24	41.08	1.255	2
457	1964	5010485	29.7	0.0	68.24	41.08	1.255	2
458	1964	5010485	28.5	2.0	68.24	41.08	1.255	2
459	1964	5010485	16.7	0.0	68.24	41.08	1.193	2
460	1964	5010485	23.5	29.0	68.24	41.08	1.193	2
461	1964	5010485	26.7	28.0	68.24	41.08	1.193	2
462	1964	5010485	28.0	0.0	68.24	41.08	1.193	2
463	1964	5010485	33.0	4.0	68.24	41.08	1.193	2
464	1964	5010485	33.1	11.0	68.24	41.08	1.193	2
465	1964	5010485	30.5	20.0	68.24	41.08	1.193	2
466	1964	5010640	31.1	0.0	46.46	57.42	1.193	2
467	1964	5010640	36.4	2.0	46.46	57.42	1.193	2
468	1964	5010640	33.4	11.0	46.46	57.42	1.193	2
469	1964	5010640	38.7	10.0	46.46	57.42	1.193	2
470	1964	5010640	12.8	0.0	46.46	57.42	1.193	2
471	1964	5010640	17.8	13.0	46.46	57.42	1.193	2
472	1964	5010640	23.8	49.0	46.46	57.42	1.193	2
473	1964	5012240	38.6	0.0	75.30	22.04	1.193	2
474	1964	5012240	37.6	16.0	75.30	22.04	1.193	2
475	1964	5012240	33.7	8.0	75.30	22.04	1.193	2
476	1964	5012240	24.0	0.0	75.30	22.04	1.193	2
477	1964	5012240	29.7	19.0	75.30	22.04	1.193	2
478	1964	5012240	33.1	16.0	75.30	22.04	1.193	2
479	1964	5012240	29.2	20.0	75.30	22.04	1.193	2
480	1964	5012720	19.8	0.0	68.23	54.65	1.193	2
481	1964	5012720	24.9	19.0	68.23	54.65	1.193	2
482	1964	5012720	27.2	26.0	68.23	54.65	1.193	2
483	1964	5021160	17.2	0.0	76.26	41.97	1.193	3
484	1964	5021160	30.9	8.0	76.26	41.97	1.193	3
485	1964	5021160	26.4	17.0	76.26	41.97	1.193	3
486	1964	5021160	28.2	10.0	76.26	41.97	1.193	3
487	1964	5021160	19.1	0.0	76.26	41.97	1.193	2
488	1964	5021160	23.0	11.0	76.26	41.97	1.193	2
489	1964	5021160	24.8	8.0	76.26	41.97	1.193	2
490	1964	5021848	21.2	0.0	68.50	18.38	1.255	1
491	1964	5021848	24.6	2.6	68.50	18.38	1.255	1

492	1964	5021848	21.3	0.0	68.50	18.38	1.255	1
493	1964	5021848	26.3	10.8	68.50	18.38	1.255	1
494	1964	5021848	21.3	0.0	68.50	18.38	1.255	1
495	1964	5021848	27.3	8.5	68.50	18.38	1.255	1
496	1964	5021848	18.3	0.0	68.50	18.38	1.255	1
497	1964	5021848	36.0	21.6	68.50	18.38	1.255	1
498	1964	5021848	18.9	0.0	68.50	18.38	1.255	1
499	1964	5021848	30.9	15.9	68.50	18.38	1.255	1
500	1964	5021848	28.7	11.9	68.50	18.38	1.255	1
501	1964	5021848	38.8	0.0	68.50	18.38	1.255	1
502	1964	5021848	28.8	2.7	68.50	18.38	1.255	1
503	1964	5021848	41.1	8.5	68.50	18.38	1.255	1
504	1964	5021848	36.2	0.0	68.50	18.38	1.255	1
505	1964	5021848	38.7	5.5	68.50	18.38	1.255	1
506	1964	5021848	37.0	0.0	68.50	18.38	1.255	1
507	1964	5021848	43.1	11.2	68.50	18.38	1.255	1
508	1964	5021848	30.1	0.0	68.50	18.38	1.193	2
509	1964	5021848	35.6	7.0	68.50	18.38	1.193	2
510	1964	5021848	39.5	18.0	68.50	18.38	1.193	2
511	1964	5021920	9.9	0.0	51.89	32.72	1.193	3
512	1964	5021920	16.5	10.0	51.89	32.72	1.193	3
513	1964	5021920	19.1	17.0	51.89	32.72	1.193	3
514	1964	5021920	24.9	23.0	51.89	32.73	1.193	3
515	1964	5022043	20.8	0.0	53.69	39.56	1.193	3
516	1964	5022043	27.1	9.0	53.69	39.56	1.193	3
517	1964	5022043	30.6	19.0	53.69	39.56	1.193	3
518	1964	5022043	40.3	44.0	53.69	39.56	1.193	3
519	1964	5022125	29.8	0.0	60.39	44.01	1.193	2
520	1964	5022125	36.7	8.0	60.39	44.01	1.193	2
521	1964	5022125	41.8	11.0	60.39	44.01	1.193	2
522	1965	5010640	23.4	0.0	64.81	32.63	1.191	3
523	1965	5010640	31.2	28.0	64.81	32.63	1.191	3
524	1965	5010640	29.5	9.0	64.81	32.63	1.191	3
525	1965	5010640	20.2	0.0	64.81	32.63	1.191	3
526	1965	5010640	21.4	6.5	64.81	32.63	1.191	3
527	1965	5010640	27.0	26.0	64.81	32.63	1.191	3
528	1966	5010485	44.1	0.0	64.48	39.29	1.191	3
529	1966	5010485	40.0	10.3	64.48	39.29	1.191	3
530	1966	5010485	46.2	15.9	64.48	39.29	1.191	3
531	1966	5010485	23.0	3.3	64.48	39.29	1.255	3
532	1966	5010485	25.5	28.8	64.48	39.29	1.255	3
533	1966	5010548	11.6	0.0	79.53	47.50	1.191	2
534	1966	5010548	14.6	7.0	79.53	47.50	1.191	2
535	1966	5010548	20.9	20.0	79.53	47.50	1.191	2
536	1966	5010548	22.0	30.0	79.53	47.50	1.191	2
537	1966	5010548	18.9	20.0	79.53	47.50	1.191	2
538	1966	5010548	19.6	20.0	79.53	47.50	1.191	2
539	1966	5010548	23.2	30.0	79.53	47.50	1.191	2
540	1966	5010548	25.1	40.0	79.53	47.50	1.191	2
541	1966	5010548	18.1	20.0	79.53	47.50	1.191	2
542	1966	5010548	22.4	40.0	79.53	47.50	1.191	2
543	1966	5010548	21.5	60.0	79.53	47.50	1.191	2
544	1966	5010548	25.6	90.0	79.53	47.50	1.191	2
545	1966	5010548	25.7	120.0	79.53	47.50	1.191	2
546	1966	5010548	23.4	60.0	79.53	47.50	1.191	2

547	1966	5010548	22.0	60.0	79.53	47.50	1.191	2
548	1966	5010548	27.0	180.0	79.53	47.50	1.191	2
549	1966	5010548	24.9	240.0	79.53	47.50	1.191	2
550	1966	5010548	21.2	40.0	79.53	47.50	1.191	2
551	1966	5010548	25.0	60.0	79.53	47.50	1.191	2
552	1966	5010548	18.4	40.0	79.53	47.50	1.191	2
553	1966	5010548	21.5	60.0	79.53	47.50	1.191	2
554	1966	5012796	7.9	0.0	88.24	22.72	1.191	2
555	1966	5012796	26.5	41.0	88.24	22.72	1.191	2
556	1966	5020040	16.7	0.0	29.94	11.35	1.191	2
557	1966	5020040	20.7	7.0	29.94	11.35	1.191	2
558	1966	5020040	27.9	20.0	29.94	11.35	1.191	2
559	1966	5020040	29.3	30.0	29.94	11.35	1.191	2
560	1966	5020040	28.4	20.0	29.94	11.35	1.191	2
561	1966	5020040	24.9	40.0	29.94	11.35	1.191	2
562	1966	5020040	28.6	30.0	29.94	11.35	1.191	2
563	1966	5020040	29.5	40.0	29.94	11.35	1.191	2
564	1966	5020040	23.9	20.0	29.94	11.35	1.191	2
565	1966	5020040	31.6	40.0	29.94	11.35	1.191	2
566	1966	5020040	27.1	60.0	29.94	11.35	1.191	2
567	1966	5020040	37.6	90.0	29.94	11.35	1.191	2
568	1966	5020040	35.9	120.0	29.94	11.35	1.191	2
569	1966	5020040	32.9	60.0	29.94	11.35	1.191	2
570	1966	5020040	36.2	60.0	29.94	11.35	1.191	2
571	1966	5020040	33.5	180.0	29.94	11.35	1.191	2
572	1966	5020040	30.5	240.0	29.94	11.35	1.191	2
573	1966	5020040	29.3	40.0	29.94	11.35	1.191	2
574	1966	5020040	33.2	60.0	29.94	11.35	1.191	2
575	1966	5020040	27.8	40.0	29.94	11.35	1.191	2
576	1966	5020040	28.7	60.0	29.94	11.35	1.191	2
577	1966	5022788	16.0	0.0	65.26	43.26	1.191	2
578	1966	5022788	15.7	4.0	65.26	43.26	1.191	2
579	1966	5022788	21.8	30.0	65.26	43.26	1.191	2
580	1966	5022788	17.9	13.0	65.26	43.26	1.191	2
581	1966	5031040	30.0	0.0	42.24	8.61	1.191	2
582	1966	5031040	28.7	4.0	42.24	8.61	1.191	2
583	1966	5031040	37.0	9.0	42.24	8.61	1.191	2
584	1966	5031040	44.5	22.0	42.24	8.61	1.191	2
585	1966	5040680	26.4	0.0	51.68	9.83	1.191	3
586	1966	5040680	30.4	11.0	51.68	9.83	1.191	3
587	1966	5040680	30.8	4.0	51.68	9.83	1.191	3
588	1966	5040680	34.3	9.0	51.68	9.83	1.191	3
589	1966	5040680	43.7	0.0	51.68	9.83	1.191	3
590	1966	5040680	44.1	24.0	51.68	9.83	1.191	3
591	1966	5040680	48.2	42.0	51.68	9.83	1.191	3
592	1966	5040680	47.8	11.0	51.68	9.83	1.191	3
593	1966	5040680	46.8	41.0	51.68	9.83	1.191	3
594	1966	5040680	42.5	27.0	51.68	9.83	1.191	3
595	1966	5040680	37.9	20.0	51.68	9.83	1.191	3
596	1966	5040680	21.0	0.0	51.68	9.83	1.191	2
597	1966	5040680	22.5	9.0	51.68	9.83	1.191	2
598	1966	5040680	22.9	4.0	51.68	9.83	1.191	2
599	1966	5040680	27.4	11.0	51.68	9.83	1.191	2
600	1967	5010480	16.9	0.0	148.58	119.86	1.191	1
601	1967	5010480	23.4	36.1	148.58	119.86	1.191	1

602	1967	5010480	23.7	51.4	148.58	119.86	1.191	1
603	1967	5010548	27.3	9.0	121.55	78.88	1.191	1
604	1967	5010548	37.2	19.2	121.55	78.88	1.191	1
605	1967	5010548	47.0	22.5	121.55	78.88	1.191	1
606	1967	5010548	29.8	29.4	121.55	78.88	1.191	1
607	1967	5010548	31.0	36.0	121.55	78.88	1.191	1
608	1967	5010760	13.3	0.0	121.54	109.12	1.191	2
609	1967	5010760	19.3	30.0	121.54	109.12	1.191	2
610	1967	5010760	16.7	40.0	121.54	109.12	1.191	2
611	1967	5010760	18.5	50.0	121.54	109.12	1.191	2
612	1967	5010760	19.7	60.0	121.54	109.12	1.191	2
613	1967	5011240	28.6	43.0	118.66	57.72	1.191	2
614	1967	5011240	29.1	61.0	118.66	57.72	1.191	2
615	1967	5012400	13.3	0.0	153.54	119.92	1.191	1
616	1967	5012400	15.0	40.0	153.54	119.92	1.191	1
617	1967	5012400	16.2	50.0	153.54	119.92	1.191	1
618	1967	5012400	16.5	60.0	153.54	119.92	1.191	1
619	1967	5012400	21.2	70.0	153.54	119.92	1.191	1
620	1967	5012500	16.0	0.0	85.53	44.30	1.191	1
621	1967	5012500	22.0	30.0	85.53	44.30	1.191	1
622	1967	5012500	20.0	9.0	85.53	44.30	1.191	1
623	1967	5012520	15.1	0.0	86.83	50.18	1.191	2
624	1967	5012520	22.0	25.0	86.83	50.18	1.191	2
625	1967	5012520	23.3	9.0	86.83	50.18	1.191	2
626	1967	5012720	20.3	9.0	138.95	112.56	1.191	2
627	1967	5012720	34.2	19.2	138.95	112.56	1.191	2
628	1967	5012720	33.3	22.5	138.95	112.56	1.191	2
629	1967	5012720	36.2	29.4	138.95	112.56	1.191	2
630	1967	5012720	39.7	36.0	138.95	112.56	1.191	2
631	1967	5020320	14.4	0.0	99.02	90.69	1.191	2
632	1967	5020320	22.0	30.0	99.02	90.69	1.191	2
633	1967	5020320	23.0	50.0	99.02	90.69	1.191	2
634	1967	5020321	13.7	0.0	99.22	96.47	1.191	2
635	1967	5020321	20.9	39.4	99.22	96.47	1.191	2
636	1967	5020321	21.8	59.8	99.22	96.47	1.191	2
637	1967	5020720	11.7	0.0	81.85	35.36	1.191	2
638	1967	5020720	32.2	54.7	81.85	35.36	1.191	2
639	1967	5020720	34.6	85.3	81.85	35.36	1.191	2
640	1967	5020720	20.1	18.4	81.85	35.36	1.191	2
641	1967	5020720	17.0	0.0	81.85	35.36	1.191	2
642	1967	5020720	25.2	37.9	81.85	35.36	1.191	2
643	1967	5020720	22.2	54.9	81.85	35.36	1.191	2
644	1967	5021160	18.0	0.0	110.54	47.27	1.191	1
645	1967	5021160	23.0	25.0	110.54	47.27	1.191	1
646	1967	5021160	29.6	40.0	110.54	47.27	1.191	1
647	1967	5021160	35.5	76.0	110.54	47.27	1.191	1
648	1967	5021848	23.2	8.0	88.67	69.00	1.191	2
649	1967	5021848	27.2	18.2	88.67	69.00	1.191	2
650	1967	5021848	31.9	21.5	88.67	69.00	1.191	2
651	1967	5021848	41.8	28.4	88.67	69.00	1.191	2
652	1967	5021848	50.3	35.0	88.67	69.00	1.191	2
653	1967	5022480	23.6	0.0	70.38	51.13	1.191	3
654	1967	5022480	28.6	8.0	70.38	51.13	1.191	3
655	1967	5022480	30.7	18.0	70.38	51.13	1.191	3
656	1967	5022480	35.7	35.0	70.38	51.13	1.191	3

657	1967	5022770	35.9	6.4	74.05	25.38	1.191	3
658	1967	5022770	47.0	16.6	74.05	25.38	1.191	3
659	1967	5022770	52.9	19.9	74.05	25.38	1.191	3
660	1967	5022770	56.5	26.8	74.05	25.38	1.191	3
661	1967	5022770	56.9	33.4	74.05	25.38	1.191	3
662	1967	5031040	11.0	0.0	71.29	7.35	1.191	2
663	1967	5031040	13.0	7.0	71.29	7.35	1.191	2
664	1967	5031040	17.0	41.0	71.29	7.35	1.191	2
665	1967	5040680	30.7	0.0	68.00	33.19	1.191	2
666	1967	5040680	38.3	20.0	68.00	33.19	1.191	2
667	1967	5040680	34.0	30.0	68.00	33.19	1.191	2
668	1967	5040680	45.5	40.0	68.00	33.19	1.191	2
669	1967	5040680	44.0	50.0	68.00	33.19	1.191	2
670	1967	5040680	35.5	0.0	68.00	33.19	1.191	3
671	1967	5040680	36.7	30.0	68.00	33.19	1.191	3
672	1967	5040680	44.0	40.0	68.00	33.19	1.191	3
673	1967	5040680	38.3	50.0	68.00	33.19	1.191	3
674	1967	5040680	43.3	60.0	68.00	33.19	1.191	3
675	1967	5042800	12.5	0.0	113.92	83.27	1.191	3
676	1967	5042800	24.7	22.0	113.92	83.27	1.191	3
677	1967	5042800	32.3	59.0	113.92	83.27	1.191	3
678	1967	5042800	29.8	60.0	113.92	83.27	1.191	3
679	1967	5042800	15.1	8.0	113.92	83.27	1.191	3
680	1967	5042800	18.0	0.0	113.92	83.27	1.191	1
681	1967	5042800	26.0	48.0	113.92	83.27	1.191	1
682	1967	5042800	21.3	0.0	113.92	83.27	1.191	3
683	1967	5042800	24.8	20.0	113.92	83.27	1.191	3
684	1967	5042800	26.0	30.0	113.92	83.27	1.191	3
685	1967	5042800	31.8	40.0	113.92	83.27	1.191	3
686	1967	5042800	32.2	50.0	113.92	83.27	1.191	3
687	1968	5010140	18.0	5.0	63.67	2.00	1.191	3
688	1968	5010140	34.0	50.0	63.67	2.00	1.191	3
689	1968	5010140	37.0	65.0	63.67	2.00	1.191	3
690	1968	5010140	40.0	80.0	63.67	2.00	1.191	3
691	1968	5010140	40.0	95.0	63.67	2.00	1.191	3
692	1968	5010240	16.0	7.0	104.55	12.27	1.191	2
693	1968	5010240	28.0	42.0	104.55	12.27	1.191	2
694	1968	5010240	29.0	77.0	104.55	12.27	1.191	2
695	1968	5010240	28.0	112.0	104.55	12.27	1.191	2
696	1968	5010760	24.0	8.0	83.98	11.46	1.191	3
697	1968	5010760	39.0	53.0	83.98	11.46	1.191	3
698	1968	5010760	39.0	68.0	83.98	11.46	1.191	3
699	1968	5010760	42.0	83.0	83.98	11.46	1.191	3
700	1968	5010760	37.0	98.0	83.98	11.46	1.191	3
701	1968	5011240	17.0	5.0	103.17	14.54	1.191	2
702	1968	5011240	26.0	40.0	103.17	14.54	1.191	2
703	1968	5011240	34.0	75.0	103.17	14.54	1.191	2
704	1968	5011240	33.0	110.0	103.17	14.54	1.191	2
705	1968	5011240	13.0	7.0	103.17	14.54	1.191	2
706	1968	5011240	21.0	33.0	103.17	14.54	1.191	2
707	1968	5011240	20.0	48.0	103.17	14.54	1.191	2
708	1968	5011240	21.0	63.0	103.17	14.54	1.191	2
709	1968	5011240	23.0	78.0	103.17	14.54	1.191	2
710	1968	5011760	8.3	0.0	73.98	2.00	1.191	2
711	1968	5011760	13.2	4.4	73.98	2.00	1.191	2

712	1968	5011760	21.7	13.4	73.98	2.00	1.191	2
713	1968	5011760	24.7	17.8	73.98	2.00	1.191	2
714	1968	5011760	33.8	44.6	73.98	2.00	1.191	2
715	1968	5011760	18.0	80.0	73.98	2.00	1.191	2
716	1968	5011760	28.2	80.0	73.98	2.00	1.191	2
717	1968	5012054	30.0	7.0	77.24	33.01	1.191	2
718	1968	5012054	34.0	9.0	77.24	33.01	1.191	2
719	1968	5012054	32.0	44.0	77.24	33.01	1.191	2
720	1968	5012054	36.0	59.0	77.24	33.01	1.191	2
721	1968	5012054	36.0	74.0	77.24	33.01	1.191	2
722	1968	5012320	22.0	0.0	63.17	2.16	1.191	1
723	1968	5012320	27.0	11.0	63.17	2.16	1.191	1
724	1968	5012320	30.0	48.0	63.17	2.16	1.191	1
725	1968	5012320	32.0	74.0	63.17	2.16	1.191	1
726	1968	5012320	33.0	93.0	63.17	2.16	1.191	1
727	1968	5012320	34.0	136.0	63.17	2.16	1.191	1
728	1968	5012322	19.0	0.0	75.79	12.48	1.191	1
729	1968	5012322	23.5	4.4	75.79	12.48	1.191	1
730	1968	5012322	26.3	13.4	75.79	12.48	1.191	1
731	1968	5012322	29.7	17.8	75.79	12.48	1.191	1
732	1968	5012322	32.7	44.6	75.79	12.48	1.191	1
733	1968	5012322	33.3	80.0	75.79	12.48	1.191	1
734	1968	5012322	35.2	80.0	75.79	12.48	1.191	1
735	1968	5012796	22.0	2.0	97.39	2.00	1.191	2
736	1968	5012796	22.0	47.0	97.39	2.00	1.191	2
737	1968	5012796	20.0	62.0	97.39	2.00	1.191	2
738	1968	5012796	21.0	77.0	97.39	2.00	1.191	2
739	1968	5012796	20.0	92.0	97.39	2.00	1.191	2
740	1968	5020040	34.9	0.0	23.55	2.00	1.191	3
741	1968	5020040	47.9	13.4	23.55	2.00	1.191	3
742	1968	5020040	47.9	26.8	23.55	2.00	1.191	3
743	1968	5020720	22.9	0.0	42.34	2.00	1.191	2
744	1968	5020720	27.5	6.0	42.34	2.00	1.191	2
745	1968	5020720	35.2	56.0	42.34	2.00	1.191	2
746	1968	5020720	29.1	86.0	42.34	2.00	1.191	2
747	1968	5020720	26.5	0.0	42.34	2.00	1.191	2
748	1968	5020720	42.2	35.0	42.34	2.00	1.191	2
749	1968	5020720	49.1	65.0	42.34	2.00	1.191	2
750	1968	5020720	20.7	0.0	42.34	2.00	1.191	2
751	1968	5020720	26.6	8.0	42.34	2.00	1.191	2
752	1968	5020720	37.2	68.0	42.34	2.00	1.191	2
753	1968	5020720	41.4	98.0	42.34	2.00	1.191	2
754	1968	5020720	16.2	3.0	42.34	2.00	1.191	2
755	1968	5020720	25.4	30.0	42.34	2.00	1.191	2
756	1968	5020720	33.0	60.0	42.34	2.00	1.191	2
757	1968	5020720	35.3	90.0	42.34	2.00	1.191	2
758	1968	5020720	12.6	5.0	42.34	2.00	1.191	2
759	1968	5020720	25.1	30.0	42.34	2.00	1.191	2
760	1968	5020720	37.6	60.0	42.34	2.00	1.191	2
761	1968	5020720	40.7	90.0	42.34	2.00	1.191	2
762	1968	5020720	17.5	4.0	42.34	2.00	1.191	2
763	1968	5020720	28.5	30.0	42.34	2.00	1.191	2
764	1968	5020720	27.6	60.0	42.34	2.00	1.191	2
765	1968	5020720	29.1	90.0	42.34	2.00	1.191	2
766	1968	5021160	27.0	0.0	64.94	2.00	1.191	2

767	1968	5021160	26.0	8.0	64.94	2.00	1.191	2
768	1968	5021160	41.0	40.0	64.94	2.00	1.191	2
769	1968	5021160	44.0	69.0	64.94	2.00	1.191	2
770	1968	5021160	47.0	100.0	64.94	2.00	1.191	2
771	1968	5021160	47.0	130.0	64.94	2.00	1.191	2
772	1968	5021848	12.8	0.0	50.99	2.00	1.191	2
773	1968	5021848	16.3	4.4	50.99	2.00	1.191	2
774	1968	5021848	32.2	13.4	50.99	2.00	1.191	2
775	1968	5021848	29.2	17.8	50.99	2.00	1.191	2
776	1968	5021848	41.8	44.6	50.99	2.00	1.191	2
777	1968	5021848	29.0	6.0	50.99	2.00	1.191	2
778	1968	5021848	36.0	26.0	50.99	2.00	1.191	2
779	1968	5021848	31.0	36.0	50.99	2.00	1.191	2
780	1968	5021848	36.0	51.0	50.99	2.00	1.191	2
781	1968	5021848	36.0	66.0	50.99	2.00	1.191	2
782	1968	5021848	36.5	80.0	50.99	2.00	1.191	2
783	1968	5021848	40.2	80.0	50.99	2.00	1.191	2
784	1968	5022770	21.0	0.0	52.40	15.95	1.191	2
785	1968	5022770	36.0	23.0	52.40	15.95	1.191	2
786	1968	5022770	29.0	34.5	52.40	15.95	1.191	2
787	1968	5022770	38.0	46.0	52.40	15.95	1.191	2
788	1968	5022770	42.0	69.0	52.40	15.95	1.191	2
789	1968	5022770	9.8	0.0	52.40	15.95	1.191	3
790	1968	5022770	13.7	4.4	52.40	15.95	1.191	3
791	1968	5022770	18.2	13.4	52.40	15.95	1.191	3
792	1968	5022770	21.0	17.8	52.40	15.95	1.191	3
793	1968	5022770	31.2	44.6	52.40	15.95	1.191	3
794	1968	5022770	35.0	80.0	52.40	15.95	1.191	3
795	1968	5022770	41.2	80.0	52.40	15.95	1.191	3
796	1968	5042003	13.0	0.0	56.44	8.23	1.191	1
797	1968	5042003	17.0	10.0	56.44	8.23	1.191	1
798	1968	5042003	24.0	47.0	56.44	8.23	1.191	1
799	1968	5042003	23.0	57.0	56.44	8.23	1.191	1
800	1968	5042003	27.0	93.0	56.44	8.23	1.191	1
801	1968	5042003	31.0	130.0	56.44	8.23	1.191	1
802	1968	5042425	19.0	7.0	63.32	2.00	1.191	2
803	1968	5042425	25.0	37.0	63.32	2.00	1.191	2
804	1968	5042425	28.0	67.0	63.32	2.00	1.191	2
805	1968	5042425	44.0	97.0	63.32	2.00	1.191	2
806	1968	5042425	53.0	127.0	63.32	2.00	1.191	2
807	1968	5042800	28.0	7.0	44.87	7.64	1.191	2
808	1968	5042800	30.0	35.0	44.87	7.64	1.191	2
809	1968	5042800	39.0	50.0	44.87	7.64	1.191	2
810	1968	5042800	33.0	65.0	44.87	7.64	1.191	2
811	1968	5042800	48.0	80.0	44.87	7.64	1.191	2
812	1969	5010240	30.0	7.0	68.59	25.71	1.191	2
813	1969	5010240	47.0	39.0	68.59	25.71	1.191	2
814	1969	5010240	51.0	68.0	68.59	25.71	1.191	2
815	1969	5010240	55.0	102.0	68.59	25.71	1.191	2
816	1969	5010240	62.0	125.0	68.59	25.71	1.191	2
817	1969	5010480	24.0	11.0	100.33	9.44	1.191	1
818	1969	5010480	31.0	31.0	100.33	9.44	1.191	1
819	1969	5010480	33.0	51.0	100.33	9.44	1.191	1
820	1969	5010480	38.1	71.0	100.33	9.44	1.191	1
821	1969	5010480	41.3	91.0	100.33	9.44	1.191	1

822	1969	5010480	20.2	11.0	100.33	9.44	1.191	1
823	1969	5010480	26.5	31.0	100.33	9.44	1.191	1
824	1969	5010480	30.5	51.0	100.33	9.44	1.191	1
825	1969	5010480	33.8	71.0	100.33	9.44	1.191	1
826	1969	5010480	37.2	91.0	100.33	9.44	1.191	1
827	1969	5010548	33.0	6.0	75.36	14.24	1.191	2
828	1969	5010548	35.0	39.0	75.36	14.24	1.191	2
829	1969	5010548	39.0	67.0	75.36	14.24	1.191	2
830	1969	5010548	34.0	101.0	75.36	14.24	1.191	2
831	1969	5010548	35.0	124.0	75.36	14.24	1.191	2
832	1969	5011240	31.0	3.0	103.12	14.51	1.191	2
833	1969	5011240	29.0	38.0	103.12	14.51	1.191	2
834	1969	5011240	47.0	63.0	103.12	14.51	1.191	2
835	1969	5011240	49.0	89.0	103.12	14.51	1.191	2
836	1969	5011760	22.7	0.0	61.08	21.82	1.191	2
837	1969	5011760	25.2	40.0	61.08	21.82	1.191	2
838	1969	5011760	33.2	0.0	61.08	21.82	1.191	2
839	1969	5011760	35.2	40.0	61.08	21.82	1.191	2
840	1969	5011760	30.0	40.0	61.08	21.82	1.191	2
841	1969	5011760	43.2	40.0	61.08	21.82	1.191	2
842	1969	5012080	14.0	6.0	88.67	44.49	1.191	1
843	1969	5012080	16.0	37.0	88.67	44.49	1.191	1
844	1969	5012080	21.0	67.0	88.67	44.49	1.191	1
845	1969	5012080	35.0	96.0	88.67	44.49	1.191	1
846	1969	5012080	41.0	126.0	88.67	44.49	1.191	1
847	1969	5012322	17.5	0.0	77.65	3.83	1.191	1
848	1969	5012322	21.7	40.0	77.65	3.83	1.191	1
849	1969	5012322	36.5	0.0	77.65	3.83	1.191	1
850	1969	5012322	40.2	40.0	77.65	3.83	1.191	1
851	1969	5012322	34.5	40.0	77.65	3.83	1.191	1
852	1969	5012322	41.2	40.0	77.65	3.83	1.191	1
853	1969	5012500	13.2	0.0	57.01	7.63	1.191	2
854	1969	5012500	24.0	10.0	57.01	7.63	1.191	2
855	1969	5012500	28.0	35.0	57.01	7.63	1.191	2
856	1969	5012500	33.2	62.0	57.01	7.63	1.191	2
857	1969	5012796	27.0	0.0	75.83	30.20	1.191	2
858	1969	5012796	32.0	9.0	75.83	30.20	1.191	2
859	1969	5012796	30.0	68.0	75.83	30.20	1.191	2
860	1969	5012796	38.0	98.0	75.83	30.20	1.191	2
861	1969	5012796	18.4	0.0	75.83	30.20	1.191	2
862	1969	5012796	23.4	9.0	75.83	30.20	1.191	2
863	1969	5012796	39.9	60.0	75.83	30.20	1.191	2
864	1969	5012796	45.6	90.0	75.83	30.20	1.191	2
865	1969	5021848	8.8	0.0	68.23	24.61	1.191	2
866	1969	5021848	12.2	0.0	68.23	24.61	1.191	2
867	1969	5021848	35.0	80.0	68.23	24.61	1.191	2
868	1969	5021848	41.2	80.0	68.23	24.61	1.191	2
869	1969	5021848	27.2	40.0	68.23	24.61	1.191	2
870	1969	5021848	44.5	120.0	68.23	24.61	1.191	2
871	1969	5022770	32.0	49.0	62.74	3.20	1.191	2
872	1969	5022770	35.0	49.0	62.74	3.20	1.191	2
873	1969	5022770	36.0	49.0	62.74	3.20	1.191	2
874	1969	5022770	39.0	49.0	62.74	3.20	1.191	2
875	1970	5010480	25.0	11.0	66.29	22.60	1.191	1
876	1970	5010480	29.3	31.0	66.29	22.60	1.191	1

877	1970	5010480	39.2	51.0	66.29	22.60	1.191	1
878	1970	5010480	41.8	71.0	66.29	22.60	1.191	1
879	1970	5010480	40.0	91.0	66.29	22.60	1.191	1
880	1970	5010548	21.0	8.0	28.89	41.11	1.191	2
881	1970	5010548	26.0	41.0	28.89	41.11	1.191	2
882	1970	5010548	28.0	69.0	28.89	41.11	1.191	2
883	1970	5010548	32.0	94.0	28.89	41.11	1.191	2
884	1970	5010548	32.0	128.0	28.89	41.11	1.191	2
885	1970	5010640	23.0	8.0	36.38	30.03	1.191	3
886	1970	5010640	29.0	41.0	36.38	30.03	1.191	3
887	1970	5010640	30.0	69.0	36.38	30.03	1.191	3
888	1970	5010640	33.0	94.0	36.38	30.03	1.191	3
889	1970	5010640	31.0	126.0	36.38	30.03	1.191	3
890	1970	5022125	23.0	8.0	18.10	47.98	1.191	2
891	1970	5022125	29.0	35.0	18.10	47.98	1.191	2
892	1970	5022125	30.0	59.0	18.10	47.98	1.191	2
893	1970	5022125	32.0	105.0	18.10	47.98	1.191	2
894	1971	5010480	28.0	11.0	54.45	25.27	1.191	1
895	1971	5010480	35.7	31.0	54.45	25.27	1.191	1
896	1971	5010480	37.7	51.0	54.45	25.27	1.191	1
897	1971	5010480	37.0	71.0	54.45	25.27	1.191	1
898	1971	5010480	40.0	91.0	54.45	25.27	1.191	1
899	1971	5011080	19.0	9.0	35.26	24.88	1.191	2
900	1971	5011080	26.0	30.0	35.26	24.88	1.191	2
901	1971	5011080	28.0	65.0	35.26	24.88	1.191	2
902	1971	5011080	26.0	0.0	35.26	24.88	1.193	2
903	1971	5011080	4.0	45.0	35.26	24.88	1.193	2
904	1971	5011080	46.0	65.0	35.26	24.88	1.193	2
905	1971	5011240	33.3	11.0	62.27	24.12	1.247	2
906	1971	5011240	35.4	31.0	62.27	24.12	1.247	2
907	1971	5011240	42.2	51.0	62.27	24.12	1.247	2
908	1971	5011240	40.0	71.0	62.27	24.12	1.247	2
909	1972	5010480	28.5	11.0	79.65	66.09	1.191	1
910	1972	5010480	33.1	31.0	79.65	66.09	1.191	1
911	1972	5010480	34.0	51.0	79.65	66.09	1.191	1
912	1972	5010480	33.8	71.0	79.65	66.09	1.191	1
913	1972	5010480	36.0	91.0	79.65	66.09	1.191	1
914	1972	5011240	27.2	11.0	102.20	74.52	1.247	2
915	1972	5011240	31.8	31.0	102.20	74.52	1.247	2
916	1972	5011240	37.0	51.0	102.20	74.52	1.247	2
917	1972	5011240	38.4	71.0	102.20	74.52	1.247	2
918	1972	5022788	21.6	8.0	99.66	56.83	1.247	1
919	1972	5022788	28.4	58.0	99.66	56.83	1.247	1
920	1972	5022788	31.0	9.0	99.66	56.83	1.247	3
921	1972	5022788	34.0	61.0	99.66	56.83	1.247	3
922	1972	5030080	29.2	20.0	95.81	28.06	1.247	2
923	1972	5030080	30.4	50.0	95.81	28.06	1.247	2
924	1973	5010240	17.9	8.0	60.68	58.48	1.180	2
925	1973	5010240	18.6	30.0	60.68	58.48	1.180	2
926	1973	5010240	24.4	60.0	60.68	58.48	1.180	2
927	1973	5010240	22.7	90.0	60.68	58.48	1.180	2
928	1973	5010240	23.0	120.0	60.68	58.48	1.180	2
929	1973	5010240	24.9	180.0	60.68	58.48	1.180	2
930	1973	5010240	26.9	240.0	60.68	58.48	1.180	2
931	1973	5010240	28.7	8.0	60.68	58.48	1.247	2

932	1973	5010240	36.5	30.0	60.68	58.48	1.247	2
933	1973	5010240	39.8	60.0	60.68	58.48	1.247	2
934	1973	5010240	46.0	90.0	60.68	58.48	1.247	2
935	1973	5010240	47.2	120.0	60.68	58.48	1.247	2
936	1973	5010240	52.5	180.0	60.68	58.48	1.247	2
937	1973	5010240	51.8	240.0	60.68	58.48	1.247	2
938	1973	5011051	25.5	8.0	44.61	8.79	1.180	1
939	1973	5011051	34.8	30.0	44.61	8.79	1.180	1
940	1973	5011051	43.3	60.0	44.61	8.79	1.180	1
941	1973	5011051	46.0	90.0	44.61	8.79	1.180	1
942	1973	5011051	53.0	120.0	44.61	8.79	1.180	1
943	1973	5011051	53.5	180.0	44.61	8.79	1.180	1
944	1973	5011051	56.8	240.0	44.61	8.79	1.180	1
945	1973	5011051	23.7	8.0	44.61	8.79	1.247	1
946	1973	5011051	35.3	30.0	44.61	8.79	1.247	1
947	1973	5011051	41.2	60.0	44.61	8.79	1.247	1
948	1973	5011051	45.0	90.0	44.61	8.79	1.247	1
949	1973	5011051	48.8	120.0	44.61	8.79	1.247	1
950	1973	5011051	50.0	180.0	44.61	8.79	1.247	1
951	1973	5011051	51.5	240.0	44.61	8.79	1.247	1
952	1973	5012320	21.8	8.0	31.11	10.37	1.180	2
953	1973	5012320	32.5	30.0	31.11	10.37	1.180	2
954	1973	5012320	42.2	60.0	31.11	10.37	1.180	2
955	1973	5012320	38.7	90.0	31.11	10.37	1.180	2
956	1973	5012320	42.7	120.0	31.11	10.37	1.180	2
957	1973	5012320	46.7	180.0	31.11	10.37	1.180	2
958	1973	5012320	44.3	240.0	31.11	10.37	1.180	2
959	1973	5012320	21.8	8.0	31.11	10.37	1.247	2
960	1973	5012320	30.7	30.0	31.11	10.37	1.247	2
961	1973	5012320	36.2	60.0	31.11	10.37	1.247	2
962	1973	5012320	36.8	90.0	31.11	10.37	1.247	2
963	1973	5012320	38.2	120.0	31.11	10.37	1.247	2
964	1973	5012320	41.0	180.0	31.11	10.37	1.247	2
965	1973	5012320	39.5	240.0	31.11	10.37	1.247	2
966	1973	5013120	34.2	8.0	69.10	35.52	1.180	2
967	1973	5013120	34.5	30.0	69.10	35.52	1.180	2
968	1973	5013120	44.5	60.0	69.10	35.52	1.180	2
969	1973	5013120	48.3	90.0	69.10	35.52	1.180	2
970	1973	5013120	50.7	120.0	69.10	35.52	1.180	2
971	1973	5013120	48.8	180.0	69.10	35.52	1.180	2
972	1973	5013120	48.5	240.0	69.10	35.52	1.180	2
973	1973	5013120	18.3	8.0	69.10	35.52	1.247	2
974	1973	5013120	30.5	30.0	69.10	35.52	1.247	2
975	1973	5013120	41.0	60.0	69.10	35.52	1.247	2
976	1973	5013120	49.0	90.0	69.10	35.52	1.247	2
977	1973	5013120	49.3	120.0	69.10	35.52	1.247	2
978	1973	5013120	47.8	180.0	69.10	35.52	1.247	2
979	1973	5013120	49.0	240.0	69.10	35.52	1.247	2
980	1973	5021920	39.3	8.0	18.81	19.26	1.180	3
981	1973	5021920	36.8	30.0	18.81	19.26	1.180	3
982	1973	5021920	46.0	60.0	18.81	19.26	1.180	3
983	1973	5021920	46.2	90.0	18.81	19.26	1.180	3
984	1973	5021920	29.5	120.0	18.81	19.26	1.180	3
985	1973	5021920	49.0	180.0	18.81	19.26	1.180	3
986	1973	5021920	44.3	240.0	18.81	19.26	1.180	3

987	1973	5021920	40.8	8.0	18.81	19.26	1.247	3
988	1973	5021920	42.0	30.0	18.81	19.26	1.247	3
989	1973	5021920	48.0	60.0	18.81	19.26	1.247	3
990	1973	5021920	46.2	90.0	18.81	19.26	1.247	3
991	1973	5021920	47.2	120.0	18.81	19.26	1.247	3
992	1973	5021920	46.8	180.0	18.81	19.26	1.247	3
993	1973	5021920	48.2	240.0	18.81	19.26	1.247	3
994	1973	5022125	19.7	8.0	47.81	6.55	1.180	2
995	1973	5022125	26.5	30.0	47.81	6.55	1.180	2
996	1973	5022125	39.0	60.0	47.81	6.55	1.180	2
997	1973	5022125	42.8	90.0	47.81	6.55	1.180	2
998	1973	5022125	45.7	120.0	47.81	6.55	1.180	2
999	1973	5022125	54.3	180.0	47.81	6.55	1.180	2
1000	1973	5022125	55.3	240.0	47.81	6.55	1.180	2
1001	1973	5022125	14.3	8.0	47.81	6.55	1.247	2
1002	1973	5022125	23.7	30.0	47.81	6.55	1.247	2
1003	1973	5022125	35.2	60.0	47.81	6.55	1.247	2
1004	1973	5022125	43.3	90.0	47.81	6.55	1.247	2
1005	1973	5022125	46.7	120.0	47.81	6.55	1.247	2
1006	1973	5022125	50.2	180.0	47.81	6.55	1.247	2
1007	1973	5022125	48.0	240.0	47.81	6.55	1.247	2
1008	1977	5010760	22.0	0.0	47.91	12.42	1.247	2
1009	1977	5010760	33.0	40.0	47.91	12.42	1.247	2
1010	1977	5020320	38.0	70.0	47.91	12.42	1.247	2
1011	1978	5010760	34.0	0.0	34.42	28.20	1.247	2
1012	1978	5010760	35.0	36.0	34.42	28.20	1.247	2
1013	1978	5010760	29.0	99.0	34.42	28.20	1.247	2
1014	1978	5011240	14.0	0.0	58.48	41.21	1.247	2
1015	1978	5011240	26.0	37.0	58.48	41.21	1.247	2
1016	1978	5011240	32.0	69.0	58.48	41.21	1.247	2
1017	1978	5020320	26.0	0.0	34.76	17.04	1.247	2
1018	1978	5020320	32.0	44.0	34.76	17.04	1.247	2
1019	1978	5020320	30.0	72.0	34.76	17.04	1.247	2

Appendix B

INPUT AND RESULT DATA FROM THE AGRONOMIC FRAMEWORK

The VSMB used in this study is VSMB Version II which requires a number of parameter values to run the program. Those parameters that are held constant for each site and scenario of the study include:

1. D - A set of three runoff control coefficients.
2. FINF - Coefficient representing the perculation factor.
3. ISTGES - Number of crop development stages per crop year (X 2).
4. KNTROL - Number of zones from the top of the soil horizon down for which TABLE1 is to be used.
5. NEW - The number of the crop development stage when adjustments of the K-coefficients commence.
6. ISYR - Number of years of calculations to be done.
7. NSY - number of crop development stages per crop year.
8. COEFS - 5*6 matrix consisting of 5 K-coefficients[15] for each of the 5 stages with 6 coefficients per stage.
9. ISFL - Beginning date for the winter budget (month/day).
10. IESG - Ending date for the winter budget (month/day).
11. IFTP - Temperature threshold for seperating precipitation into rainfall and snowfall between July 1st and December 31st (degrees C).

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[15] Crop coefficients reflecting the amount of water extracted by plant roots from the different soil zones during the growing season as a function of potential evapotranspiration.

12. AQ - 4*12 matrix consisting of 12 monthly atmospheric radiation coefficient for each of 4 thresholds. Their use is controlled by temperature and date.

The values for these parameters are outlined in Table B.1 and are taken directly from those derived by Bair (1979).

Table B.1

VSMB Input Coefficients That Are Constant

VARIABLE	VALUES											
D	.91770	1.81100	-0.97300									
FINF	0.00											
ISTGES	10											
KNTROL	6											
NEW	3											
ISYR	70											
NSY	5											
COEFS	.40	.15	.12	.10	.02	.01						
	.40	.20	.13	.12	.03	.02						
	.40	.25	.15	.12	.10	.03						
	.40	.30	.20	.15	.10	.05						
	.40	.30	.20	.15	.07	.03						
IS	1101											
IES	401											
IFTP	5											
ISTP	7											
AQ	.07	.00	.00	.00	.00	.07	.42	.77	.00	.00	.00	.25
	.28	.10	.01	.00	.13	.47	.84	1.20	.00	.00	.00	.46
	.43	.27	.16	.15	.36	.87	1.38	1.89	.00	.00	.00	.59
	.67	.42	.28	.28	.58	1.23	1.88	2.53	.00	.00	.00	.92

Those parameters that vary with site and scenario include:

1. LAT - Latitude of site in question.
2. TABLE1, TABLE2 - Two tables for selecting the appropriate soil moisture release curves for the particular soil in question.
3. CAPAC - The plant available water capacity for each of 6 soil zones (mm)

4. CONTNT - The available water contained in each of the 6 zones at the beginning of the run
5. CAP3 - 95% of the total capacity of the soil in the top 3 zones
6. SMCOF - Coefficients for the % of snow remaining on the field
7. SDATE - Seeding date for the year in question (month/day)
8. IDATES - The dates of the 5 stages of crop development for the year in question

The values for these parameters or outlined for each site and scenario in table B.2.

Table B.2

VSMB Input Coefficients That Vary

VARIABLE		GRAYSVILLE			MINNEDOSA			PIERSON		
		SPCT	SPMT	WWMT	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT
LAT		49.31	49.31	49.31	50.15	50.15	50.15	49.11	49.11	49.11
TABLE1+2		F	F	F	H	H	H	G	G	G
CAPAC (mm)										
zone	1	6.4	6.4	6.4	13.7	13.7	13.7	13.0	13.0	13.0
	2	9.6	9.6	9.6	20.6	20.6	20.6	19.5	19.5	19.5
	3	15.9	15.9	15.9	34.3	34.3	34.3	32.5	32.5	32.5
	4	31.9	31.9	31.9	68.6	68.6	68.6	65.0	65.0	65.0
	5	31.9	31.9	31.9	68.6	68.6	68.6	65.0	65.0	65.0
	6	31.9	31.9	31.9	68.6	68.6	68.6	65.0	65.0	65.0
CONTNT (mm)										
zone	1	5.8	6.4	6.4	12.4	13.7	13.7	11.7	13.0	13.0
	2	8.7	9.6	9.6	18.6	20.6	20.6	17.9	19.5	19.5
	3	14.4	15.9	15.9	31.9	34.3	34.4	29.3	32.5	32.5
	4	31.9	31.9	31.9	68.6	68.6	68.6	65.0	65.0	65.0
	5	31.9	31.9	31.9	68.6	68.6	68.6	65.0	65.0	65.0
	6	31.9	31.9	31.9	68.6	68.6	68.6	65.0	65.0	65.0
CAP3		30.3	30.3	30.3	65.2	65.2	65.2	61.8	61.8	61.8
SMCOF		.5	.75	.75	.5	.75	.75	.5	.75	.75

The LAT parameter dictates which set of coefficients are to be used for radiation values at the top of the atmosphere and thus varies from point to point on the earth's surface. TABLE1 and TABLE2, referred to as Z-tables, are different for a particular sight if the soil is heterogeneous. However, in this study the soil on a sight is assumed to be homogeneous so TABLE1 and TABLE2 are the same. These tables consist of 20 records, each consisting of 10 values which form the relationship between the actual evapotranspiration to potential evapotranspiration ratio and the available soil moisture. The Z-tables used for each site are presented in tables B.3 to B.5 The guidlines for the application of Z-tables to sites is taken directly from Bair (1979) and is based on the water holding capacity and type of soil.

Table B.3

VSMB Table F for Graysville

1.00	0.75	0.66	0.50	0.60	0.66	0.85	1.12	1.44	1.66
1.82	2.33	2.69	3.00	3.33	3.43	3.70	3.89	4.00	4.00
4.00	4.00	4.00	3.91	3.80	3.69	3.59	3.50	3.41	3.33
3.20	3.10	3.00	2.92	2.85	2.77	2.69	2.60	2.55	2.50
2.45	2.37	2.30	2.26	2.22	2.16	2.10	2.07	2.04	2.00
1.95	1.90	1.86	1.83	1.80	1.77	1.75	1.72	1.69	1.66
1.63	1.60	1.58	1.56	1.53	1.51	1.49	1.47	1.45	1.42
1.40	1.38	1.36	1.34	1.32	1.30	1.28	1.27	1.26	1.25
1.23	1.21	1.19	1.18	1.17	1.15	1.14	1.13	1.12	1.11
1.10	1.09	1.08	1.06	1.05	1.04	1.03	1.02	1.01	1.00

Table B.4

VSMB Table H for Minnedosa

2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1.96	1.92	1.88	1.85	1.81	1.78	1.75	1.72	1.69	1.67
1.64	1.61	1.59	1.56	1.53	1.52	1.49	1.47	1.45	1.43
1.40	1.38	1.35	1.34	1.33	1.31	1.29	1.28	1.26	1.25
1.23	1.21	1.19	1.18	1.17	1.15	1.14	1.13	1.12	1.11
1.10	1.08	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00

Table B.5

VSMB Table G for Pierson

1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
1.40	1.38	1.35	1.34	1.33	1.31	1.29	1.28	1.26	1.25
1.23	1.21	1.19	1.18	1.17	1.15	1.14	1.13	1.12	1.11
1.10	1.08	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00

The CAPAC values are taken from the total water holding capacities of each soil type and broken down for the 6 soil zones by the ratio 5:7.5:12.5:25:25:25 as outlined in Bair(1979). The values for CONTNT are the same as CAPAC except for the SPCT scenario where the first 3 zones are reduced by 10%. This reflects the assumption that the starting soil moisture is expected to be less for a conventional till/conventional till yearly rotation than for a minimum till/minimum till yearly rotation. The SMCOF coefficient is also reduced in the SPCT scenario since there is less trash to capture snow than under minimum till.

The SDATE and IDATES values are outlined in tables B.6 to B.14. The SDATE values are the result of a sub BMTS model given the appropriate weather and latitude inputs for each site. The IDATES were then calculated by the main BMTS model given the SDATE, weather and latitude data. For the SPMT scenario, two days were added to each SDATE of the SPCT scenario before calculating the IDATES. This reflects the assumption that seeding is delayed under minimum tillage due to increased spring moisture content and decreased spring soil temperature. SDATE values for the WWMT scenario reflect the date when winter dormancy is broken as opposed to an actual seeding date.

Table B.6

Crop Development Dates for Graysville SPCT

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1925	520	530	620	714	808	819
1926	515	524	615	711	802	817
1927	604	611	630	724	821	903
1928	513	520	613	709	804	814
1929	530	607	628	721	813	825
1930	529	606	625	715	806	819
1931	520	529	618	708	729	811
1932	519	601	620	716	807	819
1933	508	517	608	627	717	729
1934	514	523	609	704	724	806
1935	519	526	619	711	731	811
1936	513	521	613	708	724	804
1937	512	521	614	704	726	806
1938	526	603	623	713	805	814
1939	509	519	610	707	726	806
1940	530	607	628	720	811	819
1941	525	603	623	713	802	811
1942	517	526	618	714	807	818
1943	610	618	707	725	819	831
1944	504	514	604	702	725	805
1945	609	616	703	725	819	902
1946	501	516	614	706	725	803
1947	520	530	622	712	730	809
1948	527	603	623	714	808	819
1949	505	513	611	703	723	803
1950	529	606	627	723	816	901
1951	511	519	613	709	731	814
1952	503	513	611	706	729	816
1953	610	617	707	729	826	908
1954	610	617	707	726	827	909
1955	610	618	707	725	817	827
1956	525	602	620	713	806	817
1957	508	517	612	707	727	807
1958	514	523	620	714	806	817
1959	607	613	703	723	814	823
1960	523	530	620	712	802	812
1961	521	601	618	708	729	808
1962	610	616	705	728	824	913
1963	530	606	625	714	804	815
1964	522	530	626	715	806	824
1965	516	525	618	714	806	818
1966	527	605	626	713	804	818
1967	528	606	628	721	815	829
1968	507	522	614	713	807	824
1969	522	531	627	722	814	825
1970	604	613	702	723	814	829
1971	514	523	615	709	806	818
1972	510	519	609	704	729	813
1973	519	527	615	708	801	812

1974	609	617	705	722	815	830
1975	515	524	615	705	725	802
1976	521	530	617	710	801	815
1977	510	518	607	702	723	806
1978	504	513	607	630	717	729
1979	610	620	710	729	828	912
1980	503	515	527	622	712	723
1981	508	517	611	705	725	807
1982	502	513	607	707	729	809
1983	527	604	625	714	802	810
1984	518	525	613	704	725	804
1985	507	517	613	709	801	813

Table B.7

Crop Development Dates for Graysville SPMT'

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1925	522	531	621	715	810	822
1926	517	527	617	712	803	819
1927	606	613	702	725	824	905
1928	515	522	615	710	805	815
1929	601	609	629	721	813	825
1930	531	608	627	716	808	823
1931	522	531	618	708	729	811
1932	521	602	621	717	808	820
1933	510	519	609	628	718	730
1934	516	525	610	705	725	807
1935	521	529	621	711	731	811
1936	515	523	614	708	724	804
1937	514	523	615	705	727	806
1938	528	604	624	714	806	815
1939	511	520	611	707	726	806
1940	601	608	629	721	812	821
1941	527	603	623	713	802	811
1942	519	527	618	714	807	818
1943	612	619	708	726	820	901
1944	506	514	604	702	725	805
1945	611	617	704	725	819	902
1946	503	518	614	706	725	803
1947	522	601	623	713	731	810
1948	529	605	625	715	808	819
1949	507	515	611	703	723	803
1950	531	609	630	725	819	904
1951	513	520	614	711	802	816
1952	505	515	613	707	731	817
1953	612	619	709	730	827	910
1954	612	618	708	727	829	912
1955	612	619	708	726	818	828
1956	527	604	621	714	807	819
1957	510	518	613	708	727	807
1958	516	524	621	715	807	818
1959	609	616	706	726	817	826
1960	525	601	622	713	803	814
1961	523	602	618	708	729	808
1962	612	618	707	731	828	922
1963	601	607	626	715	805	816
1964	524	602	627	716	807	825
1965	518	529	620	716	808	821
1966	529	607	628	715	806	821
1967	530	608	630	722	816	830
1968	509	523	615	714	808	826
1969	524	603	629	723	815	825
1970	606	613	702	723	814	829
1971	516	526	617	711	807	818
1972	512	521	611	708	801	816
1973	521	529	616	709	802	813

1974	611	620	707	724	818	906
1975	517	525	616	706	726	803
1976	523	602	621	712	804	817
1977	511	519	608	703	724	807
1978	506	515	608	701	722	805
1979	612	621	711	730	829	913
1980	505	516	527	622	712	723
1981	510	519	612	706	727	808
1982	504	514	607	707	729	809
1983	529	606	627	716	804	813
1984	520	529	615	705	726	805
1985	509	518	614	710	802	814

Table B.8

Crop Development Dates for Graysville WWMT

YEAR	SEED	STG1	STG2	STG3	STG4	STG5
1925	420	503	606	705	727	810
1926	422	504	602	703	726	806
1927	417	501	602	628	724	806
1928	429	508	604	704	729	810
1929	419	501	610	705	726	807
1930	418	502	604	628	719	729
1931	417	503	609	630	723	801
1932	420	508	603	627	721	801
1933	421	504	602	621	711	723
1934	501	513	603	701	721	803
1935	426	509	609	704	725	804
1936	417	505	601	630	717	727
1937	504	513	609	701	722	802
1938	419	504	603	630	722	802
1939	426	506	602	702	721	801
1940	424	511	606	703	724	804
1941	417	501	527	624	715	725
1942	420	430	603	630	723	806
1943	426	509	609	705	725	806
1944	425	503	531	627	719	801
1945	510	522	617	712	802	814
1946	419	429	607	630	719	730
1947	504	515	615	707	724	804
1948	426	513	605	701	721	803
1949	418	427	531	626	715	727
1950	518	526	618	714	807	821
1951	504	512	608	706	729	809
1952	423	503	606	702	725	809
1953	430	510	608	703	726	808
1954	519	527	620	714	807	822
1955	417	430	528	626	717	726
1956	515	524	614	706	729	810
1957	429	507	606	704	724	802
1958	418	506	604	703	726	808
1959	509	521	613	707	728	807
1960	424	514	606	702	722	803
1961	429	512	608	629	719	730
1962	503	517	609	629	721	804
1963	423	506	606	629	720	730
1964	426	506	602	702	722	804
1965	509	519	616	711	803	814
1966	426	518	613	703	723	804
1967	526	604	627	720	814	828
1968	426	505	608	708	801	817
1969	424	505	608	712	804	814
1970	510	524	612	704	725	806
1971	428	509	608	701	725	810
1972	509	517	607	701	725	811
1973	502	512	607	701	723	804

1974	508	521	613	704	722	803
1975	509	518	611	702	722	731
1976	422	502	604	625	716	729
1977	424	503	526	621	712	724
1978	509	518	611	701	722	805
1979	529	607	626	715	807	822
1980	501	513	526	621	712	723
1981	501	510	608	703	722	805
1982	429	507	604	705	727	808
1983	506	519	615	708	726	804
1984	420	505	602	627	718	730
1985	422	502	601	704	725	807

Table B.9

Crop Development Dates for Minnedosa SPCT

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1882	603	611	702	731	828	913
1883	521	529	624	723	826	918
1884	520	529	620	722	822	916
No Weather data available for 1885						
1886	525	603	627	717	812	828
1887	519	528	619	717	815	905
1888	526	605	627	724	826	916
1889	520	528	623	716	810	824
1890	610	617	706	730	904	1008
1891	517	526	622	722	819	911
1892	528	607	701	725	820	908
1893	513	522	616	711	802	815
1894	521	530	620	712	802	816
1895	610	617	707	804	912	1017
1896	609	616	704	729	831	926
1897	510	519	618	713	805	817
1898	518	526	619	713	809	823
1899	610	617	707	727	826	913
1900	509	517	611	702	728	808
1901	517	525	619	712	804	818
1902	610	617	709	802	901	928
1903	514	524	615	712	808	821
1904	507	517	611	707	802	816
1905	508	519	612	712	805	816
1906	503	516	610	704	727	809
1907	601	610	629	726	828	918
1908	515	525	617	713	807	827
1909	526	602	624	718	811	822
1910	514	524	619	705	726	810
1911	506	516	610	703	731	814
1912	609	616	702	728	903	921
1913	515	526	617	711	807	820
1914	602	608	630	719	807	823
1915	508	516	613	716	813	825
1916	515	525	619	714	807	820
1917	514	524	623	718	808	821
1918	517	530	618	716	809	822
1919	520	529	620	709	730	811
1920	515	523	616	712	804	816
1921	531	608	626	714	805	823
1922	527	603	623	721	815	827
1923	520	528	616	710	803	819
1924	515	528	622	719	821	905
1925	521	530	620	714	809	823
1926	511	520	613	711	803	821
1927	610	618	707	731	905	914
1928	509	517	612	709	806	817
1929	529	607	629	723	817	831
1930	528	606	625	716	807	820

1931	517	528	618	711	803	816
1932	515	523	613	710	801	815
1933	511	520	610	701	722	806
1934	516	525	615	711	803	815
1935	528	606	628	717	810	824
1936	516	524	615	709	726	808
1937	514	523	617	708	731	811
1938	519	528	621	712	803	815
1939	507	516	609	709	729	812
1940	513	522	616	714	806	816
1941	523	601	622	713	803	814
1942	519	527	620	720	816	831
1943	610	617	706	727	825	912
1944	521	527	618	716	810	827
1945	606	613	704	730	827	909
1946	530	608	630	723	819	907
1947	510	519	620	714	805	817
1948	525	603	625	718	817	829
1949	518	530	622	716	812	823
1950	605	614	705	731	905	926
1951	513	521	617	719	811	826
1952	504	513	613	710	806	824
1953	610	617	708	801	831	925
1954	610	616	706	726	825	908
No weather data available for 1955-1956						
1957	511	520	615	713	804	817
1958	520	528	623	721	813	827
1959	610	617	708	731	830	917
1960	523	531	622	716	807	819
1961	523	601	622	713	805	818
1962	610	616	705	801	902	1001
No weather data available for 1963						
1964	527	605	626	716	809	826
1965	516	526	619	717	811	825
1966	531	608	630	719	817	831
1967	523	531	622	720	815	902
1968	508	523	615	716	817	903
1969	604	613	708	802	830	919
1970	607	613	702	725	819	906
1971	515	525	618	717	816	828
1972	512	521	612	712	812	822
1973	602	609	630	726	823	905
1974	610	618	708	729	905	1017
1975	518	528	622	714	807	824
1976	518	526	615	713	808	820
1977	523	529	619	710	807	903
1978	506	516	611	706	801	818
1979	609	617	707	728	829	920
1980	503	517	607	707	731	818
1981	525	602	625	715	810	822
1982	504	519	614	713	808	822
1983	610	618	709	729	822	902
1984	603	610	702	721	805	816
1985	518	527	610	708	803	823

Table B.10

Crop Development Dates for Minnedosa SPMT

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1882	606	614	704	801	829	915
1883	523	601	626	725	830	922
1884	522	530	621	723	824	917
No weather data available for 1885						
1886	527	605	628	718	814	830
1887	521	529	620	717	815	905
1888	528	607	628	724	826	916
1889	522	531	624	717	811	825
1890	612	619	707	731	906	1021
1891	519	528	623	723	820	913
1892	530	609	704	728	825	911
1893	515	524	617	712	803	817
1894	523	601	621	713	803	817
1895	612	618	708	804	912	1017
1896	611	618	706	731	904	930
1897	512	521	619	714	806	819
1898	520	528	620	714	811	825
1899	612	620	710	801	903	1001
1900	511	519	612	703	728	808
1901	519	526	619	712	804	818
1902	612	620	711	803	904	1002
1903	516	527	618	715	811	823
1904	509	519	613	710	806	821
1905	510	520	613	713	807	818
1906	505	517	611	705	728	810
1907	603	610	629	726	828	918
1908	517	527	619	716	811	831
1909	528	603	624	718	811	822
1910	516	527	620	706	727	812
1911	508	518	611	704	801	815
1912	611	618	702	728	903	921
1913	517	528	619	712	808	821
1914	604	610	702	721	809	826
1915	510	519	614	716	813	825
1916	517	527	620	714	807	820
1917	516	526	624	719	809	822
1918	519	602	620	718	812	824
1919	522	531	622	712	802	813
1920	517	525	617	713	805	817
1921	602	609	627	716	809	825
1922	529	607	627	724	819	902
1923	522	529	617	711	805	820
1924	517	530	622	719	821	905
1925	523	601	622	716	812	826
1926	513	523	615	712	803	821
1927	612	619	708	803	908	921
1928	511	519	614	711	807	819
1929	531	610	702	725	820	902
1930	530	608	627	718	809	822

1931	519	530	618	711	803	816
1932	517	525	615	712	803	817
1933	513	522	611	703	725	807
1934	518	528	618	713	805	817
1935	530	608	629	718	811	824
1936	518	526	617	710	727	809
1937	516	525	619	711	803	815
1938	521	530	622	713	805	816
1939	509	518	611	709	729	812
1940	515	523	616	714	806	816
1941	525	602	623	714	804	815
1942	521	529	622	721	817	831
1943	612	619	708	730	830	927
1944	523	530	621	718	812	829
1945	608	616	707	731	830	913
1946	601	610	702	724	820	909
1947	512	521	620	714	805	817
1948	527	605	627	719	818	830
1949	520	531	623	717	813	824
1950	607	616	707	802	907	1006
1951	515	523	617	719	811	826
1952	506	515	613	710	806	824
1953	612	619	710	803	902	1001
1954	612	618	708	728	829	915
No weather data available for 1955-1956						
1957	513	523	617	714	805	818
1958	522	530	625	722	814	828
1959	612	619	710	801	831	919
1960	525	602	624	717	807	819
1961	525	602	623	713	805	818
1962	612	618	707	804	910	1006
No weather data available for 1963						
1964	529	607	628	718	812	829
1965	518	530	620	718	812	826
1966	602	611	701	720	818	901
1967	525	602	624	721	817	905
1968	510	523	615	716	817	903
1969	606	615	709	803	831	920
1970	609	614	703	726	821	906
1971	517	527	619	718	817	829
1972	514	523	613	713	813	823
1973	604	612	703	729	826	909
1974	612	620	710	801	917	1041
1975	520	530	623	715	808	825
1976	520	528	616	714	809	821
1977	525	531	619	710	807	903
1978	508	517	612	706	801	818
1979	611	619	709	731	903	1004
1980	505	518	607	707	731	818
1981	527	604	626	716	811	823
1982	506	521	616	715	811	825
1983	612	619	710	731	825	904
1984	605	612	703	722	806	818
1985	520	529	610	708	803	823

Table B.11

Crop Development Dates for Minnedosa WWMT

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1882	506	516	616	718	813	825
1883	426	515	616	713	814	901
1884	426	511	612	709	810	827
No weather data available for 1885						
1886	417	426	608	703	724	812
1887	501	512	610	706	801	822
1888	509	522	621	719	820	905
1889	417	428	608	703	726	813
1890	501	518	617	708	731	818
1891	420	430	611	711	807	826
1892	516	525	621	720	814	830
1893	508	516	613	706	729	811
1894	428	508	608	627	719	801
1895	418	427	601	703	728	809
1896	430	510	604	630	722	806
1897	421	503	606	702	726	809
1898	427	508	608	705	728	811
1899	429	516	611	707	728	813
1900	416	426	527	622	714	729
1901	417	430	529	630	721	802
1902	504	516	607	711	803	817
1903	426	508	605	703	728	814
1904	504	512	609	704	730	814
1905	501	516	609	711	805	816
1906	422	501	604	629	722	803
1907	530	608	627	723	823	907
1908	419	506	605	705	728	811
1909	513	521	613	707	731	812
1910	418	429	612	629	719	803
1911	426	508	605	630	727	810
1912	416	502	602	630	725	810
1913	421	506	609	701	728	811
1914	425	508	606	704	724	802
1915	417	428	602	710	808	819
1916	425	509	609	709	731	811
1917	516	526	624	719	809	822
1918	421	503	611	706	731	815
1919	429	510	603	625	717	730
1920	515	523	616	712	804	816
1921	430	511	608	628	718	731
1922	503	511	604	629	725	806
1923	509	521	610	703	725	812
1924	521	602	625	721	823	908
1925	419	507	607	707	801	815
1926	502	510	607	707	731	816
1927	509	521	616	710	806	821
1928	512	519	614	711	807	819
1929	505	520	615	713	803	819
1930	421	505	610	704	726	807

1931	420	508	609	630	725	805
1932	430	511	606	628	723	805
1933	502	511	605	627	719	801
1934	512	521	614	711	803	815
1935	505	518	615	710	731	814
1936	517	525	616	709	726	808
1937	515	524	618	709	801	813
1938	430	513	611	705	728	809
1939	507	516	609	709	729	812
1940	504	516	612	710	802	814
1941	428	505	603	628	720	730
1942	506	515	611	715	810	826
1943	421	503	611	707	729	811
1944	423	502	531	702	726	808
1945	506	523	621	719	813	830
1946	418	427	607	706	730	811
1947	501	513	616	711	803	814
1948	425	513	607	706	731	815
1949	424	503	606	704	731	812
1950	515	525	619	718	814	901
1951	430	508	608	709	801	816
1952	418	427	602	701	726	812
1953	506	520	614	713	809	823
1954	516	524	618	714	808	822

No weather data available for 1955-1956

1957	422	502	603	709	730	811
1958	417	504	605	706	801	813
1959	501	514	612	710	802	815
1960	421	511	607	705	725	806
1961	424	514	609	704	726	807
1962	424	504	605	629	724	810

No weather data available for 1963

1964	425	504	604	703	725	807
1965	429	507	607	704	730	811
1966	507	523	619	710	802	817
1967	518	526	619	719	814	830
1968	501	515	612	714	813	831
1969	418	429	609	715	811	824
1970	508	524	616	711	805	817
1971	507	517	614	713	812	823
1972	501	512	605	703	801	817
1973	510	520	612	709	804	818
1974	429	525	620	712	805	819
1975	510	518	615	707	730	811
1976	513	521	612	710	804	818
1977	417	427	526	620	715	729
1978	430	508	606	704	729	815
1979	520	529	620	713	806	824
1980	423	502	531	702	726	813
1981	507	518	614	709	803	815
1982	429	514	608	710	804	818
1983	429	511	617	712	803	815
1984	416	425	607	705	725	730
1985	425	505	609	705	730	818

Table B.12

Crop Development Dates for Pierson SPCT

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1908	430	514	610	710	802	822
1909	430	516	517	531	621	629
1910	430	512	516	602	619	624
1911	504	517	522	605	620	626
1912	516	527	528	611	627	702
1913	512	525	526	609	623	703
1914	514	523	525	608	625	704
1915	513	523	621	723	817	902
1916	503	517	523	607	627	704
1917	508	517	521	607	623	701
1918	509	521	527	610	624	702
1919	507	520	525	602	618	623
1920	505	516	518	601	619	626
1921	511	521	523	606	620	627
1922	505	516	522	603	617	623
1923	512	521	611	702	722	808
1924	512	523	623	720	820	903
1925	518	528	619	713	805	817
1926	509	518	614	712	802	818
1927	605	612	701	722	816	829
1928	511	519	612	710	802	813
1929	525	602	624	720	811	825
1930	528	604	625	716	806	817
1931	518	529	619	713	731	813
1932	518	526	617	712	731	813
1933	507	516	607	627	717	728
1934	508	517	531	628	718	729
1935	527	603	626	715	806	817
1936	514	522	614	707	723	803
1937	522	530	622	711	802	814
1938	528	605	626	715	805	816
1939	506	515	607	707	726	806
1940	531	607	628	720	812	824
1941	525	602	623	714	803	812
No weather data available for 1942-1944						
1945	610	618	710	801	829	911
1946	508	521	615	710	801	814
1947	508	517	617	711	801	811
1948	524	602	623	714	815	825
1949	507	516	612	709	803	812
1950	601	611	702	729	901	923
1951	515	523	616	717	808	825
1952	503	512	611	710	804	819
1953	523	531	620	716	809	822
1954	523	531	622	715	808	823
1955	516	528	619	713	803	815
1956	525	601	619	715	808	822
1957	519	529	621	714	801	813
1958	513	521	618	717	807	818

1959	522	602	622	718	807	821
1960	603	610	701	722	814	825
1961	513	522	614	706	726	806
1962	430	512	607	630	725	809
1963	529	605	624	712	802	812
1964	521	528	622	712	803	817
1965	516	525	617	713	803	814
1966	524	602	624	713	803	817
1967	526	603	626	719	809	821
1968	506	517	615	713	805	823
1969	520	529	625	722	815	826
1970	524	602	621	711	802	814
1971	513	523	614	708	803	814
1972	509	518	608	703	730	813
1973	529	606	626	719	813	823
1974	606	613	702	720	812	827
1975	518	527	619	707	728	807
1976	517	524	612	707	729	811
1977	511	519	610	705	726	810
1978	504	513	605	630	722	807
1979	525	601	617	709	729	810
1980	502	512	529	623	714	725
1981	508	517	611	706	727	807
1982	504	518	613	709	731	812
1983	505	518	613	707	726	805
1984	519	528	619	712	731	809
1985	506	513	609	708	730	812

Table B.13

Crop Development Dates for Pierson SPMT

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1908	502	514	610	710	802	822
1909	502	516	517	531	621	629
1910	502	512	516	602	619	624
1911	506	519	522	605	620	626
1912	518	529	604	618	702	709
1913	514	528	602	616	701	713
1914	516	526	601	615	702	708
1915	515	525	623	724	819	903
1916	505	517	523	607	627	704
1917	510	520	521	607	623	701
1918	511	525	527	610	624	702
1919	509	521	525	602	618	623
1920	507	516	518	601	619	626
1921	513	524	525	608	622	629
1922	507	517	522	603	617	623
1923	514	523	613	705	724	811
1924	514	524	623	720	820	903
1925	520	530	620	713	805	817
1926	511	520	615	713	803	819
1927	607	614	703	724	820	831
1928	513	521	613	711	803	814
1929	527	604	626	722	813	826
1930	530	606	626	717	807	818
1931	520	531	619	713	731	813
1932	520	528	618	714	802	815
1933	509	518	609	628	718	729
1934	510	519	601	629	719	730
1935	529	605	628	716	807	819
1936	516	524	616	708	724	804
1937	524	601	624	713	804	815
1938	530	608	629	718	809	820
1939	508	517	609	708	727	807
1940	602	609	630	721	813	825
1941	527	604	624	716	805	815
No weather data for 1942-1944						
1945	612	620	713	803	831	915
1946	510	522	616	711	802	816
1947	510	519	618	712	802	812
1948	526	604	625	716	817	827
1949	509	518	613	709	803	812
1950	603	613	704	731	905	927
1951	517	525	618	720	813	827
1952	505	513	611	710	804	819
1953	525	602	622	717	810	822
1954	525	604	625	718	812	826
1955	518	529	620	714	804	816
1956	527	603	620	716	810	825
1957	521	531	623	715	803	815
1958	515	523	619	718	808	819

1959	524	604	624	719	809	822
1960	605	612	702	722	814	825
1961	523	601	621	710	801	813
1962	502	515	609	701	727	810
1963	531	606	625	714	804	815
1964	523	530	623	713	804	819
1965	518	528	619	715	805	816
1966	526	603	625	713	803	817
1967	528	605	628	720	811	824
1968	508	518	615	713	805	823
1969	522	531	627	723	816	827
1970	526	604	623	713	805	816
1971	515	525	615	710	805	815
1972	511	520	610	707	802	815
1973	531	608	627	720	814	824
1974	608	615	704	721	813	828
1975	520	529	620	708	729	808
1976	519	526	614	709	731	813
1977	513	520	610	705	726	810
1978	506	515	607	701	723	807
1979	527	604	619	710	730	811
1980	504	513	530	623	714	725
1981	510	519	612	706	727	807
1982	506	520	615	711	802	814
1983	507	521	615	708	727	806
1984	521	530	620	713	801	810
1985	508	516	610	708	730	812

Table B.14

Crop Development Dates for Pierson WWMT

YEAR	SDATE	STG1	STG2	STG3	STG4	STG5
1908	416	514	610	710	802	822
1909	417	516	517	531	621	629
1910	417	512	516	602	619	624
1911	417	426	501	522	610	616
1912	416	502	507	527	611	621
1913	417	430	505	526	609	616
1914	417	505	511	527	613	622
1915	417	428	605	712	809	822
1916	417	507	509	530	618	627
1917	418	513	514	528	617	625
1918	417	502	506	527	614	620
1919	417	430	505	525	609	616
1920	416	513	518	601	619	626
1921	417	505	509	525	613	620
1922	417	502	508	525	608	618
1923	423	503	605	625	717	726
1924	507	520	622	719	818	901
1925	417	429	604	703	723	807
1926	420	429	601	703	725	806
1927	501	518	613	706	727	812
1928	505	514	607	708	730	811
1929	429	514	613	710	730	812
1930	417	501	607	703	724	805
1931	417	502	607	629	721	731
1932	424	510	606	627	721	802
1933	426	506	602	623	713	726
1934	428	508	530	626	717	728
1935	429	516	612	707	727	807
1936	426	506	602	630	717	727
1937	420	505	603	630	720	801
1938	420	503	604	630	719	802
1939	426	505	601	704	723	802
1940	501	512	607	706	727	808
1941	422	502	530	626	719	729
No weather data available for 1942-1944						
1945	505	518	618	716	806	819
1946	417	425	606	703	725	806
1947	428	507	611	708	729	808
1948	423	512	606	705	730	813
1949	421	501	601	630	724	806
1950	514	525	619	718	815	902
1951	430	507	605	707	730	811
1952	417	426	529	628	723	806
1953	425	508	608	703	725	807
1954	417	511	610	707	728	813
1955	417	502	531	629	721	801
1956	510	520	611	703	727	808
1957	426	505	606	706	724	803
1958	417	501	605	705	729	810

1959	503	516	612	708	729	810
1960	422	511	606	703	723	803
1961	426	513	610	701	721	803
1962	423	502	531	627	722	806
1963	418	503	605	629	720	729
1964	429	510	607	704	725	806
1965	503	513	610	704	726	806
1966	510	522	616	706	725	806
1967	420	516	611	707	727	808
1968	504	516	614	712	804	821
1969	421	503	605	711	803	813
1970	510	523	614	706	727	808
1971	417	504	604	628	723	807
1972	503	512	603	627	723	805
1973	427	510	605	629	722	803
1974	427	510	607	630	719	731
1975	501	511	606	701	721	731
1976	417	505	601	623	716	729
1977	417	426	523	618	711	723
1978	503	511	604	629	721	806
1979	524	531	616	708	727	807
1980	426	506	527	620	711	722
1981	425	504	603	701	720	803
1982	426	505	605	704	727	807
1983	501	510	611	704	723	803
1984	416	425	604	630	721	731
1985	424	504	531	703	723	806

Given the data input set for each site and scenario, the VSMB calculates soil moisture shortfalls for the 5 crop development stages. These values are given in Tables B.15 to B.23.

Table B.15

VSMB Results for Graysville SPCT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1925	23.73	16.92	18.53	79.03	19.30	157.50
1926	21.46	59.54	6.43	41.86	32.94	162.23
1927	15.23	34.23	6.04	52.15	4.14	111.80
1928	18.82	47.94	3.51	0.50	21.53	92.30
1929	16.54	69.46	92.26	95.56	44.43	318.23
1930	18.29	34.82	19.79	54.25	57.28	184.42
1931	23.90	56.54	65.25	46.50	48.86	241.04
1932	28.10	40.16	6.18	68.44	54.25	197.13
1933	28.58	40.24	45.47	68.63	59.87	242.79
1934	30.37	70.63	55.51	98.16	60.88	315.56
1935	19.63	23.13	1.53	33.12	7.56	84.96
1936	24.62	71.58	91.31	68.41	55.68	311.60
1937	17.67	30.89	17.73	32.97	19.37	118.64
1938	29.47	42.15	22.78	35.19	30.62	160.21
1939	22.44	27.70	13.92	84.83	61.48	210.37
1940	19.32	41.24	26.24	34.26	15.43	136.49
1941	8.62	15.82	16.44	86.50	41.82	169.20
1942	12.64	43.18	12.32	38.17	38.01	144.32
1943	7.42	18.41	6.90	47.16	46.70	126.59
1944	21.07	46.08	2.81	3.00	33.12	106.07
1945	17.54	40.62	26.19	58.88	58.18	201.41
1946	24.68	110.47	29.33	26.64	55.43	246.55
1947	22.50	47.14	11.66	25.69	34.41	141.40
1948	26.78	56.13	24.82	43.02	31.42	182.17
1949	22.56	53.17	29.59	86.97	26.02	218.31
1950	21.30	32.13	8.42	47.87	37.33	147.05
1951	25.18	63.61	76.17	92.88	13.00	270.84
1952	27.70	81.90	22.66	17.88	44.61	194.74
1953	16.34	10.78	1.30	40.90	27.23	96.56
1954	5.83	9.35	16.58	53.64	24.57	109.96
1955	13.57	46.36	11.43	62.36	30.66	164.37
1956	15.47	45.04	14.15	54.90	11.58	141.15
1957	20.12	41.09	18.35	67.20	37.67	184.43
1958	39.00	103.37	33.49	42.11	46.43	264.40
1959	9.56	31.64	36.95	87.56	16.09	181.79
1960	13.05	30.65	13.54	62.34	30.79	150.37
1961	51.90	80.25	85.14	71.18	55.68	344.14
1962	15.29	46.30	17.03	25.24	24.09	127.95
1963	10.22	21.42	8.43	27.38	45.16	112.62
1964	27.67	61.54	7.50	48.51	61.43	206.65
1965	15.62	41.68	18.70	16.98	51.18	144.17
1966	27.70	46.19	5.38	39.03	11.63	129.94
1967	34.57	65.76	24.91	24.26	55.21	204.71

1968	10.06	34.62	33.98	0.75	0.39	79.80
1969	34.98	55.88	0.66	25.42	13.38	130.32
1970	28.55	33.07	22.67	80.49	59.19	223.97
1971	14.90	34.74	0.0	11.75	48.26	109.64
1972	27.68	50.12	41.23	61.07	35.43	215.53
1973	16.15	31.39	41.18	40.70	16.16	145.58
1974	27.04	75.19	31.21	86.94	12.41	232.81
1975	9.10	25.84	17.64	59.11	39.76	151.45
1976	40.52	51.92	52.86	75.06	55.13	275.49
1977	19.93	37.42	15.94	57.92	39.87	171.09
1978	16.79	33.61	15.90	23.97	9.56	99.83
1979	43.54	51.43	34.94	67.93	26.28	224.11
1980	38.72	81.17	118.50	45.65	20.77	304.80
1981	30.11	48.94	5.26	49.00	27.62	160.93
1982	18.10	49.17	23.60	12.81	34.45	138.13
1983	22.98	44.44	13.26	59.19	47.11	186.99
1984	8.90	27.05	2.96	52.19	40.06	131.15
1985	21.47	43.65	11.55	53.15	11.73	141.55

Table B.16

VSMB Results for Graysville SPMT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1925	23.73	16.92	18.53	79.03	19.30	157.50
1926	21.46	59.53	6.43	41.86	32.94	162.22
1927	15.23	34.23	6.04	52.15	4.14	111.80
1928	18.68	47.63	3.51	0.50	21.53	91.85
1929	16.11	67.30	89.45	95.48	44.38	312.71
1930	18.29	34.82	19.52	40.50	56.05	169.19
1931	22.67	51.41	36.97	42.41	48.34	201.80
1932	27.88	39.32	4.90	64.65	54.00	190.75
1933	28.58	40.23	45.48	64.82	59.74	238.86
1934	30.02	70.22	54.89	97.29	60.70	313.11
1935	19.63	23.13	1.53	33.12	7.56	84.96
1936	21.35	68.37	90.74	68.40	55.68	304.55
1937	17.37	29.73	17.73	32.97	19.37	117.17
1938	29.42	41.76	19.51	22.80	28.54	142.03
1939	21.76	24.89	3.68	76.98	61.32	188.63
1940	19.32	41.25	22.14	33.81	15.34	131.86
1941	8.40	14.28	11.14	72.93	41.66	148.42
1942	12.64	43.18	12.32	38.17	38.01	144.32
1943	7.41	18.40	6.90	42.79	46.12	121.62
1944	20.52	43.08	0.49	2.76	29.63	96.48
1945	17.54	40.62	26.19	58.88	58.18	201.41
1946	24.68	110.46	29.32	23.68	54.52	242.65
1947	22.50	47.13	11.61	25.64	34.38	141.26
1948	26.78	56.13	24.82	43.02	31.42	182.17
1949	22.09	50.76	21.87	70.78	25.79	191.30
1950	21.30	32.13	8.42	47.87	37.33	147.05
1951	25.17	63.34	66.83	83.43	12.94	251.70
1952	27.31	79.03	13.93	16.21	44.51	180.99
1953	16.34	10.78	1.30	39.82	26.65	94.88
1954	5.83	9.33	16.58	50.32	24.32	106.38
1955	13.57	46.36	11.43	62.36	30.66	164.37
1956	14.89	42.20	7.38	54.00	11.56	130.03
1957	20.12	41.12	9.79	63.66	37.65	172.34
1958	38.96	102.66	29.78	41.56	46.39	259.35
1959	9.56	31.67	40.06	88.34	16.10	185.74
1960	13.05	30.65	13.54	62.34	30.79	150.37
1961	51.26	78.25	68.96	66.14	55.53	320.14
1962	15.29	46.30	17.03	25.24	24.09	127.95
1963	10.21	21.42	8.43	22.81	42.36	105.24
1964	27.59	58.62	5.16	47.57	61.43	200.37
1965	15.62	41.68	18.70	16.98	51.18	144.17
1966	27.70	46.19	5.38	39.03	11.63	129.94
1967	34.57	65.76	24.91	24.26	55.21	204.71
1968	10.05	34.62	34.02	0.0	0.10	78.79
1969	34.98	55.88	0.66	25.42	13.38	130.32
1970	28.55	33.07	22.67	80.49	59.19	223.97
1971	14.90	34.74	0.0	8.26	43.02	100.92
1972	27.68	50.12	41.23	61.07	35.43	215.53
1973	16.16	28.10	40.16	40.65	16.11	141.19

1974	27.04	75.19	31.21	86.94	12.41	232.81
1975	9.10	25.84	14.16	58.79	39.78	147.67
1976	39.52	48.99	35.07	73.58	54.92	252.08
1977	19.93	37.39	8.22	55.73	39.76	161.03
1978	16.79	33.61	15.90	23.97	9.56	99.83
1979	43.54	51.43	34.94	67.93	26.28	224.11
1980	35.13	74.35	117.16	45.59	20.48	292.71
1981	29.66	48.85	5.03	45.58	27.32	156.45
1982	18.12	49.11	20.75	10.54	32.53	131.05
1983	22.40	44.25	13.14	59.11	47.09	185.99
1984	8.90	27.04	2.96	47.62	39.55	126.07
1985	21.47	43.65	11.55	53.15	11.73	141.55

Table B.17

VSMB Results for Graysville WWMT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1925	10.32	62.35	3.94	47.01	55.76	179.37
1926	24.84	72.85	28.42	20.65	37.42	184.18
1927	4.89	15.75	13.24	3.31	38.54	75.73
1928	13.68	74.83	3.07	0.10	10.00	101.68
1929	11.42	64.67	72.93	89.61	53.28	291.90
1930	12.54	37.22	16.24	33.78	25.80	125.57
1931	30.36	82.26	47.44	31.28	44.07	235.42
1932	5.78	49.40	14.89	33.29	36.40	139.75
1933	18.96	62.49	30.81	82.09	38.41	232.75
1934	30.53	89.41	58.36	92.02	60.96	331.29
1935	11.11	37.22	3.84	29.07	20.46	101.71
1936	14.69	75.03	81.73	88.10	37.73	297.27
1937	16.67	36.81	14.18	43.47	20.00	131.13
1938	7.82	54.19	25.72	28.39	22.20	138.31
1939	19.18	38.93	2.47	66.88	62.28	189.74
1940	8.25	38.86	26.98	61.76	11.36	147.22
1941	10.94	22.63	0.27	36.52	45.23	115.60
1942	4.58	29.97	32.02	36.16	19.30	122.04
1943	6.91	29.35	0.78	8.63	46.17	91.84
1944	15.93	52.98	3.66	0.0	27.03	99.60
1945	7.42	37.30	30.77	36.56	33.66	145.72
1946	16.19	112.18	45.99	26.02	40.38	240.77
1947	16.58	58.37	6.69	43.49	31.99	157.12
1948	8.60	60.98	26.05	41.14	31.87	168.64
1949	16.04	64.80	24.95	58.12	47.52	211.43
1950	8.64	44.36	13.90	30.52	42.45	139.86
1951	20.20	77.00	62.97	93.38	16.86	270.42
1952	35.91	92.77	23.46	20.35	16.05	188.53
1953	15.64	8.80	2.26	8.44	18.79	53.93
1954	14.06	12.65	6.06	43.57	28.30	104.64
1955	6.10	22.62	4.05	12.83	38.09	83.70
1956	14.17	36.87	14.72	54.02	11.24	131.02
1957	22.66	53.89	10.35	56.81	45.80	189.52
1958	17.59	100.12	84.91	17.21	46.53	266.36
1959	7.25	23.57	16.20	71.09	51.51	169.60
1960	19.04	33.51	9.90	56.66	45.39	164.50
1961	8.21	107.63	67.91	74.21	41.45	299.41
1962	11.06	15.15	8.26	23.60	49.94	108.00
1963	9.62	29.30	2.50	17.61	27.81	86.85
1964	10.54	61.42	44.56	35.92	17.19	169.62
1965	19.85	42.63	20.29	17.52	42.23	142.51
1966	14.63	56.01	17.68	9.30	49.69	147.30
1967	30.04	66.94	25.92	26.47	51.45	200.82
1968	16.64	36.51	37.35	0.0	1.83	92.34
1969	9.27	55.31	28.18	2.87	36.14	131.76
1970	15.55	37.21	15.91	33.98	50.48	153.13
1971	10.17	50.99	0.0	7.17	27.42	95.75
1972	20.32	56.22	37.90	64.45	34.63	213.53
1973	11.25	49.79	39.46	48.37	9.24	158.10

1974	5.19	33.17	47.32	56.35	53.64	195.67
1975	20.69	23.80	19.43	54.61	43.02	161.55
1976	10.94	100.83	11.36	73.69	39.59	236.40
1977	32.58	33.43	19.59	54.45	26.67	166.71
1978	17.91	31.02	19.00	15.55	34.98	118.46
1979	7.33	49.85	32.55	44.59	55.19	189.51
1980	39.93	72.70	116.78	52.02	20.49	301.92
1981	20.16	72.25	3.15	40.25	37.76	173.57
1982	16.85	43.65	24.08	10.90	37.22	132.70
1983	20.44	71.32	3.53	61.57	35.95	192.81
1984	19.89	35.29	4.59	34.85	58.01	152.62
1985	19.51	63.16	18.49	51.12	26.25	178.55

Table B.18

VSMB Results for Minnedosa SPCT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1882	19.23	21.51	5.74	5.37	30.54	82.40
1883	9.32	29.12	27.88	45.98	35.42	147.73
1884	26.23	46.35	24.09	11.66	19.21	127.55
No weather data available for 1885						
1886	24.42	56.51	14.77	28.88	52.98	177.55
1887	15.56	31.18	9.42	42.69	47.36	146.20
1888	31.92	40.66	27.05	51.23	62.49	213.34
1889	21.14	95.95	98.99	103.06	42.67	361.81
1890	20.12	38.11	40.94	53.09	17.16	169.41
1891	37.28	74.05	23.05	53.69	85.74	273.80
1892	19.52	70.16	74.39	88.76	53.68	306.51
1893	16.32	57.80	81.99	53.08	63.60	272.80
1894	24.70	70.24	24.87	85.66	57.49	262.95
1895	15.44	38.73	43.32	93.45	20.53	211.46
1896	8.45	22.66	32.86	23.35	23.65	110.97
1897	19.31	75.83	47.32	74.16	40.10	256.72
1898	34.85	59.08	46.69	21.45	22.11	184.17
1899	6.29	22.75	38.95	61.99	28.40	158.40
1900	28.55	109.75	104.50	27.40	39.95	310.15
1901	19.93	39.62	0.0	1.00	23.25	83.80
1902	6.35	16.28	18.01	55.59	46.30	142.53
1903	19.41	34.65	34.36	31.80	10.62	130.83
1904	15.71	40.42	2.63	20.03	13.30	92.10
1905	11.02	41.97	28.62	66.27	28.96	176.84
1906	28.47	22.10	5.12	12.78	21.77	90.25
1907	14.15	17.09	20.21	33.05	13.59	98.10
1908	15.75	32.32	53.81	39.74	53.36	194.99
1909	13.29	56.82	30.27	39.35	37.37	177.10
1910	21.75	63.48	58.07	96.91	37.12	277.33
1911	22.60	34.67	36.94	57.16	13.77	165.14
1912	18.44	64.48	18.65	23.28	5.99	130.84
1913	11.54	59.70	35.25	24.63	23.59	154.71
1914	12.67	55.24	52.40	87.18	67.56	275.05
1915	11.95	57.15	36.09	64.00	31.71	200.91
1916	19.73	25.32	16.45	3.44	19.62	84.55
1917	28.28	81.13	54.91	86.79	54.02	305.13
1918	13.58	39.41	105.84	71.40	36.57	266.80
1919	24.41	60.40	17.84	73.51	52.75	228.91
1920	22.33	36.77	68.67	68.90	36.40	233.08
1921	7.84	19.10	23.97	66.56	19.11	136.58
1922	11.24	46.53	12.15	45.30	12.75	127.97
1923	25.35	17.18	14.78	1.74	3.81	62.86
1924	21.41	57.56	74.65	70.17	5.16	228.94
1925	13.28	10.06	14.92	74.52	38.23	151.01
1926	18.38	67.81	60.38	75.90	35.28	257.74
1927	17.84	21.29	1.16	5.22	0.53	46.03
1928	18.94	44.33	1.53	0.29	7.49	72.58
1929	18.29	63.95	86.21	99.70	71.85	340.00
1930	22.56	39.45	31.29	64.75	48.69	206.75

1931	31.14	92.70	61.00	47.04	34.81	266.69
1932	20.98	36.05	16.67	38.02	43.39	155.11
1933	18.64	16.33	19.07	29.78	61.82	145.64
1934	18.98	49.95	36.66	66.28	42.99	214.87
1935	9.28	16.63	1.87	0.0	4.67	32.45
1936	11.98	56.04	54.10	79.57	66.29	267.97
1937	11.69	23.19	18.40	58.92	18.10	130.30
1938	17.47	42.87	48.29	78.32	35.04	221.99
1939	19.04	44.47	40.72	60.09	65.43	229.75
1940	12.27	66.84	58.34	63.29	36.37	237.12
1941	14.67	22.45	39.62	46.88	5.08	128.70
1942	19.46	24.76	11.66	57.56	13.32	126.76
1943	8.52	27.64	21.61	42.80	36.85	137.42
1944	10.10	31.47	25.16	18.77	40.15	125.64
1945	17.80	42.52	30.24	82.09	40.48	213.13
1946	25.35	60.22	31.27	58.46	27.77	203.07
1947	15.50	58.52	13.48	20.65	5.93	114.09
1948	30.16	59.83	31.40	16.86	11.65	149.89
1949	12.54	29.60	23.67	11.69	28.83	106.33
1950	9.14	11.62	4.29	29.05	24.04	78.14
1951	17.57	45.06	86.65	64.90	20.02	234.22
1952	21.96	73.51	34.42	55.71	61.96	247.57
1953	11.00	11.60	15.30	28.50	36.67	103.06
1954	5.54	15.92	16.71	67.76	17.44	123.37
No weather data available for 1955-1956						
1957	14.31	24.85	1.59	0.08	0.37	41.21
1958	25.05	65.12	39.37	69.62	36.30	235.45
1959	13.10	37.69	57.10	82.05	11.92	201.86
1960	10.72	17.52	5.81	20.55	33.05	87.65
1961	29.73	74.20	86.10	35.07	64.95	290.05
1962	12.32	31.17	12.53	2.95	7.83	66.80
No weather data available for 1963						
1964	18.67	16.95	1.90	5.33	14.38	57.22
1965	8.93	18.46	3.73	9.51	28.18	68.82
1966	14.69	44.27	12.66	34.05	11.82	117.49
1967	21.48	58.25	78.07	57.49	55.94	271.23
1968	9.87	36.31	48.37	16.37	1.74	112.66
1969	17.65	40.48	1.62	9.37	16.38	85.50
1970	14.09	16.07	4.97	42.55	24.53	102.21
1971	13.42	36.51	1.11	10.10	16.04	77.20
1972	10.27	40.35	16.13	59.07	25.63	151.45
1973	10.74	35.41	85.59	78.58	21.56	231.89
1974	11.21	59.56	3.63	17.66	9.75	101.81
1975	8.10	15.36	25.23	28.02	2.00	78.71
1976	24.05	39.80	2.20	45.43	27.45	138.93
1977	12.33	32.60	36.63	9.09	27.66	118.31
1978	13.62	35.00	46.79	62.19	58.49	216.09
1979	20.70	38.44	55.70	83.63	26.32	224.78
1980	40.56	96.17	74.63	37.89	15.43	264.69
1981	8.21	21.92	9.97	47.33	28.42	115.85
1982	8.36	22.85	45.98	12.28	25.55	115.01
1983	7.70	16.30	2.62	39.66	34.73	101.01
1984	16.26	35.35	76.70	91.50	52.59	272.41
1985	18.08	19.57	9.12	63.10	3.23	113.10

Table B.19

VSMB Results for Minnedosa SPMT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1882	19.23	21.51	5.74	5.37	30.54	82.40
1883	9.32	29.07	26.31	40.75	34.51	139.96
1884	25.94	44.70	12.74	5.92	16.68	105.98
No weather data available for 1885						
1886	24.42	56.51	14.77	28.88	52.98	177.55
1887	14.87	30.29	8.84	42.17	47.21	143.39
1888	28.75	35.93	24.47	49.69	62.09	200.93
1889	20.74	94.83	98.50	102.98	42.67	359.72
1890	19.28	35.91	35.13	49.61	16.67	156.60
1891	36.65	72.74	21.91	52.79	85.46	269.56
1892	17.44	67.72	73.68	88.74	53.68	301.26
1893	14.77	50.79	72.70	49.28	62.29	249.83
1894	24.55	66.44	15.21	73.69	55.07	234.97
1895	15.05	37.87	42.79	93.31	20.53	209.54
1896	8.25	22.01	32.03	22.86	23.52	108.67
1897	18.61	68.96	32.69	62.45	37.89	220.60
1898	32.94	55.75	44.34	20.91	22.03	175.96
1899	6.19	22.26	35.90	60.07	28.17	152.59
1900	27.79	107.99	103.09	27.14	39.95	305.96
1901	19.72	38.56	0.0	0.17	21.07	79.51
1902	6.28	15.84	16.48	51.19	45.44	135.24
1903	17.99	32.96	29.92	28.86	10.13	119.86
1904	15.63	39.91	1.01	7.96	10.34	74.85
1905	9.38	37.68	22.70	61.60	28.32	159.67
1906	27.92	21.13	3.65	9.69	20.65	83.03
1907	13.72	15.81	17.86	30.31	13.11	90.81
1908	15.29	31.44	52.18	38.71	53.07	190.70
1909	12.68	52.20	21.18	31.37	35.13	152.56
1910	20.58	60.45	56.02	96.47	37.12	270.65
1911	21.52	33.57	34.79	56.26	13.71	159.85
1912	18.26	63.67	15.00	20.78	5.68	123.39
1913	10.25	55.33	30.77	21.82	22.73	140.90
1914	12.46	54.30	51.00	86.38	67.23	271.37
1915	11.33	53.51	32.89	62.15	31.58	191.45
1916	18.69	20.59	8.34	0.52	16.65	64.79
1917	27.65	78.31	41.75	79.70	52.89	280.28
1918	12.36	35.25	100.25	70.71	36.57	255.14
1919	23.19	57.73	15.77	70.89	52.21	219.79
1920	22.02	35.90	67.53	68.06	36.40	229.91
1921	7.67	18.29	18.46	61.55	18.39	124.37
1922	11.12	45.32	10.12	35.84	11.01	113.42
1923	24.39	15.26	12.19	1.07	3.43	56.34
1924	21.32	56.16	70.78	67.21	4.85	220.33
1925	12.84	8.78	8.80	63.03	36.46	129.93
1926	17.72	66.34	58.22	75.12	35.27	252.67
1927	17.84	21.29	1.16	5.22	0.53	46.03
1928	18.66	41.18	1.15	0.06	6.32	67.36
1929	17.13	61.43	83.86	98.80	71.82	333.04
1930	20.60	34.97	26.25	59.86	47.22	188.90

1931	30.19	90.14	58.88	45.99	34.78	259.98
1932	20.88	35.77	16.37	37.77	43.30	154.08
1933	17.79	15.83	17.72	24.02	59.40	134.76
1934	18.73	47.09	23.20	56.67	40.98	186.68
1935	7.66	11.93	0.87	0.0	3.37	23.83
1936	11.02	52.44	47.06	75.50	65.27	251.29
1937	11.35	22.02	15.46	53.00	17.14	118.99
1938	16.98	40.59	29.44	63.84	33.14	183.98
1939	17.60	41.64	36.23	57.98	65.09	218.54
1940	11.12	60.49	54.36	62.47	36.27	224.72
1941	13.06	17.82	32.99	42.28	4.32	110.48
1942	18.75	23.03	9.45	55.45	12.98	119.65
1943	7.02	22.91	15.90	36.86	35.50	118.19
1944	9.44	30.05	24.10	18.41	39.99	122.00
1945	17.62	42.00	29.55	81.56	40.40	211.14
1946	23.98	56.61	27.79	55.20	27.14	190.71
1947	15.52	57.46	9.32	16.03	4.99	103.32
1948	28.81	57.04	27.29	14.72	10.97	138.84
1949	11.15	26.13	18.41	8.89	27.24	91.82
1950	9.10	11.43	3.55	26.85	23.56	74.48
1951	16.62	39.62	72.19	59.35	19.12	206.90
1952	20.35	67.34	29.94	51.74	60.54	229.92
1953	10.93	11.47	12.50	23.74	34.93	93.57
1954	4.86	13.35	13.73	64.17	17.02	113.14
No weather data available for 1955-1956						
1957	14.31	24.85	1.59	0.08	0.37	41.21
1958	23.87	61.70	36.00	67.00	35.65	224.22
1959	12.73	36.65	55.55	81.01	11.71	197.65
1960	10.72	17.51	5.83	19.12	30.82	84.01
1961	27.08	67.78	75.48	30.76	62.70	263.79
1962	12.01	29.73	4.80	0.57	5.98	53.09
No weather data available for 1963						
1964	18.67	16.95	1.90	5.33	14.38	57.22
1965	8.61	17.13	0.22	4.12	23.86	53.94
1966	14.14	41.52	5.99	23.81	10.25	95.70
1967	19.82	54.09	68.03	53.58	54.77	250.29
1968	9.87	36.19	45.72	15.40	1.58	108.78
1969	17.28	39.04	0.23	6.01	14.02	76.58
1970	13.95	15.14	3.25	29.77	21.88	83.99
1971	13.10	34.91	0.00	7.07	14.18	69.26
1972	9.89	38.63	9.80	52.52	24.78	135.62
1973	10.54	32.69	81.21	76.89	21.57	222.90
1974	11.21	59.56	3.64	16.00	8.33	98.73
1975	7.62	12.99	11.63	12.61	0.81	45.66
1976	23.91	39.17	0.33	28.40	24.52	116.33
1977	12.21	31.61	32.84	7.81	26.69	111.17
1978	11.87	29.22	40.00	58.14	57.16	196.39
1979	20.00	36.17	39.96	74.84	25.34	196.32
1980	38.55	92.90	71.24	37.10	15.43	255.21
1981	7.49	19.49	5.33	39.70	26.87	98.89
1982	8.32	21.58	35.94	8.61	23.86	98.31
1983	7.36	14.39	0.99	19.85	29.78	72.37
1984	14.63	25.84	51.47	75.54	49.44	216.93
1985	17.62	18.46	2.14	44.41	2.42	85.05

Table B.20

VSMB Results for Minnedosa WWMT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1882	8.49	47.27	0.27	4.76	9.43	70.22
1883	14.88	36.82	21.49	34.21	22.72	130.12
1884	8.88	74.53	13.89	5.14	10.73	113.16
No weather data available for 1885						
1886	10.16	79.15	85.96	71.00	67.74	314.00
1887	21.67	43.95	18.30	28.80	52.63	165.35
1888	17.64	71.55	20.38	41.88	58.03	209.48
1889	10.52	96.85	115.69	80.90	75.82	379.78
1890	13.68	48.63	26.42	45.61	33.59	167.93
1891	14.21	116.82	31.87	37.65	38.55	239.10
1892	20.24	59.40	96.76	80.80	47.14	304.33
1893	11.62	51.29	69.84	49.92	60.01	242.69
1894	5.50	68.19	28.55	29.73	60.30	192.28
1895	19.02	56.67	45.80	49.73	27.69	198.90
1896	9.33	18.40	18.04	40.02	12.23	98.02
1897	10.28	66.21	35.05	46.43	52.51	210.48
1898	20.56	93.93	57.12	20.35	12.60	204.56
1899	9.81	17.35	6.37	47.23	37.21	117.97
1900	16.38	91.06	118.61	60.44	19.57	306.05
1901	6.46	39.33	5.17	0.0	4.75	55.71
1902	7.67	13.75	0.15	21.40	40.29	83.26
1903	16.71	42.66	43.25	22.34	17.68	142.65
1904	13.51	45.07	0.34	7.70	8.59	75.22
1905	14.38	34.69	25.25	64.27	28.43	167.01
1906	25.11	48.35	7.27	8.18	18.02	106.93
1907	12.73	17.94	16.73	33.11	8.69	89.20
1908	18.69	44.14	39.54	63.07	20.44	185.89
1909	5.26	34.49	38.92	26.03	23.73	128.43
1910	15.79	89.55	54.21	88.72	50.75	299.02
1911	32.12	41.31	36.54	47.05	25.66	182.69
1912	7.65	15.60	41.48	34.71	16.24	115.68
1913	18.02	51.75	44.90	8.93	28.29	151.88
1914	8.09	43.21	67.72	56.25	47.08	222.35
1915	21.21	57.41	42.24	48.44	37.59	206.90
1916	12.80	34.45	16.58	2.05	2.65	68.52
1917	26.27	74.22	43.73	77.35	54.62	276.19
1918	20.01	59.35	79.85	82.61	51.80	293.62
1919	11.60	37.78	43.82	25.66	66.83	185.69
1920	22.01	35.89	67.51	68.05	36.40	229.87
1921	12.56	14.09	3.79	34.94	54.51	119.88
1922	5.53	23.78	29.59	10.62	37.55	107.08
1923	15.54	29.33	10.20	3.08	1.35	59.51
1924	22.57	48.79	74.45	63.67	7.46	216.93
1925	8.02	38.67	3.64	47.96	49.55	147.84
1926	21.15	65.40	68.24	70.46	48.89	274.14
1927	6.25	19.94	1.36	3.55	20.38	51.48
1928	16.13	38.03	0.82	0.0	5.37	60.35
1929	11.79	64.01	68.78	90.05	66.20	300.83
1930	9.33	46.31	30.64	36.81	44.99	168.08

1931	30.53	108.33	84.63	26.67	38.10	288.26
1932	8.83	59.50	12.74	22.27	36.79	140.13
1933	11.50	28.71	16.17	21.22	45.82	123.42
1934	22.97	51.13	23.74	56.90	41.02	195.75
1935	6.78	24.98	2.12	0.0	0.88	34.76
1936	9.26	51.98	45.43	74.95	65.12	246.74
1937	10.68	23.90	17.07	53.28	16.87	121.82
1938	6.69	43.30	24.43	61.08	40.35	175.86
1939	17.62	41.69	36.46	58.07	65.14	218.99
1940	16.33	61.44	50.88	66.61	32.35	227.62
1941	4.70	25.67	11.47	53.14	25.40	120.37
1942	11.38	34.25	5.84	46.44	21.82	119.73
1943	11.55	28.29	18.82	17.01	18.78	94.46
1944	19.18	43.94	36.06	8.61	17.02	124.81
1945	11.25	50.82	33.13	39.14	70.08	204.41
1946	8.84	57.82	65.70	22.03	39.80	194.18
1947	13.32	59.76	12.43	14.52	6.95	106.99
1948	6.33	50.43	49.62	21.37	15.68	143.43
1949	20.98	38.39	15.08	28.84	2.65	105.94
1950	6.44	19.36	2.92	12.10	19.51	60.33
1951	5.85	51.41	46.78	73.92	29.04	206.99
1952	19.54	92.45	40.96	33.13	44.46	230.54
1953	16.18	15.90	7.61	13.17	12.98	65.85
1954	11.68	13.67	7.35	42.93	31.97	107.60
No weather data available for 1955-1956						
1957	6.10	36.76	0.70	0.78	0.96	45.29
1958	13.07	61.76	50.70	48.12	50.95	224.60
1959	7.62	24.62	44.19	67.21	48.33	191.97
1960	7.83	24.12	0.31	7.70	30.33	70.30
1961	7.07	58.22	76.01	40.16	43.95	225.40
1962	10.72	13.23	12.12	9.52	16.65	62.24
No weather data available for 1963						
1964	3.42	29.82	1.22	3.59	14.77	52.80
1965	5.24	12.70	1.45	0.0	13.23	32.62
1966	7.80	43.07	3.52	25.47	17.40	97.26
1967	13.53	63.82	64.87	58.48	42.01	242.71
1968	11.56	37.93	46.10	16.80	2.59	114.97
1969	9.47	48.06	23.59	0.0	4.72	85.84
1970	7.92	32.17	1.84	4.84	37.26	84.03
1971	10.18	41.71	0.0	3.21	12.59	67.69
1972	11.87	31.89	8.56	41.76	34.14	128.21
1973	16.87	32.14	43.92	86.86	49.63	229.43
1974	8.08	23.86	14.68	8.86	29.02	84.50
1975	14.90	14.65	5.76	11.56	7.48	54.36
1976	18.70	51.14	0.07	17.89	33.14	120.95
1977	25.36	57.64	22.05	41.21	4.94	151.19
1978	16.81	28.37	32.40	54.32	53.27	185.17
1979	9.56	30.21	22.21	56.29	46.89	165.18
1980	30.18	110.99	84.76	39.79	19.24	284.96
1981	17.58	32.61	3.70	35.64	19.49	109.02
1982	14.42	17.98	33.05	12.52	19.50	97.48
1983	13.77	15.23	0.0	5.85	31.78	66.63
1984	10.71	35.36	21.88	80.79	31.90	180.63
1985	23.43	45.53	5.39	36.55	19.11	130.01

Table B.21

VSMB Results for Pierson SPCT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1908	56.77	46.40	18.29	27.75	51.87	201.08
1909	78.98	39.41	48.20	30.03	196.62	393.26
1910	69.85	24.27	57.69	80.07	32.46	264.35
1911	58.85	17.79	29.10	43.51	28.75	178.00
1912	32.43	39.81	73.81	36.92	182.97	365.94
1913	33.46	80.26	71.95	33.57	219.24	448.68
1914	28.43	10.74	30.19	12.10	8.30	89.77
1915	19.02	75.84	72.00	115.97	75.96	358.79
1916	55.06	29.77	50.97	84.07	25.41	245.27
1917	51.48	30.88	87.79	94.94	37.12	302.22
1918	51.32	12.20	52.47	80.99	38.09	235.06
1919	29.64	26.26	57.31	73.86	21.01	208.08
1920	27.02	13.62	69.79	49.62	29.53	189.57
1921	30.61	7.87	49.46	65.97	23.89	177.80
1922	50.24	30.71	84.89	90.51	42.50	298.85
1923	28.18	80.76	34.66	8.65	44.49	196.74
1924	18.77	67.21	16.58	28.50	49.55	180.60
1925	35.82	38.71	46.73	69.95	29.25	220.45
1926	15.19	68.20	30.90	49.78	41.00	205.07
1927	12.82	36.69	2.48	8.28	0.28	60.55
1928	16.68	64.32	0.27	0.31	12.39	93.97
1929	8.79	45.41	45.52	73.70	56.63	230.05
1930	22.21	60.20	48.74	77.38	46.33	254.86
1931	37.00	103.64	84.25	89.82	33.64	348.34
1932	26.71	50.49	41.03	69.08	36.73	224.03
1933	14.15	37.41	51.37	61.77	45.00	209.70
1934	34.79	67.56	79.91	93.66	59.52	335.44
1935	9.05	28.40	7.30	1.51	7.80	54.05
1936	29.24	78.12	60.32	81.91	65.93	315.51
1937	16.62	43.33	51.51	46.47	15.74	173.67
1938	21.54	64.96	62.55	77.62	15.82	242.49
1939	16.15	62.57	44.85	35.51	28.70	187.78
1940	22.43	40.51	42.65	14.97	14.41	134.97
1941	8.03	17.16	29.56	58.25	15.04	128.05
No weather data available for 1942-1944						
1945	10.57	24.26	23.81	43.69	32.91	135.23
1946	30.45	73.63	60.97	25.62	52.80	243.46
1947	12.04	53.47	11.48	39.98	24.63	141.59
1948	26.35	50.02	32.92	6.39	8.95	124.63
1949	28.94	44.72	38.29	46.06	34.17	192.18
1950	17.14	15.06	12.18	3.49	4.12	51.99
1951	15.43	43.40	47.15	62.94	16.76	185.69
1952	29.39	96.47	64.39	78.22	46.71	315.19
1953	15.26	32.03	39.33	69.06	67.32	223.00
1954	8.26	14.24	3.78	23.23	34.36	83.87
1955	20.68	34.28	28.40	28.94	23.07	135.37
1956	16.11	44.58	20.81	55.65	22.84	159.99
1957	15.54	36.28	64.74	90.36	26.99	233.91
1958	32.17	101.60	90.73	97.64	65.45	387.58

1959	20.31	83.38	53.25	84.32	45.81	287.07
1960	12.50	35.88	31.76	47.24	20.87	148.25
1961	19.43	107.19	103.84	86.02	59.28	375.76
1962	18.85	18.62	13.59	29.45	53.51	134.03
1963	14.43	21.66	27.77	34.46	19.97	118.29
1964	19.56	44.55	17.66	22.87	19.63	124.28
1965	18.51	30.36	55.48	62.37	51.70	218.42
1966	23.83	58.94	27.86	66.83	26.75	204.21
1967	21.00	87.01	107.15	110.24	56.82	382.20
1968	13.77	84.82	108.24	76.31	18.09	301.23
1969	24.32	58.34	1.44	23.14	27.47	134.71
1970	14.16	55.91	27.81	5.41	28.12	131.42
1971	22.27	34.59	8.62	23.31	39.59	128.37
1972	12.85	28.26	6.68	33.25	7.72	88.76
1973	17.68	31.13	38.31	26.80	23.33	137.24
1974	7.62	61.67	15.10	44.47	20.86	149.72
1975	9.98	23.49	8.46	25.99	32.60	100.51
1976	17.31	27.47	3.70	19.19	36.38	104.05
1977	24.92	60.71	32.57	63.81	38.82	220.82
1978	11.49	29.66	30.63	48.67	62.57	183.02
1979	13.24	44.82	65.87	80.73	18.30	222.95
1980	39.33	89.76	111.15	77.85	30.86	348.94
1981	21.48	67.26	30.10	64.56	37.49	220.88
1982	13.04	34.60	54.68	33.12	27.19	162.63
1983	15.37	42.59	22.12	16.19	27.84	124.11
1984	18.82	57.41	53.71	76.90	47.48	254.32
1985	12.90	45.31	11.03	37.28	28.77	135.28

Table B.22

VSMB Results for Pierson SPMT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1908	56.77	46.40	18.29	27.75	51.87	201.08
1909	78.98	39.41	48.20	30.03	196.62	393.24
1910	69.85	24.27	57.69	80.07	32.46	264.35
1911	58.85	17.79	29.10	43.51	28.75	178.00
1912	32.43	39.81	73.81	36.92	182.97	365.94
1913	33.46	80.26	71.95	33.57	219.24	448.48
1914	28.43	10.74	30.19	12.10	8.30	89.77
1915	19.02	75.84	72.00	115.97	75.96	358.79
1916	55.06	29.77	50.97	84.07	25.41	245.27
1917	51.48	30.88	87.79	94.94	37.12	302.22
1918	51.32	12.20	52.47	80.99	38.09	235.06
1919	29.64	26.26	57.31	73.86	21.01	208.08
1920	27.02	13.62	69.79	49.62	29.53	189.57
1921	30.61	7.87	49.46	65.97	23.89	177.80
1922	50.24	30.71	84.89	90.51	42.50	298.85
1923	28.18	80.76	34.66	8.65	44.49	196.74
1924	18.77	67.21	16.58	28.50	49.55	180.60
1925	35.68	38.48	46.36	69.66	29.19	219.36
1926	14.14	64.66	28.69	46.17	39.93	193.60
1927	12.82	36.69	2.48	8.28	0.28	60.55
1928	16.68	64.32	0.27	0.31	12.39	93.97
1929	8.36	43.94	30.47	58.85	53.33	194.96
1930	21.38	56.98	31.46	60.50	42.90	213.21
1931	36.57	102.31	79.53	86.51	33.05	337.98
1932	26.25	49.24	39.15	67.43	36.32	218.39
1933	13.27	36.21	47.20	58.47	43.95	199.10
1934	34.51	67.12	79.33	93.26	59.52	333.73
1935	8.69	27.07	6.76	1.16	7.38	51.07
1936	28.26	76.48	58.95	81.10	65.73	310.52
1937	16.21	42.55	50.69	45.88	15.57	170.90
1938	20.33	61.14	53.90	70.62	14.84	220.83
1939	15.34	60.51	42.09	34.16	28.23	180.33
1940	21.63	38.17	40.16	13.91	14.02	127.89
1941	8.02	16.93	26.66	54.26	14.36	120.23
No weather data available for 1942-1944						
1945	10.57	24.26	23.81	43.69	32.91	135.23
1946	29.09	70.43	58.59	24.63	52.13	234.87
1947	11.05	47.97	7.23	33.61	23.27	123.14
1948	25.92	48.57	22.15	3.40	7.09	107.12
1949	28.42	43.34	33.18	42.16	33.15	180.25
1950	17.10	14.89	11.09	3.23	3.98	50.29
1951	15.25	42.36	36.14	51.25	15.09	160.09
1952	28.00	91.40	56.34	71.25	45.09	292.08
1953	12.77	27.82	32.65	62.13	64.77	200.14
1954	7.72	13.36	2.35	21.08	33.50	78.02
1955	20.22	32.82	19.87	23.12	21.25	117.29
1956	14.52	37.22	11.54	44.26	20.06	127.60
1957	14.83	34.34	61.01	87.84	26.60	224.62
1958	31.81	100.39	89.29	96.77	65.21	383.48

1959	18.89	80.20	50.12	82.03	45.31	276.54
1960	12.43	35.50	29.55	45.48	20.57	143.52
1961	18.19	103.05	98.35	83.23	58.44	361.26
1962	17.48	16.01	11.38	22.90	49.91	117.68
1963	14.08	21.37	25.92	32.81	19.58	113.77
1964	19.44	44.01	15.21	20.70	18.88	118.25
1965	17.84	28.88	55.24	64.70	52.28	218.94
1966	23.42	57.73	21.51	61.23	25.76	189.65
1967	19.21	82.10	97.93	105.73	55.69	360.67
1968	13.65	84.42	108.29	76.40	18.09	300.85
1969	24.03	56.84	0.82	14.34	24.27	120.30
1970	14.01	55.00	24.81	3.84	26.22	123.88
1971	21.87	33.31	6.93	20.53	38.16	120.80
1972	12.63	27.25	2.66	24.47	6.07	73.08
1973	17.18	30.28	33.56	23.87	22.39	127.29
1974	7.47	60.43	12.72	32.16	19.01	131.79
1975	9.85	22.73	7.00	19.86	30.28	89.72
1976	17.26	27.17	3.14	13.92	33.72	95.21
1977	24.07	59.13	30.18	59.17	37.79	210.34
1978	10.31	24.76	24.46	42.33	59.63	161.50
1979	12.60	42.90	62.02	77.25	17.72	212.49
1980	38.31	88.31	109.87	77.46	30.75	344.70
1981	21.10	65.32	20.44	49.66	34.59	191.11
1982	11.67	26.30	31.28	19.43	22.58	111.27
1983	15.09	40.39	16.74	8.04	23.34	103.61
1984	18.16	53.72	31.69	53.49	42.34	199.39
1985	12.90	45.31	11.03	37.28	28.77	135.28

Table B.23

VSMB Results for Pierson WWMT (mm shortfall)

YEAR	STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	TOTAL
1908	200.78	46.40	18.29	27.75	51.87	345.09
1909	244.03	39.41	48.20	30.03	361.67	0.0
1910	235.72	24.27	57.69	80.07	32.46	430.22
1911	32.59	27.60	83.57	35.30	16.70	195.76
1912	26.19	16.10	50.81	39.00	39.44	171.54
1913	55.10	19.82	71.31	71.96	35.52	253.72
1914	40.55	6.01	39.05	27.59	11.21	124.41
1915	34.15	107.04	78.60	94.38	73.35	387.52
1916	54.08	12.57	84.30	77.79	37.96	266.69
1917	318.36	98.81	105.18	51.14	573.49	0.0
1918	39.14	28.15	73.29	72.43	33.50	246.51
1919	37.38	22.41	54.46	102.31	29.47	246.04
1920	58.54	21.27	69.95	49.63	29.53	228.93
1921	61.80	25.03	52.84	73.94	34.83	248.43
1922	59.98	30.97	83.39	100.55	56.85	331.74
1923	14.15	110.79	46.68	3.83	18.59	194.04
1924	16.14	71.40	15.36	26.55	45.80	175.25
1925	9.72	89.22	39.74	61.30	43.12	243.11
1926	9.03	63.60	50.52	24.20	51.55	198.90
1927	10.56	17.80	10.98	0.0	20.01	59.35
1928	21.23	66.28	1.90	0.0	10.51	99.92
1929	15.03	33.09	20.53	47.88	50.89	167.42
1930	15.89	49.75	39.54	43.43	52.91	201.51
1931	31.49	127.93	100.22	66.12	61.49	387.25
1932	6.90	74.32	40.03	39.61	55.26	216.13
1933	10.50	37.76	41.66	62.08	46.57	198.58
1934	31.54	94.39	78.84	93.65	60.86	359.27
1935	9.83	30.10	18.75	0.0	5.10	63.78
1936	16.89	91.93	58.47	75.70	61.29	304.27
1937	10.36	60.58	37.16	60.90	30.43	199.43
1938	12.50	33.28	60.27	66.42	51.54	224.01
1939	23.28	73.32	44.70	34.60	16.25	192.16
1940	17.43	47.90	43.84	43.11	2.67	154.95
1941	13.20	22.78	7.12	34.17	35.04	112.31
No weather data for 1942-1944						
1945	9.44	31.35	6.61	22.84	28.22	98.46
1946	19.83	113.18	60.49	17.85	40.93	252.28
1947	16.46	49.15	11.82	26.74	30.77	134.93
1948	5.23	48.70	27.20	16.11	6.24	103.49
1949	23.01	65.34	21.45	51.62	23.20	184.61
1950	7.10	33.08	10.09	7.24	0.0	57.51
1951	3.70	49.77	24.47	55.12	20.28	153.34
1952	25.27	107.00	76.05	40.78	51.03	300.13
1953	15.76	38.30	24.92	43.77	36.74	159.49
1954	14.25	41.07	3.17	4.30	34.93	97.73
1955	8.37	32.01	22.59	23.11	20.71	106.79
1956	9.63	41.62	22.47	30.96	24.71	129.39
1957	18.59	58.36	41.02	88.32	40.82	247.11
1958	19.35	123.14	110.59	69.71	72.71	395.48

1959	18.20	76.88	60.70	61.95	62.90	280.64
1960	12.10	28.45	21.54	37.40	49.07	148.55
1961	11.46	98.65	99.50	83.96	57.87	351.44
1962	16.93	23.35	10.59	18.85	49.19	118.91
1963	9.53	40.37	15.16	36.26	24.08	125.40
1964	6.08	61.36	19.24	16.00	14.93	117.61
1965	12.39	35.32	47.14	64.05	38.75	197.65
1966	8.97	55.75	21.37	50.91	46.97	183.98
1967	11.71	70.53	93.87	98.72	64.07	338.90
1968	16.15	83.75	106.03	76.12	22.12	304.17
1969	8.61	51.01	14.44	5.27	23.49	102.82
1970	10.14	51.64	22.29	13.45	10.46	107.98
1971	10.19	59.38	11.21	5.06	35.23	121.08
1972	10.85	25.51	3.13	26.90	6.93	73.31
1973	8.68	37.99	15.14	42.34	8.56	112.70
1974	5.81	15.10	18.35	13.94	27.19	80.40
1975	5.69	28.13	4.35	13.24	26.31	77.71
1976	6.72	42.31	2.39	7.76	21.56	80.73
1977	21.09	66.16	49.43	36.52	43.41	216.61
1978	12.06	24.19	23.99	39.98	55.71	155.93
1979	14.15	39.83	59.72	80.87	11.74	206.31
1980	48.34	93.87	110.83	73.92	34.59	361.54
1981	13.24	70.63	26.62	38.39	48.12	197.00
1982	21.83	27.31	26.39	22.66	31.82	130.01
1983	16.58	41.07	18.01	5.20	23.17	104.03
1984	11.74	59.02	25.63	45.38	41.67	183.44
1985	15.52	43.83	13.16	27.49	41.02	141.01

Tables II.24 to II.31 outline the variable values for the yield simulation model for each site and scenario.

Table B.24

Graysville Yield Simulation Input: SPCT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1925	5021160	41.07	51.18	98.33	20.5217
2	1926	5021160	41.07	87.43	74.80	26.6618
3	1927	5021160	41.07	55.50	56.29	27.6432
4	1928	5021160	41.07	70.27	22.03	34.7874
5	1929	5021160	41.07	178.26	139.99	25.9174
6	1930	5021160	41.07	72.90	111.53	19.2237
7	1931	5021160	41.07	145.69	95.39	30.3749
8	1932	5021160	41.07	74.44	122.69	17.7154
9	1933	5021160	41.07	114.29	128.50	19.7154
10	1934	5021160	41.07	156.51	159.04	19.6207
11	1935	5021160	41.07	44.29	40.68	30.2617
12	1936	5021160	41.07	187.51	124.09	31.0467
13	1937	5021160	41.07	66.29	52.34	29.0500
14	1938	5021160	41.07	94.40	65.81	29.2461
15	1939	5021160	41.07	64.06	146.31	14.2783
16	1940	5021160	41.07	86.80	49.69	31.6400
17	1941	5021160	41.07	40.88	128.32	16.0306
18	1942	5021160	41.07	68.14	76.18	24.7234
19	1943	5021160	41.07	32.73	93.86	21.1831
20	1944	5021160	41.07	69.96	36.12	32.4520
21	1945	5021160	41.07	84.35	117.06	19.1625
22	1946	5021160	41.07	164.48	82.07	37.3036
23	1947	5021160	41.07	81.30	60.10	28.9059
24	1948	5021160	41.07	107.73	74.44	29.1803
25	1949	5021160	41.07	105.32	112.99	21.6022
26	1950	5021160	41.07	61.85	85.20	22.7749
27	1951	5021160	41.07	164.96	105.88	31.2718
28	1952	5021160	41.07	132.26	62.49	35.8991
29	1953	5021160	41.07	28.42	68.13	25.9768
30	1954	5021160	41.07	31.76	78.21	23.8594
31	1955	5021160	41.07	76.36	93.02	22.0322
32	1956	5021160	41.07	74.66	66.48	27.0272
33	1957	5021160	41.07	79.56	104.87	20.6857
34	1958	5021160	41.07	175.86	88.54	38.0095
35	1959	5021160	41.07	78.15	103.65	20.7774
36	1960	5021160	41.07	57.24	93.13	21.2650
37	1961	5021160	41.07	217.29	126.86	36.5276
38	1962	5021160	41.07	78.62	49.33	30.7730
39	1963	5021160	41.07	40.07	72.54	24.4755
40	1964	5021160	41.07	96.71	109.94	21.2848
41	1965	5021160	41.07	76.00	68.16	26.8253
42	1966	5021160	41.07	79.27	50.66	30.5768
43	1967	5021160	41.07	125.24	79.47	30.6565

44	1968	5021160	41.07	78.66	1.14	31.0381
45	1969	5021160	41.07	91.52	38.80	34.4996
46	1970	5021160	41.07	84.29	139.68	16.0453
47	1971	5021160	41.07	49.64	60.01	26.1705
48	1972	5021160	41.07	119.03	96.50	30.3970
49	1973	5021160	41.07	88.72	56.86	27.5816
50	1974	5021160	41.07	133.44	99.35	27.5816
51	1975	5021160	41.07	52.58	98.87	20.2171
52	1975	5021160	41.07	145.30	130.19	23.1668
53	1977	5021160	41.07	73.29	97.79	21.3797
54	1978	5021160	41.07	66.30	33.53	32.5897
55	1979	5021160	41.07	129.91	94.21	28.1475
56	1980	5021160	41.07	238.39	66.42	65.8545
57	1981	5021160	41.07	84.31	76.62	25.9988
58	1982	5021160	41.07	90.87	47.26	32.6637
59	1983	5021160	41.07	80.68	106.30	20.5419
60	1984	5021160	41.07	38.91	92.25	21.1932
61	1985	5021160	41.07	76.67	64.88	27.5144

Table B.25

Graysville Yield Simulation Input: SPMT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1925	5021160	40.69	59.18	98.33	20.4975
2	1926	5021160	40.69	87.42	74.80	26.6293
3	1927	5021160	40.69	55.50	56.29	27.6106
4	1928	5021160	40.69	69.82	22.03	34.7008
5	1929	5021160	40.69	172.86	139.86	25.0975
6	1930	5021160	40.69	72.63	96.55	21.5115
7	1931	5021160	40.69	111.05	90.75	26.2542
8	1932	5021160	40.69	72.10	118.65	18.1263
9	1933	5021160	40.69	114.29	124.56	20.5758
10	1934	5021160	40.69	155.13	157.99	19.6088
11	1935	5021160	40.69	44.29	40.68	30.2260
12	1936	5021160	40.69	180.46	124.08	29.7246
13	1937	5021160	40.69	64.83	52.34	28.7246
14	1938	5021160	40.69	90.69	51.34	31.7508
15	1939	5021160	40.69	50.33	138.30	14.8317
16	1940	5021160	40.69	82.71	49.15	31.2261
17	1941	5021160	40.69	33.82	114.59	18.0074
18	1942	5021160	40.69	68.14	76.18	24.6943
19	1943	5021160	40.69	32.71	88.91	21.9593
20	1944	5021160	40.69	64.09	32.39	32.5678
21	1945	5021160	40.69	84.35	117.06	19.1399
22	1946	5021160	40.69	164.46	78.20	38.3273
23	1947	5021160	40.69	81.24	60.02	28.8814
24	1948	5021160	40.69	107.73	74.44	29.1458
25	1949	5021160	40.69	94.72	96.57	23.3452
26	1950	5021160	40.69	61.85	85.20	22.7481
27	1951	5021160	40.69	155.34	96.37	31.7781
28	1952	5021160	40.69	120.27	60.72	34.1274
29	1953	5021160	40.69	28.42	66.47	26.2525
30	1954	5021160	40.69	31.74	74.64	24.4589
31	1955	5021160	40.69	71.36	93.02	22.0062
32	1956	5021160	40.69	64.47	65.56	26.3858
33	1957	5021160	40.69	71.03	101.31	20.6475
34	1958	5021160	40.69	171.40	87.95	37.1412
35	1959	5021160	40.69	81.29	104.44	20.8576
36	1960	5021160	40.69	57.24	93.13	21.2399
37	1961	5021160	40.69	198.47	121.67	33.7881
38	1962	5021160	40.69	78.62	49.33	30.7367
39	1963	5021160	40.69	40.06	65.17	25.7613
40	1964	5021160	40.69	91.37	109.00	20.9397
41	1965	5021160	40.69	76.00	68.16	26.7937
42	1966	5021160	40.69	79.27	50.66	30.5407
43	1967	5021160	40.69	125.24	79.47	30.6203
44	1968	5021160	40.69	79.69	0.10	24.0020
45	1969	5021160	40.69	91.52	38.80	34.4589
46	1970	5021160	40.69	84.29	139.68	16.0263
47	1971	5021160	40.69	49.64	51.28	28.3392

48	1972	5021160	40.69	119.03	96.50	26.1397
49	1973	5021160	40.69	84.42	56.76	29.8798
50	1974	5021160	40.69	133.44	99.35	27.5490
51	1975	5021160	40.69	49.10	98.57	20.1669
52	1976	5021160	40.69	123.58	128.50	20.8944
53	1977	5021160	40.69	65.54	95.49	21.2512
54	1978	5021160	40.69	66.30	33.53	32.5512
55	1979	5021160	40.69	129.91	94.21	28.1142
56	1980	5021160	40.69	226.64	66.07	61.1527
57	1981	5021160	40.69	83.54	72.90	26.5994
58	1982	5021160	40.69	87.98	43.07	33.1092
59	1983	5021160	40.69	79.90	106.20	20.4685
60	1984	5021160	40.69	38.90	87.17	21.9877
61	1985	5021160	40.69	76.67	64.88	27.4819

Table B.26

Graysville Yield Simulation Input: WWMT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1925	5021160	57.94	76.61	102.77	26.0784
2	1926	5021160	57.94	126.11	58.07	44.9185
3	1927	5021160	57.94	33.88	41.85	38.0897
4	1928	5021160	57.94	91.58	10.10	47.9308
5	1929	5021160	57.94	149.02	142.89	26.8123
6	1930	5021160	57.94	66.00	59.58	34.6469
7	1931	5021160	57.94	160.06	73.35	47.8689
8	1932	5021160	57.94	70.07	69.69	32.6454
9	1933	5021160	57.94	112.26	120.50	26.3882
10	1934	5021160	57.94	178.30	152.98	29.3031
11	1935	5021160	57.94	52.17	49.53	36.0618
12	1936	5021160	57.94	171.45	125.83	34.8762
13	1937	5021160	57.94	67.66	63.47	33.8772
14	1938	5021160	57.94	87.73	50.59	39.5650
15	1939	5021160	57.94	60.58	129.16	20.3268
16	1940	5021160	57.94	74.09	73.12	32.2473
17	1941	5021160	57.94	33.84	81.75	28.9697
18	1942	5021160	57.94	66.57	55.46	35.6842
19	1943	5021160	57.94	37.04	54.80	34.8333
20	1944	5021160	57.94	72.57	27.03	42.9817
21	1945	5021160	57.94	75.49	70.22	33.0744
22	1946	5021160	57.94	174.36	66.40	55.4652
23	1947	5021160	57.94	81.64	75.48	32.5312
24	1948	5021160	57.94	95.63	73.01	35.0036
25	1949	5021160	57.94	105.79	105.64	28.7103
26	1950	5021160	57.94	66.90	72.97	31.6051
27	1951	5021160	57.94	160.17	110.24	36.8687
28	1952	5021160	57.94	152.15	36.40	59.3071
29	1953	5021160	57.94	26.70	27.23	42.3818
30	1954	5021160	57.94	32.77	71.87	31.2136
31	1955	5021160	57.94	32.77	50.92	36.0666
32	1956	5021160	57.94	65.76	65.26	33.2862
33	1957	5021160	57.94	86.90	102.61	27.1042
34	1958	5021160	57.94	202.62	63.74	67.0632
35	1959	5021160	57.94	47.02	122.60	21.0019
36	1960	5021160	57.94	62.45	102.05	25.1792
37	1961	5021160	57.94	183.75	115.66	40.6155
38	1962	5021160	57.94	34.47	73.54	30.7102
39	1963	5021160	57.94	41.42	45.42	36.8621
40	1964	5021160	57.94	116.52	53.11	44.2551
41	1965	5021160	57.94	82.77	59.75	36.5094
42	1966	5021160	57.94	88.32	58.99	37.4875
43	1967	5021160	57.94	122.90	77.92	38.3975
44	1968	5021160	57.94	90.50	1.83	42.5715
45	1969	5021160	57.94	92.76	39.01	43.4049
46	1970	5021160	57.94	68.67	84.46	29.2031
47	1971	5021160	57.94	61.16	34.59	40.1041

48	1972	5021160	57.94	114.44	99.08	31.4456
49	1973	5021160	57.94	100.50	57.61	39.8309
50	1974	5021160	57.94	85.68	109.99	25.4933
51	1975	5021160	57.94	63.92	97.63	26.1304
52	1976	5021160	57.94	123.13	113.28	29.4487
53	1977	5021160	57.94	85.60	81.12	31.6841
54	1978	5021160	57.94	67.93	50.53	37.0066
55	1979	5021160	57.94	89.73	99.78	28.0062
56	1980	5021160	57.94	229.41	72.51	74.6015
57	1981	5021160	57.94	95.56	78.01	33.7479
58	1982	5021160	57.94	84.58	48.12	39.7183
59	1983	5021160	57.94	95.29	97.52	29.1528
60	1984	5021160	57.94	59.77	92.86	26.8357
61	1985	5021160	57.94	101.16	77.37	34.7435

Table B.27

Minnedosa Yield Simulation Input: SPCT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1882	5011760	52.96	46.48	35.91	28.4091
2	1883	5011760	52.96	66.32	81.40	29.2179
3	1884	5011760	52.96	96.67	30.87	45.4529
4	1886	5011760	52.96	95.70	81.86	32.3191
5	1887	5011760	52.96	56.16	90.05	26.7995
6	1888	5011760	52.96	99.63	113.72	25.8328
7	1889	5011760	52.96	216.08	145.73	38.5393
8	1890	5011760	52.96	99.17	70.25	35.6909
9	1891	5011760	52.96	134.38	139.43	25.0500
10	1892	5011760	52.96	164.07	142.44	28.8550
11	1893	5011760	52.96	156.11	116.68	33.7430
12	1894	5011760	52.96	119.81	143.15	22.5608
13	1895	5011760	52.96	97.49	113.98	25.5411
14	1896	5011760	52.96	63.97	47.00	36.8888
15	1897	5011760	52.96	142.46	114.26	31.8632
16	1898	5011760	52.96	140.62	43.56	52.4970
17	1899	5011760	52.96	67.99	90.39	27.4561
18	1900	5011760	52.96	242.80	67.35	83.0543
19	1901	5011760	52.96	59.55	24.25	41.4129
20	1902	5011760	52.96	40.64	101.89	24.2717
21	1903	5011760	52.96	88.42	42.42	41.1337
22	1904	5011760	52.96	58.76	33.33	39.5573
23	1905	5011760	52.96	81.61	95.23	27.6642
24	1906	5011760	52.96	55.69	34.55	39.0773
25	1907	5011760	52.96	51.45	46.64	36.1369
26	1908	5011760	52.96	101.88	93.10	30.5398
27	1909	5011760	52.96	100.38	76.72	34.2472
28	1910	5011760	52.96	143.30	134.03	27.4300
29	1911	5011760	52.96	94.21	70.93	34.7688
30	1912	5011760	52.96	101.57	29.27	46.8184
31	1913	5011760	52.96	106.49	48.22	42.8789
32	1914	5011760	52.96	120.31	154.74	20.6245
33	1915	5011760	52.96	105.19	95.71	30.3982
34	1916	5011760	52.96	61.50	23.06	41.7882
35	1917	5011760	52.96	164.32	140.81	29.2723
36	1918	5011760	52.96	158.83	107.97	36.6532
37	1919	5011760	52.96	102.65	126.26	23.7488
38	1920	5011760	52.96	127.77	105.30	31.5692
39	1921	5011760	52.96	50.91	85.67	27.4895
40	1922	5011760	52.96	69.92	58.05	34.8433
41	1923	5011760	52.96	57.31	5.55	41.3130
42	1924	5011760	52.96	153.62	75.33	45.4376
43	1925	5011760	52.96	38.26	112.75	22.3820
44	1926	5011760	52.96	146.57	111.18	33.3758
45	1927	5011760	52.96	40.29	5.75	40.9315
46	1928	5011760	52.96	64.80	7.78	42.7294
47	1929	5011760	52.96	168.45	171.55	23.4542

48	1930	5011760	52.96	93.30	113.44	25.1955
49	1931	5011760	52.96	184.84	81.85	51.9977
50	1932	5011760	52.96	73.70	81.41	29.8506
51	1933	5011760	52.96	54.04	91.60	26.4025
52	1934	5011760	52.96	105.59	109.27	27.4625
53	1935	5011760	52.96	27.78	4.67	41.6688
54	1936	5011760	52.96	122.12	145.86	22.3385
55	1937	5011760	52.96	53.28	77.02	29.3770
56	1938	5011760	52.96	108.63	113.36	26.9888
57	1939	5011760	52.96	104.23	125.52	24.0584
58	1940	5011760	52.96	137.45	99.66	34.6843
59	1941	5011760	52.96	76.74	51.96	37.0820
60	1942	5011760	52.96	55.88	70.88	30.8280
61	1943	5011760	52.96	57.77	79.65	29.0274
62	1944	5011760	52.96	66.73	58.92	34.3297
63	1945	5011760	52.96	90.69	122.57	23.2080
64	1946	5011760	52.96	116.84	86.23	34.4974
65	1947	5011760	52.96	87.50	26.58	44.6983
66	1948	5011760	52.96	121.39	28.51	51.6538
67	1949	5011760	52.96	65.81	40.52	38.5787
68	1950	5011760	52.96	25.05	53.09	36.1742
69	1951	5011760	52.96	149.28	84.92	41.3354
70	1952	5011760	52.96	129.89	117.67	29.0151
71	1953	5011760	52.96	37.90	65.17	31.8954
72	1954	5011760	52.96	38.17	85.20	27.5844
73	1957	5011760	52.96	40.75	0.45	32.4649
74	1958	5011760	52.96	129.54	105.92	31.7101
75	1959	5011760	52.96	107.89	93.97	31.1873
76	1960	5011760	52.96	34.05	53.60	34.7694
77	1961	5011760	52.96	190.03	100.02	46.8313
78	1962	5011760	52.96	56.02	10.78	42.3424
79	1964	5011760	52.96	37.52	19.71	41.5861
80	1965	5011760	52.96	31.12	37.69	38.7426
81	1966	5011760	52.96	71.62	45.87	37.9437
82	1967	5011760	52.96	157.80	113.43	34.9371
83	1968	5011760	52.96	94.55	18.11	47.4866
84	1969	5011760	52.96	59.75	25.75	41.1616
85	1970	5011760	52.96	35.13	67.08	31.6157
86	1971	5011760	52.96	51.04	26.14	40.5262
87	1972	5011760	52.96	66.75	84.70	28.5477
88	1973	5011760	52.96	131.74	100.14	33.5245
89	1974	5011760	52.96	74.40	27.41	42.4835
90	1975	5011760	52.96	48.69	30.02	39.6940
91	1976	5011760	52.96	66.06	72.88	31.0645
92	1977	5011760	52.96	81.56	36.75	41.4472
93	1978	5011760	52.96	95.41	120.68	24.0316
94	1979	5011760	52.96	114.84	109.95	28.5438
95	1980	5011760	52.96	211.36	53.32	74.8528
96	1981	5011760	52.96	40.10	75.75	29.5054
97	1982	5011760	52.96	77.19	37.83	40.5634
98	1983	5011760	52.96	26.62	74.39	30.9120
99	1984	5011760	52.96	128.31	144.09	23.3845
100	1985	5011760	52.96	46.77	66.33	31.5290

Table B.28

Minnedosa Yield Simulation Input: SPMT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1882	5011760	40.32	46.48	35.91	37.1019
2	1883	5011760	40.32	64.70	75.26	29.3942
3	1884	5011760	40.32	83.38	22.60	43.2279
4	1886	5011760	40.32	95.70	81.86	31.2191
5	1887	5011760	40.32	54.00	89.38	25.9298
6	1888	5011760	40.32	89.15	111.78	24.2380
7	1889	5011760	40.32	214.07	145.65	36.7831
8	1890	5011760	40.32	90.32	66.28	34.1606
9	1891	5011760	40.32	131.30	138.25	24.0300
10	1892	5011760	40.32	158.84	142.42	27.0514
11	1893	5011760	40.32	138.26	111.57	30.7172
12	1894	5011760	40.32	106.20	128.76	22.8631
13	1895	5011760	40.32	95.71	113.84	24.5105
14	1896	5011760	40.32	62.29	46.38	35.6317
15	1897	5011760	40.32	120.26	100.34	30.4820
16	1898	5011760	40.32	133.03	42.94	48.8753
17	1899	5011760	40.32	64.35	88.24	26.6946
18	1900	5011760	40.32	238.87	67.09	78.3585
19	1901	5011760	40.32	58.28	21.24	40.3737
20	1902	5011760	40.32	38.60	96.63	24.4467
21	1903	5011760	40.32	80.87	38.99	39.4204
22	1904	5011760	40.32	56.55	18.30	40.6237
23	1905	5011760	40.32	69.76	89.92	26.7490
24	1906	5011760	40.32	52.70	30.34	38.4359
25	1907	5011760	40.32	47.39	43.42	35.4992
26	1908	5011760	40.32	98.91	91.78	29.4048
27	1909	5011760	40.32	86.06	66.50	33.5388
28	1910	5011760	40.32	137.05	133.59	25.7026
29	1911	5011760	40.32	89.88	69.97	33.2194
30	1912	5011760	40.32	96.93	26.46	44.9118
31	1913	5011760	40.32	96.35	44.55	40.5183
32	1914	5011760	40.32	117.76	153.61	19.8496
33	1915	5011760	40.32	97.73	93.73	28.8284
34	1916	5011760	40.32	47.62	17.17	40.3139
35	1917	5011760	40.32	147.71	132.59	27.4580
36	1918	5011760	40.32	147.86	107.28	33.4601
37	1919	5011760	40.32	96.69	123.10	22.9048
38	1920	5011760	40.32	125.45	104.46	30.3266
39	1921	5011760	40.32	44.42	79.94	27.5992
40	1922	5011760	40.32	66.56	46.85	35.9040
41	1923	5011760	40.32	51.84	4.50	39.0421
42	1924	5011760	40.32	148.26	72.06	43.6097
43	1925	5011760	40.32	30.42	99.49	24.3721
44	1926	5011760	40.32	142.28	110.39	31.6810
45	1927	5011760	40.32	40.29	5.75	39.5384
46	1928	5011760	40.32	60.99	6.38	40.5229
47	1929	5011760	40.32	162.42	170.62	22.0413

48	1930	5011760	40.32	81.82	107.08	24.4365
49	1931	5011760	40.32	179.21	80.77	48.9477
50	1932	5011760	40.32	73.02	81.07	28.8451
51	1933	5011760	40.32	51.34	83.42	27.0122
52	1934	5011760	40.32	89.02	97.65	26.9900
53	1935	5011760	40.32	20.46	3.37	41.2655
54	1936	5011760	40.32	110.52	140.77	21.2239
55	1937	5011760	40.32	48.83	70.14	29.6801
56	1938	5011760	40.32	87.01	96.98	26.9132
57	1939	5011760	40.32	95.47	123.07	22.7910
58	1940	5011760	40.32	125.97	98.74	31.7619
59	1941	5011760	40.32	63.87	46.60	35.7154
60	1942	5011760	40.32	51.23	68.43	30.1099
61	1943	5011760	40.32	45.83	72.36	29.1666
62	1944	5011760	40.32	63.59	58.40	33.0145
63	1945	5011760	40.32	89.17	121.96	22.3994
64	1946	5011760	40.32	108.38	82.34	32.9289
65	1947	5011760	40.32	82.30	21.02	43.3079
66	1948	5011760	40.32	113.14	25.69	48.5408
67	1949	5011760	40.32	55.69	36.13	37.4144
68	1950	5011760	40.32	24.08	50.41	35.7845
69	1951	5011760	40.32	128.43	78.47	37.4156
70	1952	5011760	40.32	117.63	112.28	27.4548
71	1953	5011760	40.32	34.90	58.67	32.3947
72	1954	5011760	40.32	31.94	81.19	27.8068
73	1957	5011760	40.32	40.75	0.45	31.3599
74	1958	5011760	40.32	121.57	102.65	30.1481
75	1959	5011760	40.32	104.93	92.72	29.9967
76	1960	5011760	40.32	34.06	49.94	34.4045
77	1961	5011760	40.32	170.34	93.46	42.2625
78	1962	5011760	40.32	46.54	6.55	39.7856
79	1964	5011760	40.32	37.52	19.71	40.1708
80	1965	5011760	40.32	25.96	27.98	40.3208
81	1966	5011760	40.32	61.65	34.06	38.2910
82	1967	5011760	40.32	141.94	108.35	32.1226
83	1968	5011760	40.32	91.78	16.98	45.4720
84	1969	5011760	40.32	56.55	20.03	40.4132
85	1970	5011760	40.32	32.34	51.65	34.1759
86	1971	5011760	40.32	48.01	21.25	39.8329
87	1972	5011760	40.32	58.32	77.30	28.5544
88	1973	5011760	40.32	124.44	98.46	31.5809
89	1974	5011760	40.32	74.41	24.33	41.6085
90	1975	5011760	40.32	32.24	13.42	41.1504
91	1976	5011760	40.32	63.41	52.92	34.2403
92	1977	5011760	40.32	76.66	34.50	39.8593
93	1978	5011760	40.32	81.09	115.30	22.8754
94	1979	5011760	40.32	96.13	100.18	27.2668
95	1980	5011760	40.32	202.69	52.53	68.8642
96	1981	5011760	40.32	32.31	66.57	30.8642
97	1982	5011760	40.32	65.84	32.47	39.0163
98	1983	5011760	40.32	22.74	49.63	36.3078
99	1984	5011760	40.32	91.94	124.98	22.1244
100	1985	5011760	40.32	38.22	46.83	34.8412

Table B.29

Minnedosa Yield Simulation Input: WWMT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1882	5011760	51.96	56.03	14.19	50.6906
2	1883	5011760	51.96	73.19	56.93	42.4360
3	1884	5011760	51.96	97.30	15.87	57.7952
4	1886	5011760	51.96	175.27	138.74	37.9695
5	1887	5011760	51.96	83.92	81.43	37.0089
6	1888	5011760	51.96	109.57	99.91	35.9669
7	1889	5011760	51.96	223.06	156.72	44.1627
8	1890	5011760	51.96	88.73	79.20	38.3245
9	1891	5011760	51.96	162.90	76.20	56.9755
10	1892	5011760	51.96	176.40	127.94	41.6167
11	1893	5011760	51.96	132.75	109.93	37.4244
12	1894	5011760	51.96	102.24	90.03	37.4612
13	1895	5011760	51.96	121.49	77.42	45.0825
14	1896	5011760	51.96	45.77	52.25	41.5357
15	1897	5011760	51.96	111.54	98.94	36.5737
16	1898	5011760	51.96	171.61	32.95	79.6689
17	1899	5011760	51.96	33.53	84.44	33.4869
18	1900	5011760	51.96	226.06	80.01	81.4712
19	1901	5011760	51.96	50.96	4.75	48.5039
20	1902	5011760	51.96	21.57	61.69	41.8638
21	1903	5011760	51.96	102.62	40.02	53.0524
22	1904	5011760	51.96	58.92	16.29	50.7951
23	1905	5011760	51.96	74.32	92.70	32.9126
24	1906	5011760	51.96	80.73	26.20	G2.2419
25	1907	5011760	51.96	47.40	41.80	44.4210
26	1908	5011760	51.96	102.37	83.51	39.3446
27	1909	5011760	51.96	78.67	49.76	45.3204
28	1910	5011760	51.96	159.55	139.47	34.4468
29	1911	5011760	51.96	109.97	72.71	44.0902
30	1912	5011760	51.96	64.73	50.95	43.1158
31	1913	5011760	51.96	114.67	37.22	57.0693
32	1914	5011760	51.96	119.02	103.33	36.6869
33	1915	5011760	51.96	120.86	86.03	42.1820
34	1916	5011760	51.96	63.83	4.70	49.6003
35	1917	5011760	51.96	144.22	131.97	33.5329
36	1918	5011760	51.96	159.21	134.41	35.7809
37	1919	5011760	51.96	93.20	92.49	35.3638
38	1920	5011760	51.96	125.41	104.45	37.5682
39	1921	5011760	51.96	30.44	89.45	32.5665
40	1922	5011760	51.96	58.90	48.17	43.3287
41	1923	5011760	51.96	55.07	4.43	48.5317
42	1924	5011760	51.96	145.81	71.13	53.6584
43	1925	5011760	51.96	50.33	97.51	30.0863
44	1926	5011760	51.96	154.79	119.35	39.2593
45	1927	5011760	51.96	27.55	23.93	50.4543
46	1928	5011760	51.96	54.98	5.37	49.1494
47	1929	5011760	51.96	144.58	156.25	27.7135

48	1930	5011760	51.96	86.28	81.80	37.2412
49	1931	5011760	51.96	223.49	64.77	89.4229
50	1932	5011760	51.96	81.07	59.06	42.9523
51	1933	5011760	51.96	56.38	67.04	37.9473
52	1934	5011760	51.96	97.84	97.92	34.6207
53	1935	5011760	51.96	33.88	0.88	42.0705
54	1936	5011760	51.96	106.67	140.07	25.9677
55	1937	5011760	51.96	51.65	70.15	36.8678
56	1938	5011760	51.96	74.42	101.43	30.8186
57	1939	5011760	51.96	95.77	123.21	28.2420
58	1940	5011760	51.96	128.65	98.96	39.8336
59	1941	5011760	51.96	41.84	78.54	34.5639
60	1942	5011760	51.96	51.47	68.26	37.3594
61	1943	5011760	51.96	58.66	35.79	46.6917
62	1944	5011760	51.96	99.18	25.63	46.6917
63	1945	5011760	51.96	95.20	109.22	56.4010
64	1946	5011760	51.96	132.36	61.83	53.2798
65	1947	5011760	51.96	85.51	21.47	54.2182
66	1948	5011760	51.96	106.38	37.05	54.9194
67	1949	5011760	51.96	74.45	31.49	49.8277
68	1950	5011760	51.96	28.72	31.61	48.3926
69	1951	5011760	51.96	104.04	102.96	34.2508
70	1952	5011760	51.96	152.95	77.59	53.2916
71	1953	5011760	51.96	39.69	26.15	48.4110
72	1954	5011760	51.96	32.70	74.90	35.9886
73	1957	5011760	51.96	43.56	1.74	44.4680
74	1958	5011760	51.96	125.53	99.07	39.1642
75	1959	5011760	51.96	76.43	115.54	27.8347
76	1960	5011760	51.96	32.26	38.03	46.1099
77	1961	5011760	51.96	141.30	84.11	47.6263
78	1962	5011760	51.96	36.07	26.17	48.6406
79	1964	5011760	51.96	34.46	18.36	50.2476
80	1965	5011760	51.96	19.39	13.23	55.0304
81	1966	5011760	51.96	54.39	42.87	44.4495
82	1967	5011760	51.96	142.22	100.49	42.3278
83	1968	5011760	51.96	95.59	19.39	56.8719
84	1969	5011760	51.96	81.12	4.72	52.3146
85	1970	5011760	51.96	41.93	42.10	44.3230
86	1971	5011760	51.96	51.89	15.80	50.2771
87	1972	5011760	51.96	52.32	75.90	35.4012
88	1973	5011760	51.96	92.93	136.49	25.1438
89	1974	5011760	51.96	46.62	37.88	45.4532
90	1975	5011760	51.96	35.31	19.04	50.0595
91	1976	5011760	51.96	69.91	51.03	43.7036
92	1977	5011760	51.96	105.05	46.15	51.6549
93	1978	5011760	51.96	77.58	107.59	29.7098
94	1979	5011760	51.96	61.98	103.18	29.3798
95	1980	5011760	51.96	225.93	59.03	94.5067
96	1981	5011760	51.96	53.89	55.13	41.0375
97	1982	5011760	51.96	65.45	32.02	48.4060
98	1983	5011760	51.96	29.00	37.63	46.7512
99	1984	5011760	51.96	67.95	112.69	27.7255
100	1985	5011760	51.96	74.35	55.66	42.9595

Table B.30

Pierson Yield Simulation Input: SPCT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1908	5012080	43.14	121.46	79.62	33.0392
2	1909	5012080	43.14	166.59	226.65	13.2077
3	1910	5012080	43.14	151.81	112.53	30.3156
4	1911	5012080	43.14	105.74	72.26	32.3017
5	1912	5012080	43.14	146.05	219.89	12.4242
6	1913	5012080	43.14	185.67	252.81	11.9236
7	1914	5012080	43.14	69.36	20.40	38.3809
8	1915	5012080	43.14	166.86	191.93	17.5659
9	1916	5012080	43.14	135.80	109.48	28.4288
10	1917	5012080	43.14	170.15	132.06	28.9248
11	1918	5012080	43.14	115.99	119.08	23.8423
12	1919	5012080	43.14	113.21	94.87	28.3197
13	1920	5012080	43.14	110.43	79.15	31.4096
14	1921	5012080	43.14	87.94	89.86	26.2982
15	1922	5012080	43.14	165.84	133.01	27.9964
16	1923	5012080	43.14	143.60	53.14	44.7220
17	1924	5012080	43.14	102.56	78.05	30.5300
18	1925	5012080	43.14	121.26	99.20	28.5168
19	1926	5012080	43.14	114.29	90.78	29.3569
20	1927	5012080	43.14	51.99	8.56	37.3093
21	1928	5012080	43.14	81.27	12.70	40.5155
22	1929	5012080	43.14	99.72	130.33	20.2389
23	1930	5012080	43.14	131.15	123.71	24.8394
24	1931	5012080	43.14	224.89	123.46	43.2917
25	1932	5012080	43.14	118.23	105.81	26.7075
26	1933	5012080	43.14	102.93	106.77	24.6541
27	1934	5012080	43.14	182.26	153.18	26.2895
28	1935	5012080	43.14	44.75	9.31	37.2276
29	1936	5012080	43.14	167.68	147.84	25.1644
30	1937	5012080	43.14	111.46	62.21	35.6231
31	1938	5012080	43.14	149.05	93.44	34.5313
32	1939	5012080	43.14	123.57	64.21	37.2947
33	1940	5012080	43.14	105.59	29.38	42.4795
34	1941	5012080	43.14	54.75	73.29	26.9606
35	1945	5012080	43.14	58.64	76.60	26.5014
36	1946	5012080	43.14	165.05	78.42	42.2798
37	1947	5012080	43.14	76.99	64.61	30.3510
38	1948	5012080	43.14	109.29	15.34	45.4900
39	1949	5012080	43.14	111.95	80.23	31.3890
40	1950	5012080	43.14	44.38	7.61	36.9602
41	1951	5012080	43.14	105.98	79.70	30.6383
42	1952	5012080	43.14	190.25	124.93	34.4911
43	1953	5012080	43.14	86.62	136.38	18.2752
44	1954	5012080	43.14	26.28	57.59	31.0658
45	1955	5012080	43.14	83.36	52.01	33.8285
46	1956	5012080	43.14	81.50	78.49	27.9159
47	1957	5012080	43.14	116.56	117.35	24.2325

48	1958	5012080	43.14	224.50	163.09	31.5456
49	1959	5012080	43.14	156.94	130.13	27.2089
50	1960	5012080	43.14	80.14	68.11	29.9361
51	1961	5012080	43.14	230.46	145.30	37.7682
52	1962	5012080	43.14	51.06	82.96	25.0046
53	1963	5012080	43.14	63.86	54.43	31.3153
54	1964	5012080	43.14	81.77	42.50	35.7339
55	1965	5012080	43.14	104.35	114.07	23.4568
56	1966	5012080	43.14	110.63	93.58	28.2450
57	1967	5012080	43.14	215.16	167.06	28.8025
58	1968	5012080	43.14	206.83	94.40	48.3047
59	1969	5012080	43.14	84.10	50.61	34.2355
60	1970	5012080	43.14	97.88	33.53	40.1587
61	1971	5012080	43.14	65.48	62.90	29.6754
62	1972	5012080	43.14	47.79	40.97	33.2606
63	1973	5012080	43.14	87.12	50.13	34.7423
64	1974	5012080	43.14	84.39	65.33	31.0081
65	1975	5012080	43.14	41.93	58.89	29.6548
66	1976	5012080	43.14	48.48	55.57	30.3000
67	1977	5012080	43.14	118.20	102.63	27.3606
68	1978	5012080	43.14	71.78	111.24	21.1172
69	1979	5012080	43.14	123.93	99.03	28.9422
70	1980	5012080	43.14	240.24	108.71	53.5558
71	1981	5012080	43.14	118.84	102.05	27.5694
72	1982	5012080	43.14	102.32	60.31	34.5947
73	1983	5012080	43.14	80.08	44.03	35.1838
74	1984	5012080	43.14	129.94	124.38	24.5537
75	1985	5012080	43.14	69.24	66.05	29.3265

Table B.31

Pierson Yield Simulation Input: SPMT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1908	5012080	40.32	121.46	79.62	32.7568
2	1909	5012080	40.32	166.59	226.65	13.0948
3	1910	5012080	40.32	151.81	112.53	30.0565
4	1911	5012080	40.32	105.74	72.26	32.0256
5	1912	5012080	40.32	146.05	219.89	12.3180
6	1913	5012080	40.32	185.67	252.81	11.8217
7	1914	5012080	40.32	69.36	20.40	38.0528
8	1915	5012080	40.32	166.86	191.93	17.4158
9	1916	5012080	40.32	135.80	109.48	28.1858
10	1917	5012080	40.32	170.15	132.06	28.6776
11	1918	5012080	40.32	115.99	119.08	23.6385
12	1919	5012080	40.32	113.21	94.87	28.0776
13	1920	5012080	40.32	110.43	79.15	31.1412
14	1921	5012080	40.32	87.94	89.86	26.0734
15	1922	5012080	40.32	165.84	133.01	27.7571
16	1923	5012080	40.32	143.60	53.14	44.3398
17	1924	5012080	40.32	102.56	78.05	30.2691
18	1925	5012080	40.32	120.52	98.85	28.2430
19	1926	5012080	40.32	107.49	86.10	29.1796
20	1927	5012080	40.32	51.99	8.56	36.9904
21	1928	5012080	40.32	81.27	12.70	40.1692
22	1929	5012080	40.32	82.77	112.18	21.5721
23	1930	5012080	40.32	109.82	103.40	25.8944
24	1931	5012080	40.32	218.41	119.56	42.4653
25	1932	5012080	40.32	114.64	103.75	26.4296
26	1933	5012080	40.32	96.68	102.42	24.5832
27	1934	5012080	40.32	180.96	152.78	25.9452
28	1935	5012080	40.32	42.52	8.54	36.8183
29	1936	5012080	40.32	163.69	146.83	24.5745
30	1937	5012080	40.32	109.45	61.45	35.1677
31	1938	5012080	40.32	135.37	85.46	33.7260
32	1939	5012080	40.32	117.94	62.39	36.4045
33	1940	5012080	40.32	99.96	27.93	41.3522
34	1941	5012080	40.32	51.61	68.62	27.5229
35	1945	5012080	40.32	58.64	76.60	26.2748
36	1946	5012080	40.32	158.11	76.76	40.7680
37	1947	5012080	40.32	66.25	56.88	30.7254
38	1948	5012080	40.32	96.64	10.49	42.6298
39	1949	5012080	40.32	104.94	75.31	31.2138
40	1950	5012080	40.32	43.08	7.21	36.5605
41	1951	5012080	40.32	93.75	66.34	31.6854
42	1952	5012080	40.32	175.74	116.34	33.5107
43	1953	5012080	40.32	73.24	126.90	18.6208
44	1954	5012080	40.32	23.43	54.58	31.9912
45	1955	5012080	40.32	72.91	44.37	33.9859
46	1956	5012080	40.32	63.28	64.32	28.9731
47	1957	5012080	40.32	110.18	114.44	23.8277

48	1958	5012080	40.32	221.49	161.98	30.9582
49	1959	5012080	40.32	149.21	127.34	26.3986
50	1960	5012080	40.32	77.48	66.05	29.8383
51	1961	5012080	40.32	219.59	141.67	35.9633
52	1962	5012080	40.32	44.87	72.81	26.5942
53	1963	5012080	40.32	61.37	52.39	31.2900
54	1964	5012080	40.32	78.66	39.58	35.6620
55	1965	5012080	40.32	101.96	116.98	22.4933
56	1966	5012080	40.32	102.66	86.99	28.3522
57	1967	5012080	40.32	199.24	161.42	27.0579
58	1968	5012080	40.32	206.36	94.49	47.7195
59	1969	5012080	40.32	81.69	38.61	36.2548
60	1970	5012080	40.32	93.82	30.06	39.8527
61	1971	5012080	40.32	62.11	58.69	30.0416
62	1972	5012080	40.32	42.54	30.54	34.9388
63	1973	5012080	40.32	81.02	46.26	34.5139
64	1974	5012080	40.32	80.62	51.17	33.3897
65	1975	5012080	40.32	39.58	50.14	31.1587
66	1976	5012080	40.32	47.57	47.64	31.6308
67	1977	5012080	40.32	113.38	96.96	27.6605
68	1978	5012080	40.32	59.53	101.96	21.7838
69	1979	5012080	40.32	117.52	94.97	28.6533
70	1980	5012080	40.32	236.49	108.21	52.0285
71	1981	5012080	40.32	106.86	84.25	29.4958
72	1982	5012080	40.32	69.25	42.01	34.1086
73	1983	5012080	40.32	72.22	31.38	36.5603
74	1984	5012080	40.32	103.57	95.83	26.6435
75	1985	5012080	40.32	69.24	66.05	29.0759

Table B.32

Pierson Yield Simulation Input: WWMT

Observation	Year	Weather Station	Nitrogen Fertilizer	Early Stage Stress	Late Stage Stress	Simulated Yield
1	1908	5012080	48.93	265.47	79.62	95.8218
2	1909	5012080	48.93	331.64	391.70	11.826
3	1910	5012080	48.93	317.68	112.53	106.147
4	1911	5012080	48.93	143.76	52.00	54.978
5	1912	5012080	48.93	93.10	78.44	35.619
6	1913	5012080	48.93	146.23	107.48	37.245
7	1914	5012080	48.93	85.61	38.80	45.183
8	1915	5012080	48.93	219.79	167.73	35.958
9	1916	5012080	48.93	150.95	115.75	35.873
10	1917	5012080	48.93	522.35	624.63	6.350
11	1918	5012080	48.93	140.58	105.93	36.542
12	1919	5012080	48.93	114.25	131.78	26.094
13	1920	5012080	48.93	149.76	79.16	46.988
14	1921	5012080	48.93	139.67	108.77	35.578
15	1922	5012080	48.93	174.34	157.40	29.558
16	1923	5012080	48.93	171.62	22.42	76.018
17	1924	5012080	48.93	102.90	72.35	38.844
18	1925	5012080	48.93	138.68	104.42	36.588
19	1926	5012080	48.93	123.15	75.75	41.783
20	1927	5012080	48.93	39.34	20.01	45.048
21	1928	5012080	48.93	89.41	10.51	50.866
22	1929	5012080	48.93	68.65	98.77	28.061
23	1930	5012080	48.93	105.18	96.34	32.874
24	1931	5012080	48.93	259.64	127.61	63.972
25	1932	5012080	48.93	121.25	94.87	35.919
26	1933	5012080	48.93	89.92	108.65	28.018
27	1934	5012080	48.93	204.77	154.51	36.3830
28	1935	5012080	48.93	58.68	5.10	44.7705
29	1936	5012080	48.93	167.29	136.99	33.3542
30	1937	5012080	48.93	108.10	91.33	34.6025
31	1938	5012080	48.93	106.05	117.96	27.9624
32	1939	5012080	48.93	141.30	50.85	54.6556
33	1940	5012080	48.93	109.17	45.78	47.9205
34	1941	5012080	48.93	43.10	69.21	33.5541
35	1945	5012080	48.93	47.40	51.06	38.0348
36	1946	5012080	48.93	193.50	58.78	70.1935
37	1947	5012080	48.93	77.43	57.51	38.9151
38	1948	5012080	48.93	81.13	22.35	48.2758
39	1949	5012080	48.93	109.80	74.82	39.3964
40	1950	5012080	48.93	50.27	7.24	45.0909
41	1951	5012080	48.93	77.94	75.40	34.3693
42	1952	5012080	48.93	208.32	91.81	60.6026
43	1953	5012080	48.93	78.98	80.51	33.2315
44	1954	5012080	48.93	58.49	39.23	41.5460
45	1955	5012080	48.93	62.97	43.82	40.7968
46	1956	5012080	48.93	73.72	55.67	38.9252
47	1957	5012080	48.93	117.97	129.14	27.1310

48	1958	5012080	48.93	253.08	142.42	54.5286
49	1959	5012080	48.93	155.78	124.85	34.3421
50	1960	5012080	48.93	62.09	86.47	30.2646
51	1961	5012080	48.93	209.61	141.83	41.4758
52	1962	5012080	48.93	50.87	68.04	33.9524
53	1963	5012080	48.93	65.06	60.34	36.7821
54	1964	5012080	48.93	86.68	30.93	47.3961
55	1965	5012080	48.93	94.85	102.80	29.9041
56	1966	5012080	48.93	86.09	97.88	29.9630
57	1967	5012080	48.93	176.11	162.79	28.6070
58	1968	5012080	48.93	205.93	98.24	56.8803
59	1969	5012080	48.93	74.06	28.76	45.8158
60	1970	5012080	48.93	84.07	23.91	48.4989
61	1971	5012080	48.93	80.78	40.29	43.9899
62	1972	5012080	48.93	39.49	33.83	42.2955
63	1973	5012080	48.93	61.81	50.90	38.8892
64	1974	5012080	48.93	39.26	41.13	40.5587
65	1975	5012080	48.93	38.17	39.55	40.9947
66	1976	5012080	48.93	51.42	29.32	43.3942
67	1977	5012080	48.93	136.68	79.93	43.4960
68	1978	5012080	48.93	60.24	95.69	28.1300
69	1979	5012080	48.93	113.70	92.61	35.1978
70	1980	5012080	48.93	253.04	108.51	71.0588
71	1981	5012080	48.93	110.49	86.51	36.2767
72	1982	5012080	48.93	75.53	54.48	39.4672
73	1983	5012080	48.93	75.66	28.37	46.1417
74	1984	5012080	48.93	96.39	87.05	33.8961
75	1985	5012080	48.93	72.51	68.51	35.4770

Appendix C

INPUT DATA FOR THE CROP PRODUCTION SIMULATOR

Tables C.1 to C.9 present the equipment inventories, hours used and the associated costs of operations.

Table C.1

Equipment Iventory: Graysville SPCT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Tandom disc	25'	1f	12.44	80	95.7	1.60	0.24	0.64	2.48
Cultivator	30'	1f,1s	15.03	133	162.4	1.36	0.20	0.49	2.06
Harrow	40'	1f,2s	19.95	150	174.4	0.51	0.08	0.20	0.79
Gran. appl.	30'	1s	11.05	90	103.1	0.61	0.09	0.00	0.95
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.30	0.20	1.98	3.48
Sprayer	40'	1s	14.93	67	81.7	0.32	0.05	0.19	0.56
Gas trac.	75hp	-	-	224	-	-	-	0.50	0.50
Dies.trac.	150hp	-	-	471	-	-	-	2.44	2.44
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1707.2	14.75	2.21	15.94	34.20

Table C.2

Equipment Iventory: Graysville SPMT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Cultivator	30'	1f	15.03	67	81.2	1.36	0.20	0.40	1.97
Harrow	40'	1f,2s	19.95	100	116.3	0.51	0.08	0.18	0.77
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.30	0.20	1.98	3.48
Sprayer	40'	1s	14.93	201	245.1	0.32	0.05	0.29	0.66
Gas trac.	75hp	-	-	268	-	-	-	0.65	0.65
Dies.trac.	150hp	-	-	274	-	-	-	1.08	1.08
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1707.2	15.18	2.28	15.94	34.70

Table C.3

Equipment Iventory: Graysville WWMT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Cultivator	30'	1f	15.03	67	81.2	1.36	0.20	0.40	1.97
Harrow	40'	1f,2s	19.95	100	116.3	0.51	0.08	0.18	0.77
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.30	0.20	1.98	3.48
Sprayer	40'	1s	14.93	201	106.2	0.32	0.05	0.21	0.58
Gas trac.	75hp	-	-	268	-	-	-	0.28	0.28
Dies.trac.	150hp	-	-	274	-	-	-	1.08	1.08
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1393.6	10.76	1.61	12.98	26.40

Table C.4

Equipment Inventory: Minnedosa SPCT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Tandom disc	25'	1f	12.44	80	95.7	1.79	0.27	0.64	2.71
Cultivator	30'	1f,1s	15.03	133	162.4	1.64	0.25	0.49	2.38
Harrow	40'	1f,2s	19.95	150	174.4	0.53	0.08	0.20	0.81
Gran. appl.	30'	1s	11.05	90	103.1	0.61	0.09	0.00	0.95
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.35	0.20	1.98	3.54
Sprayer	40'	1s	14.93	67	81.7	0.33	0.05	0.19	0.57
Gas trac.	75hp	-	-	224	-	-	-	0.50	0.50
Dies.trac.	150hp	-	-	471	-	-	-	2.44	2.44
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1707.2	15.62	2.34	15.94	35.20

Table C.5

Equipment Inventory: Minnedosa SPMT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Cultivator	30'	1f	15.03	67	81.2	1.64	0.25	0.40	2.29
Harrow	40'	1f,2s	19.95	100	116.3	0.53	0.08	0.18	0.79
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.35	0.20	1.98	3.54
Sprayer	40'	1s	14.93	201	245.1	0.33	0.05	0.29	0.67
Gas trac.	75hp	-	-	268	-	-	-	0.65	0.65
Dies.trac.	150hp	-	-	274	-	-	-	1.08	1.08
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1532.5	11.70	1.76	13.94	28.44

Table C.6

Equipment Inventory: Minnedosa WWMT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	WWB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Cultivator	30'	1f	15.03	67	81.2	1.64	0.25	0.40	2.29
Harrow	40'	1f,2s	19.95	100	116.3	0.53	0.08	0.18	0.79
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.30	0.20	1.98	3.48
Sprayer	40'	1s	14.93	201	245.1	0.35	0.05	0.29	0.54
Gas trac.	75hp	-	-	268	106.2	- 3	-	0.61	0.60
Dies.trac.	150hp	-	-	274	-	-	-	1.08	1.08
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1393.6	11.14	1.67	12.98	26.83

Table C.7

Equipment Iventory: Pierson SPCT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Tandom disc	25'	1f	12.44	80	95.7	1.69	0.25	0.64	2.59
Cultivator	30'	1f,1s	15.03	133	162.4	1.50	0.23	0.49	2.22
Harrow	40'	1f,2s	19.95	150	174.4	0.52	0.08	0.20	0.80
Gran. appl.	30'	1s	11.05	90	103.1	0.61	0.09	0.00	0.95
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.33	0.20	1.98	3.51
Sprayer	40'	1s	14.93	67	81.7	0.33	0.05	0.19	0.57
Gas trac.	75hp	-	-	224	-	-	-	0.50	0.50
Dies.trac.	150hp	-	-	471	-	-	-	2.44	2.44
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1707.2	15.18	2.28	15.94	34.70

Table C.8

Equipment Inventory: Pierson SPMT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Cultivator	30'	1f	15.03	67	81.2	1.50	0.23	0.40	2.13
Harrow	40'	1f,2s	19.95	100	116.3	0.52	0.08	0.18	0.78
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.33	0.20	1.98	3.51
Sprayer	40'	1s	14.93	201	245.1	0.33	0.05	0.29	0.67
Gas trac.	75hp	-	-	268	-	-	-	0.65	0.65
Dies.trac.	150hp	-	-	274	-	-	-	1.08	1.08
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1532.5	11.51	1.73	13.94	28.22

Table C.9

Equipment Inventory: Pierson WWMT

IMPLIMENT	SIZE	SEASON USED	ACRES /HR	HRS USED	LABOR HRS	FUEL $/AC	LUB. $/AC	REP. $/AC	TOT.VAR. COST $/AC
Cultivator	30'	1f	15.03	67	81.2	1.50	0.23	0.40	2.13
Harrow	40'	1f,2s	19.95	100	116.3	0.52	0.08	0.18	0.78
Fert. appl.	40'	1s	14.93	67	76.3	0.45	0.07	0.00	1.56
Seed drill	24'	1s	9.31	107	132.1	1.33	0.20	1.98	3.51
Sprayer	40'	1s	14.93	201	106.2	0.33	0.05	0.21	0.59
Gas trac.	75hp	-	-	268	-	-	-	0.12	0.12
Dies.trac.	150hp	-	-	274	-	-	-	1.08	1.08
Swather	20'	1f	9.27	108	122.9	0.47	0.07	0.77	1.31
Combine	12	1f	7.33	136	165.0	1.26	0.19	2.67	4.12
Truck	285bu	1f,1w	3.70	540	567.4	2.18	0.33	2.55	5.06
Auger 1	7"	1f	22.67	44	11.0	0.05	0.01	0.02	0.07
Auger 2	6"	1w	16.53	60	15.1	0.06	0.01	0.02	0.10
Total	-	-	-	-	1408.7	10.56	1.58	12.85	26.56

Table C.10 presents the fertilizer source and amounts for each site and scenario.

Table C.10

Fertilizer Inputs (lbs/acre)

SOURCE	GRAYSVILLE			MINNEDOSA			PIERSON		
	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT	SPCT	SPMT	WWMT
Optimal N	41.07	40.69	57.94	52.96	40.32	51.96	43.14	40.32	48.93
11-48-0	50	50	50	50	50	50	50	50	50
46-0-0	80	75	115	105	75	100	80	75	95

Table C.11 presents the herbicide requirements, rates of application and associated cost for each management scenario.

Table C.11

Chemical Inputs

CHEMICAL	SPCT			SPMT			WWMT		
	rate (/ac)	%farm appl.	$/ac	rate (/ac)	%farm appl.	$/ac	rate (/ac)	%farm appl.	$/ac
Avadex	6 kg	100	13.32	-	-	-	-	-	-
Buctril M	0.5 l	100	5.93	0.5 l	100	5.93	-	-	-
Dyvel	-	-	-	0.5 l	75	2.99	-	-	-
Hoe-Grass	-	-	-	1.5 l	100	12.30	1.5 l	20	2.40
Roundup	-	-	-	1.9 l	25	12.14	1.9 l	10	4.85
Diathane	-	-	-	-	-	-	2.3 l	100	10.73