THE ECONOMIC FEASIBILITY
OF A NATIONAL DROUGHT RESERVE OF GRAIN

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A thesis submitted for the Degree of
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The following work - "The Economic Feasibility of a National Drought Reserve of Grain" by H.I. Toft - is a thesis submitted for the degree of Doctor of Philosophy in the Australian National University.

The work was carried out with research assistance firstly from Mrs. D. Dancer and subsequently from Mr. J. Kelleher.

The author developed the overall approach, developed the models used, wrote the necessary computer programs and carried out the interpretation of results. The research assistants performed the large amount of detailed work involved in identifying series of droughts by shires and sheep numbers, calculating transportation costs, running computer programs and extracting and tabulating the computer output. Mr. Kelleher wrote Appendix VI discussing the methods adopted to estimate transportation costs.

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GLOSSARY

The following is a list of some of the notation used:

NDR = national drought reserve of grain.

NAS(I) = the number of adult sheep in a declared drought in year I in the State; NAS(I) equals zero in a non-drought year; years are measured from dates of drought declaration.

MNAS = the maximum number of adult sheep observed in a drought in a State.

ADL = the number of weeks' ration demanded from NDR at 5 lb. of wheat or sorghum per week during the period from grain intake to the end of the year.

ADL' = the number of weeks' ration demanded from NDR at 5 lb. of wheat or sorghum per week during the period from drought declaration to grain intake.

GI = the level of grain intake into NDR in a particular year.

D and E are control variables in the wheat intake equation, GI = D * NAS(I) + E * MNAS.

UL = an upper limit to grain held which may be used as a control variable affecting grain intake.

DW, EW and DS are control variables for grain intake, where DW and EW are similar to D and E; and DS applies to the sorghum part of the grain intake.

* = multiplied by.

CHAPTER 1

Introduction

In Australia, rainfall is recognized as being both low and variable. Losses, frequently severe, occur through failures in crop production and through mortality and lost production in livestock industries. Various attempts have been made to measure the effects of droughts as they occur in Australia. This effect is felt directly of course in primary industries. Estimates of the cost of sheep losses which have been made by Franklin [1] and by Davidson [2] vary considerably. Davidson uses an estimating procedure which attempts to measure the effect of drought sheep mortality on subsequent flock growth. Taking a "measuring horizon" of 20 years, he obtains an estimate of a total discounted loss over the 20 years of approximately $1,300 million. Franklin's estimate, which was not discounted, is much larger.

Powell [3] has measured the effect of drought by using analysis of variance to study the contribution made by variation in supply to observed variation in aggregate wool receipts. To do this the variance in observed wool receipts was partitioned into a "demand effect", measuring variations in demand; a "supply effect", measuring "non-secular fluctuations in supply"; a measurement of secular change in supply; and an error term. Powell, after statistical analysis of relevant time series, reaches the conclusion that only a small proportion of the observed variability in export earnings could be attributed to the "supply effect". The inference is made that policies aimed at stabilizing annual supplies of wool "would not reduce the variance of Australian wool export earnings by more than ten percent, and probably by considerably less than this amount". As Powell points out this has implications regarding the effects of possible stabilizing policies in the wool industry on the stability of Australian balance of payments. The question remains whether policies which reduced drought sheep losses might have had an effect on the rate of secular increase in supply as well as on the short term variations in supply. However the inference regarding the likely impact on short-term stability of the balance of payments probably holds. Also in the decade ended 1970 there has been a remarkable growth in export sources other than the wool industry, so the importance of possible policies in the wool industry on balance of payments has decreased.

However the number and value of livestock which are lost in droughts, together with the order of estimates of drought losses, indicate the seriousness of the problem. If research shows that a strategy such as a national drought reserve of grain would yield benefits in excess of the cost, then the net benefits could well be considerable because of the large numbers of sheep in most droughts.

The current research endeavours to specify some possible systems of national drought reserve and to analyze the costs and benefits which would be associated with them. The national drought reserve has been subdivided by States, while allowing movement of grain between

States. The State was chosen as the unit for the holding of grain because the organizational structure of grain storage and of rail transport in Australia is on this basis. The discussion of benefits is associated mainly with the individual farmer, although some aggregation has been possible. The use of a national drought reserve of grain would vary between farms in accordance with individual choices between alternative drought strategies. Because of this, any attempt to obtain an overall aggregative measure of the benefits of purchasing grain from a national drought reserve depends on assumptions made regarding these choices. Such assumptions have not been made in the present instance.

The choice of the State as the basic unit of enquiry was thought likely to increase the probability of implementation. The scheme may be more relevant in some States than others. Decisions to implement such a scheme, and subsequent control, could be on a State basis. Admittedly this is a fairly pragmatic approach. The search for low cost policies must suffer to some extent from limiting the enquiry to States considered separately. However even with this constraint policies are obtained which in terms of cost seem economically feasible.

Currently there are conditions of excess supply of grain in Australia. This study, in order to take a long-term view, has not assumed that the grain required in a drought would have been automatically available. Full costs of storage and opportunity costs have been charged on grain held in the national drought reserve. As grain is ordinarily (because of limits on available rolling-stock) held in storage for a considerable period after grain intake, this introduces an upward bias in the cost estimates.

This of course mitigates against the NDR policies and to a certain extent puts any recommendation towards implementation on firmer grounds.

While a variety of possible systems have been studied at the level of individual States, the final comparison of costs and benefits is made at the level of the individual farm. The measurements of cost components in the study differ from measurements which would apply in a social as distinct from a private evaluation. For example transportation cost has been measured in this study on the basis of ruling rates of transporting grain by rail (without drought subsidy). The social cost of transporting grain to drought areas is the cost to society of the resources used, estimated at the opportunity cost of not using these resources for other purposes. Such cost would be unlikely to equal the freight rates charged, which for example would include a fixed cost component related to investment in railway facilities as a whole. The introduction of a scheme to provide drought feed could also introduce new social costs or benefits apart from those considered at the level of the individual grazier. For example any increase in stability and profitability in the wool industry would have beneficial effects on other sections of the community through taxation and through stabilizing effects on related industries. A social evaluation would also involve measurements aggregated to the society as a whole. This aggregation while desirable has not been carried out given the resources available to the current study.

It is not envisaged that such a scheme should be subsidized. Graziers obtaining grain through such a scheme would be expected to pay "ruling prices", which ideally should equal the opportunity cost of diverting the grain from any alternative market. Rather than make an estimate of what this price might be in the recently somewhat unsettled wheat market the analyses have been carried out for a wide range of grain prices.

The models as developed are felt to be consistent with the outlines for such a scheme as given by Morley and Ward. [46] In particular the scheme is based on grain, largely wheat, which generally is in relatively plentiful supply, and the scheme utilizes the existing framework of storage and transport facilities. Contrary to the suggestion made by Morley and Ward advantage has not been taken of quantities of grain normally held by grain storage authorities in periods between grain intakes. Use of such grain could lead to a further lowering of costs beyond those estimated.

Results obtained are more favourable to the implementation of a National Drought Reserve than were the results of previous research in this area. Costs estimated for National Drought Reserve grain, including between-drought storage costs, are of the same general order as prices actually paid for wheat which was available in recent droughts. There is evidence that it could well be worthwhile to the grazier to feed grain at this price depending on his individual circumstances.

CHAPTER 2

Related Applied Research

Droughts in Australia undoubtedly have serious impacts both at the level of the individual property and at more aggregative levels. This has induced a considerable body of research in agricultural economics, which can be grouped as micro-analysis or aggregative analysis according to its orientation. It is proposed to give a brief outline of research in these two groups with an indication of some of the implications for the current project.

2.1 Micro-analysis of the Effects of Droughts

Candler in 1958 [4] carried out an analysis of optimal on-farm drought reserve for a given probability distribution of drought length, measured in terms of the number of months' feeding required, and with the further assumptions that:

"(a) Wheaten hay can be grown (or bought) and stored in a "normal" year for £8 per ton.

(b) The stocking is conservative so that by the time it is necessary to feed, wheaten hay has risen to £16 a ton.

(c) Stock are not fed until it becomes essential and then they are fed 2 lb. of wheaten hay per day (or ½ cwt. per four weeks).

(d) The grazier believes he can safely get 8% on his money if he invests in industrial shares. A financial rather than a fodder reserve would yield this in non-drought years.

(e) The grazier is unwilling to consider the possibility of selling sheep early in the drought or letting them die."

Candler then associates different numbers of months of drought reserve with the probability distribution of drought length to estimate the number of months' drought reserve required to minimize average annual cost. No empirical results were obtained as data used were hypothetical only.

Mauldon and Dillon, 1959 [5] developed an "on-farm fodder reserve" model in a somewhat broader framework than that used by Candler. Strategies considered are feeding from on-farm fodder reserves, then allowing sheep to die (or selling sheep) when reserves are exhausted. Revenue and costs, including general production costs, are included in net revenue functions. One such function enables discounted net revenue to be calculated where stocking rate has been specified. This function can be maximized with respect to the level of fodder reserves. An alternative function was also derived including stocking rate as a variable. Mauldon and Dillon indicate that "the derivation of the optimal plan ... in terms of (fodder reserve and stocking rate) is a problem in the calculus of variations." The first function was applied in empirical work related to Hughenden, Queensland.

The authors found that at that time, for the parameters used, optimal fodder reserves varied between five and eight months' reserve. They also found that, "For a given stocking rate, the normative demand for fodder is highly inelastic with respect to the prices of wool and sheep and only slightly responsive to fodder price changes."

Waring, 1960 [6], illustrates that for a given probability distribution of drought length, a given (constant) wheat price, given within-drought and post-drought sheep prices, given the rate of production of wool per sheep-month, and given the price per pound of wool, it is possible to decide whether sheep should be sold at different stages of a drought. By placing different values on different sections of an individual flock, it is possible to decide which sections of the flock should be sold at different stages.

Dillon and Lloyd, 1962 [7], carried out an analysis on a mathematically derived probability distribution of dry months. The rainfall data consists of waiting-time probabilities for effective rain, generated by Verhagen and Hirst [8] by using the binomial distribution. Drought is defined as "a period during which the supply of grazing feed is inadequate to keep the desired number of livestock alive". The probability distribution of ineffective rain is converted to a probability distribution of drought-length by measuring stocking rate in terms of the number of months indigenous feed which would be available for that stocking rate in a period of ineffective rainfall. This number of months of ineffective rainfall elapses before the "drought" commences. Drought strategies considered are feeding stored fodder or letting sheep die. A net revenue function is derived and from this it is possible to measure the expected value and the variance of net revenue associated with a given level of on-farm reserve. Comparison of on-farm strategies allows a trade-off between the expected value and variance of net revenue. It was found that some strategies were dominated by others, that is, the former had smaller expected values and larger variances, and so could be neglected. It was also found that, if there was a reserve of 6 or 7 months feed in the paddock, it did not pay to keep an on-farm fodder reserve except in the case where wool prices were high and the cost of harvested fodder was low.

Officer and Dillon in "Calculating the Best-Bet Fodder Reserve", 1965 [9], have discussed the method of calculating a desirable level of fodder reserve, where the desirability of a level is determined by two criteria, expected cost and variance of cost. A computer program has been drawn up to allow calculation of the expected costs and the variance of costs for different probability distributions of feed shortage, and different feed-price parameters. The calculation assumes [9 pp. 2-3] that because:

"(1) getting together a fodder reserve is an active drought-planning step that a farmer can undertake without much cost before a feed shortage actually occurs;

(2) sheep are generally scarce so that selling them or letting them die is unlikely to be the best strategy; and

(3) in the high rainfall and wheat-sheep zones, widespread and long droughts are not too likely and fodder can usually be obtained ... the farmer feeds from his own reserves, or buys feed, or does both if he should face a feed shortage."

The above models vary in assumptions and approaches. One significant characteristic of each model is determined by the selection of drought strategies to be considered in the model. It is clear [10 P.21] that farmers use various strategies in a drought and also that they have a strong tendency to use mixed strategies. This has particular relevance for any national drought reserve of grain as it is likely that the purchase of grain by farmers from such a reserve is likely to be combined with other strategies. This means that the grazier could be expected to be selective in the use of national drought reserve grain, applying it where and when it seemed worthwhile to him as an individual.

2.2 Aggregative Analysis of the Effects of Droughts

The two major analyses carried out at a level of aggregation above the individual farm are those carried out by Powell, 1963 [3], and Davidson, 1966 [2]. The general finding by Powell was that, with the mortality rates he assumed it would not pay to feed sheep in a drought.

However Powell encountered considerable difficulty in estimating sheep mortality caused by droughts. The finding by Davidson was that his investigations led to inconclusive results due to inadequate data. The additional data he specified as being required were:

"... for each grazing zone:

(1) The number and the age of ewes dying or sold for slaughter because of drought.

(2) The probable amount of fodder which would have to be fed to ewes to prevent these losses."

Instead of trying to estimate the value of feeding in terms of sheep prevented from dying Davidson uses break-even points to indicate what proportion of the flock would need to be prevented from dying to cover costs. Sheep values in this study were imputed and considerably higher than market values.

The basic approach adopted by Powell was to use dynamic programming to derive an optimizing rule, where the quantity of grain to be put into the reserve in any year is a function of the number of sheep and the carry-over grain in stock at that time. [3 P67] Working firstly at the level of an individual shire and then at the level of a group of shires Powell obtains optimizing rules in both cases. However on account of the extreme amount of computer time required Powell regarded the optimizing rules as being inoperable even after adjustments had been made to reduce the computer time involved.

To obtain evidence as to whether a National Drought Reserve would "pay" Powell makes estimates of the cost of "freight plus acquisition cost of grain" as applicable to 31 shires in Queensland. The cost of the grain is charged plus freight from Brisbane. No storage costs are charged. [3 pp. 183-184] Even without storage costs sheep prices would have had to be well above market price to cover the cost of the grain plus transport.

It could perhaps be argued that at this point it had been shown conclusively that a National Drought Reserve would not pay. However there are a number of considerations which indicate that the question was still open. Among these were the facts that:

(1) The distances from grain silos to the sheep industry are generally greater in Queensland than in the other States,

(2) The fact that the imputed value of a sheep may be higher than its market price, (1)

(3) If Powell's estimate, which excluded storage costs, indicates that a National Drought Reserve of grain would not pay it also throws doubt on the purchase of supplementary feed in general as a drought strategy. In the 1964-66 droughts in Queensland and New South Wales supplementary feeding was extensively practised, "being by far the most important (strategy) both alone and in combination". [10 P.21] Further examination seems warranted.

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(1) Further discussion of methods of imputing sheep values is given in Section 4.2.

CHAPTER 3

Development of National Drought Reserve Systems and Estimates of Costs and Grain Flows

The study of the economic feasibility of a National Drought Reserve has been separated into the broad subdivisions of costs and benefits. The aim is to provide a link between the two by using demand for National Drought Reserve (NDR) grain as the nexus. The breaking-up of a problem in this way is a recognized simplifying technique in systems analysis [11 P.474]. In the present problem it enables model-building and empirical analysis to be carried out firstly with regard to the manipulation of grain within and between States, and secondly with regard to use of this grain at the farm level. This subdivision agrees with the break-up into decision-making units which would exist if a National Drought Reserve were implemented and so offers the possibility of providing information useful to each of these sectors. This chapter deals with the evolution and empirical application of models related to costs and grain flows of possible NDR systems.

3.1 Evolution of Relevant Systems

The amount of constructive model-building varies between problems. It may be possible to use a defined and available model - for example, linear programming may solve a problem neatly and without further inventiveness - or it may be necessary to construct a model, as is unavoidable in the use of simulation procedures. William T Morris, in an article entitled "On the Art of Modeling" [12], outlines general procedures which may be adopted. In his opinion - "The process of model development may be usefully viewed as a process of enrichment or elaboration. One begins with very simple models, quite distinct from reality, and attempts to move in an evolutionary fashion toward more elaborate models which more nearly reflect the complexity of the actual management situation ... Anology or association with previously well developed logical structures plays an important role in the determination of the starting point of this procedure of elaboration or enrichment." Morris suggests that one should refuse to "resort to simulation until a serious attempt at analysis has been made." He also suggests the development of a numerical example early in the model-building process. Advantages of doing this include enforced thought regarding assumptions, the derivation of insight into the problem, and the development of an empirical model which can be subsequently generalized by the use of symbols.

Where a problem can be neatly solved by analytical methods these would normally be used. Where the problem does not seem amenable to solution analytically, simulation may be used. However analytical techniques and simulation are not mutually exclusive. Where the over-all technique chosen is simulation this can still include analytical solutions of parts of the problem. Or a preliminary analytical solution may be tested further by a simulated application of actions indicated by the results of the analysis. [45].

The evolutionary approach referred to by Morris is the one adopted in development of models to study the costs of NDR systems. The "chain" of evolution consisted of a pilot study, a parametric budget which "generalised the pilot study by the use of symbols", an inventory model which considered possible optimization, and finally simulation models which were more general in their scope than any of the previous "links in the chain" and which also considered optimization.(1)

3.1.1 Drought Declaration

A basic problem in the study of National Drought Reserves of grain is that of drought definition and declaration. Criteria used to define droughts vary. The Bureau of Agricultural Economics in a recent drought survey [10] cites a definition given by Foley [13 P.3]: 'A period of rainfall deficiency extending over months or years of such a nature that crops and pasturage for stock are seriously affected if not completely burnt up and destroyed, water supplies are seriously depleted or dried up and sheep and cattle perish".

In carrying out research as in the current project there may be the need to obtain data of past "drought occurrences". The tendency is to develop a historical series of "drought occurrence" according to relevant meteorological statistics, for example, of rainfall.

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(1) Optimization in the form of a minimization of costs.

However drought as defined above is a result not only of meteorological characteristics but also of human activities such as the selection of stocking rates, and use of improved pastures. If droughts are identified according to past crop failures and stock losses, as indicated in the definition cited, there remains a question as to whether these droughts would have occurred and lasted the same length of time with current cropping and livestock husbandry practices. The build-up in the area of improved pastures is pertinent here. However as past weather patterns are relevant today a historical series of weather data can be used to identify "drought situations" thought to be of relevance to current farming practice.

Historical identification of droughts using meteorological data has been carried out in Australia by Foley [13] and by Gibbs and Maher [14].(2) Work is currently being done by the C.S.I.R.O., Canberra, to estimate historical series of soil moisture levels on a weekly basis. However the estimates of historical levels of soil moisture would still have to be translated into information of significance to the NDR analysis; as far as "drought identification" is concerned for the purposes of an NDR the final aim is to translate drought occurrence

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(2) Thornthwaite [15] in the United States has set out ways of calculating soil moisture using data of evapo-transpiration and of monthly rainfall.

into levels of demand for NDR grain. What levels of soil moisture would be associated with what levels of demand for NDR grain?

The models developed in the current chapter are based on the identification of droughts carried out by Gibbs and Maher [14]. Gibbs and Maher have used a classification of annual rainfall by deciles as a basis of drought identification. This is a simple approach, as the authors point out, and does not take into account evapotranspiration rates, soil moisture, etc. An area is identified as being in drought conditions whenever the annual rainfall for a particular calender year is below the first decile point. This definition takes no account of soil moisture conditions at the beginning of any calendar year, which if considered would have given some weight to rainfall levels in previous time periods. Also there is no definition of how many months during the year the "drought" lasted. It is likely that, if droughts were identified as a series of months when the cumulative rainfall was less than the first decile point for those months, many of the droughts identified by Gibbs and Maher as being within a calendar year would now occupy parts of two successive calender years. A similar argument would apply to the use of weeks as the unit of time as compared with months; and so on. In the final analysis the necessary degree of precision in the choice of units depends on the effects on results obtained. What these effects are may become clear only after the analysis has been carried out [16 pp. 57-59]. In this regard a pilot study may be of considerable value in deciding the level of accuracy demanded.

The use of deciles as drought indicators has a number of promising characteristics. One is its simplicity, another is related to the fact that the measure is based on relative frequency of occurrence of a particular level of rainfall. Any location will be in a "drought situation" once every ten years. In one locality the first decile rainfall may be 5 inches so that a drought is identified historically by Gibbs and Maher whenever annual rainfall is less than 5 inches. In another locality the first decile rainfall may be 10 inches. A grazier, knowing the long-term rainfall pattern in his district, can to some degree choose for himself how frequently he will be drastically short of feed by his selection of stocking rate and on-farm feed supply and fodder reserves. [39 Fig. 3] This may be about once every ten years, but would vary between districts and farms. The analysis which has been developed has been based on an average of one year in ten for all districts. The one-year-in-ten basis implies that graziers must meet their feed requirements in the other nine years, when rainfall is higher, without a guaranteed supply of NDR grain. However, a side-effect of the NDR would be that the flow of unused NDR grain onto the market could usefully augment feed supplies in "non-first decile" years.

Droughts identified by Gibbs and Maher, especially when these occupy relatively large areas (e.g. over 10% of Australia by area), show a close correspondence to droughts "popularly" declared [14 P.16] An NDR scheme based on "first-decile droughts" would have the advantage of simplicity in actual drought declaration. A group of shires could be declared to be in a first decile area if the accumulated rainfall over a selected number of months was below the first decile point for those months.

Droughts identified by Gibbs and Maher relate to calendar years. Droughts in the ensuing models are "declared" whenever a Gibbs and Maher drought occurs, but the declaration is made during the year of the Gibbs and Maher drought and continues into the next calendar year. In those mainland States whose climate in general has a winter rainfall pattern droughts are "declared" in the September of each Gibbs and Maher drought and remain "declared" until the following September. In Queensland, where there is a summer rainfall pattern, droughts for some simulations (based on wheat only) are declared in April of a Gibbs and Maher drought, while for other simulations (based on wheat and sorghum) they are assumed to be declared in July (during the sorghum intake). Throughout, these "drought declarations" are intended to mean that NDR grain is then guaranteed to be available if required, rather than that there are necessarily feed deficits from these dates.

3.1.2 Pilot Study

Early work was directed towards a pilot study related to the sheep industry in the southern portion of Western Australia. The method of analysis considered in the pilot study was basically a simple budget. Fairly prominent in the models considered at this stage was the linear programming transportation algorithm. It was thought that this might be of use in studying the desirable pattern of grain flows from those shires with official grain storage to shires in a declared drought area.

The basic form of the transportation model is well known. Algebraically it can be expressed as follows:

$$\text{Minimize} \quad \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} \quad x$$

$$\text{when} \quad \sum_{j=1}^{n} x_{ij} = a_i \qquad (3.1)$$

$$\sum_{i=1}^{m} x_{ij} = b_j \qquad (3.2)$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1} b_j \qquad (3.3)$$

$$x_{ij} \geq o, \quad \text{for all } i, j \qquad (3.4)$$

Here restriction (3.1) expresses the requirement that the total quantity transported from source i is a_i; restriction (3.2) expresses the requirement that the total quantity transported to demand point j is b_j. The cost per unit transported from source i to destination j is c_{ij}. The algorithm proceeds by iterations to select a set of x_{ij} which will satisfy restrictions (3.1) and (3.2) at minimum cost. The constraint (3.3) implies that the total amount of this commodity available at sources of supply equals the total amount required at demand points. In actual fact the algorithm will function satisfactorily if the total amount available is greater than, equal to, or less than total requirements. If one of these inequalities does exist a dummy row (source) or dummy column (demand point) is included to create the equality of restriction (3.3). Constraint (3.4) is common to linear programming algorithms.

In the transportation models the levels of demand for drought feed in shires in a declared drought area constitute column totals b_j, with j varying from 1 to n. The quantity of feed required for a shire is calculated by multiplying the number of adult sheep in the shire by the number of weeks' demand at the full maintenance ration which is taken to be 5 lb. of wheat per week. [17] As a preliminary concept, the possibility of including more than one type of drought strategy within this one transportation model was considered. For example, it might be possible to include both the transport of grain to drought areas and the transport of sheep away from, and back to, drought areas within the one transportation model.

Figure 3.1

A Transportation Matrix

$$
\begin{array}{llll|l}
\hline
x_{11}\,x_{12} & \cdots & x_{1n} & R_1 & \\
x_{21} & \cdots & & R_2 & \\
 & & & \cdot & \text{Agistment} \\
\cdot & & \cdot & \cdot & \text{available} \\
 & & & \cdot & \\
\cdot & & \cdot & & \\
 & & & R_k & \\
 & & & R_{k+1} & \\
 & & & \cdot & \text{NDR grain} \\
 & & & \cdot & \text{available} \\
 & & & \cdot & \\
x_{m1}\,x_{m2} & \cdots & x_{mn} & R_m & \\
\hline
C_1\;C_2 & & C_n & & \\
\end{array}
$$

This is illustrated in Figure 3.1, where quantities of agistment available in shires i, $i=1,2,\ldots,k$ are represented by $R_1, R_2, \ldots, R_k$ while the quantities of NDR grain available in shires $i=k+1,\ldots,m$ are represented by $R_{k+1}, \ldots, R_m$. These are assumed to be measured in a common unit, for example, sheep-months of feed. The quantities of feed required in shires $j = 1, \ldots, n$ are represented by $C_1, C_2, \ldots, C_n$, again measured in sheep-months. Transportation costs, c_{ij}, where $i = 1, \ldots, k$ and $j = 1, \ldots, n$ represent the cost per unit of moving sheep to and from agistment shires, $i = 1, \ldots, k$ from drought shires $j = 1, \ldots, n$. Transportation costs, c_{ij}, when $i = k+1, \ldots, m$ and $j = 1, \ldots, n$ represent the cost of moving grain from shires $i = k+1, \ldots, m$ to drought shires $j = 1, \ldots, n$. With the above data available it would be possible to use the linear programming algorithm to determine the physical movement of sheep and of NDR grain which would minimize the total transportation cost of sheep and grain.

Alternatively it might be possible to apply the linear programming transportation model to grain movements only to minimize the transportation cost associated with movement of grain to drought areas. This would involve the elimination of rows i = 1, ... ,k from Figure 3.1.

However application of the transportation model in the "agistment-grain" framework outlined assumes knowledge of quantities of grain and of agistment available and of the number of sheep-months of feed-deficit which will occur in the drought in each "destination" shire. It also assumes that in spite of individual choices regarding on-farm drought strategies the flows of grain and of sheep to agistment are in accordance with the optimum. Similar assumptions are made where grain only is considered. In spite of these limitations the transportation model was used[(3)] in the pilot study.

The pilot study was carried out for an area of Western Australia which was not regarded as very drought prone. However it was thought that this area would still be satisfactory as a location of a pilot study, to gain experience with, and to test and develop the method of analysis being used. This would mean that subsequent application to the sheep industry in the eastern States, where drought had been more of a problem, should benefit. (However sheep numbers in Western Australia have been increasing more rapidly than the average.)

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(3) In modified form only as iterations were not followed through to a minimum cost.

The area included in the pilot study consisted of the divisions of Metropolitan, South West, Southern Agricultural, Central Agricultural, and those shires which are both in the Eastern Goldfields Division and predominantly south of latitude 30°S.

Costs considered were the cost of transporting grain from shires with NDR grain to shires in the drought declared area; the value of the grain fed; storage costs of holding grain in existing silos(4); and interest allowed at 10% per year as an opportunity cost on the capital tied up in the grain. No alternative strategies such as agistment were considered.

To study the transportation flows 71 shires were identified as containing official wheat silos. Each of these was allocated a possible NDR storage of wheat of 10,000 tons (approximately 26/71 million bushels). This was based on an assumed demand on NDR grain of 26 weeks of maintenance ration at 5 lb. per week, applied to all adult sheep in the 1940 first decile drought in the area of enquiry. This drought was the largest by sheep numbers during the period 1936-1965.

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(4) These costs are based on estimates given for New South Wales in J.W. Freebairn's article, "Wheat Storage Costs in New South Wales". [21] Freebairn divided costs of storage into fixed and variable costs. The storage costs used throughout the analysis were variable costs of 40 cents per ton per year. This was based on the smallest of the official storage facilities considered by Freebairn, which had the highest variable costs per ton. [21 P.31 Table 14]

With these assumed supply levels a transportation model was set up for each of the droughts, 1940, 1950 and 1954. These were selected on the evidence of the period 1936-1965 as representing small, medium and large droughts in terms of sheep numbers. A minimum cost solution was not derived but feasible solutions meeting the row and column restrictions with emphasis on low cost routes were obtained. These gave transportation costs per ton of \$3.78 for the 1940 drought, \$3.65 for the 1950 drought, and \$3.38 for the 1954 drought. These transport costs were fairly low and were influenced by the fact that the portion of Western Australia included in the pilot study is fairly close to the grain growing regions. All official silos are near railway lines and transport has been taken to be by rail to a point as near as possible to the shires in the drought areas. The remaining transport was by road and involved a limited number of shires and short distances.(5)

In constructing the budgets it became apparent that if the period of a declared drought continued after a wheat intake, it would be possible to take advantage of this fact. When this particular wheat intake occurred the location of the declared drought and the number of sheep in the area is already known, so that the quantity of wheat and the location of the wheat held as NDR could be selected accordingly.

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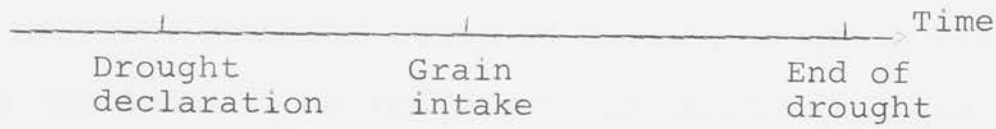
(5) All transport costs were taken to be at full wagon load rates by rail or road service, which data are published by the Western Australia Government Railways Commission and the West Australian Road Transport Association.

Figure 3.2

Drought year time flow.



As illustrated in Figure 3.2 the size of grain intake put into the NDR in this drought year can be adjusted according to the number of sheep in the drought area. However any demand for NDR grain during the period from drought declaration to the drought year grain intake has to be met from grain already held in the NDR. This grain of course is put aside without knowledge of the forthcoming drought.

A number of budgets have been constructed for the pilot study area. These give estimates of NDR costs associated with each of the drought years 1940, 1950 and 1954. Throughout the budgets and the subsequent simulations the number of sheep "in a drought" were estimated on the basis of 1964 sheep numbers; 1964 being selected as a year prior to recent large droughts in Australia.[6] The costs attempt to estimate the position given 1964 sheep numbers but with weather as it was in 1940, 1950 and 1954. On this basis the 1940 drought delineated by Gibbs and Maher would have included 12,180,000 adult sheep, the 1950 drought 360,000 adult sheep, and the 1954 drought 2,100,000 sheep.

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(6) The results obtained from the simulations can be readily updated for changes in sheep numbers. The possibility of varying sheep numbers is discussed in later sections.

Cost per sheep was estimated for each of these three droughts using the components - transportation cost from official silos to the drought, the value of grain fed at $60 per ton, variable costs of holding grain in official storage (excludes fixed costs such as depreciation on storage facilities and administrative costs), interest on the average value of grain held at 10% per dollar-year. As there were 14 droughts in the 30 years, somewhere in the area being studied, that is approximately one drought-year in two, each drought year was allocated costs associated with one non-drought year, as well as costs directly associated with the drought year itself.

Costs "associated with the drought year itself" were estimated for a number of combinations of grain input and demand. These were not intended at this stage to be necessarily realistic but aimed at gaining further insight into what relationships were involved in the problem and the importance of different components. Altogether six combinations were considered.

Implicit in the combinations considered is that a quantity of grain per sheep is put aside to cover the "largest" number of sheep in a drought up to the next grain intake. In the combinations budgeted for, 3 months', 2 months' and 1 months ration are set aside to give a maintenance ration to the largest number of sheep in a first decile drought from 1936 to 1965. Demand for this grain <u>per sheep</u> is also taken at 3 months', 2 months' and 1 month's maintenance ration but applied to the number of sheep in the drought being considered - 1940, 1950 or 1954. In a drought year a separate component of grain input is also assumed and is taken in these budgets as invariably 6 months' ration per sheep, applied to the actual number of sheep in the declared drought. Demand for this in a drought is taken as 6 months' and 3 month's ration per sheep. The combinations of grain input with demand and the associated costs are shown in Table 3.1. For example, in the fourth row of Table 3.1: 6 months' ration is put aside during the drought and 3 months' ration is assumed to be demanded, both applied to the actual number of sheep in the drought (1940, 1950 or 1954); 3 months' ration were put aside in the previous grain input to cover the "maximum" number of adult sheep, and 3 months' ration demanded for the actual number of sheep (1940, 1950 or 1954); for these supply-demand situations the cost of feed, transportation cost, storage and interest are calculated as applied to the drought years; to these costs are added for each drought the storage and interest costs associated with putting aside 3 months' ration for the "maximum" number of adult sheep for one non-drought year.

The budgets are limited to a few supply and demand combinations; no combinations have been considered where demand for grain exceeds supply, however the results draw attention to the importance of the quantity of grain demanded per sheep on total costs per sheep. From the column of Input / Demand Combinations it can be seen that the level of demand decreases from 9 months per sheep in the first row to 4 months per sheep in the sixth row. Associated with the decrease in the level of demand going down the columns there is a decrease in the costs per sheep. For a given input - demand combination costs per sheep are consistently smaller in the large drought (1940) than in the medium sized drought (1954), and these again are consistently smaller than those in the small drought (1950). This reflects the method chosen at this stage to allocate non-drought year costs. This causes a consistent aggregate non-drought year cost to be allocated to each drought regardless of the number of sheep in the particular drought.

Table 3.1

NDR Cost per Sheep-fed - Pilot Study only.

Input/Demand Combination [a]	1940 Drought	1950 Drought	1954 Drought
	$	$	$
(6,6; 3,3)	6.00	18.00	7.70
(6,6; 2,2)	5.20	13.30	6.40
(6,6; 1,1)	4.50	8.60	5.10
(6,3; 3,3)	4.20	16.30	6.00
(6,3; 2,2)	3.50	11.60	4.70
(6,3; 1,1)	2.80	6.80	3.40

(a) Here (6,3; 2,2) for example, indicates that 6 months' feed is being put into NDR per adult sheep in a declared drought and 3 months' feed demanded, while 2 months' feed is put aside each year per maximum number of adult sheep and in the particular drought 2 months' feed were demanded per sheep.

A number of characteristics of the budgeting stage were carried into the subsequent simulations. These included the combination of 1964 sheep numbers with drought locations defined by Gibbs and Maher as from 1936 to 1965, and the splitting of a drought into a "pre-wheat-intake period" and a "post wheat-intake period" with adjustment of the drought reserve to the known drought location and size. In addition the budgets draw attention to the importance of the cost of the grain itself, which influenced the type of simulations carried out later. For example transportation cost was later included directly as a cost per unit of grain rather than attempting a study via the linear programming transportation model. Similarly the costs of holding the grain are small compared with the cost of the feed itself suggesting that cost per sheep is not greatly affected by the effect of the timing of drought declaration on between-drought holding costs. The actual overall costs per sheep given in Table 3.1 were superseded by later simulations which involved more realistic models than those in the budgets.

3.1.3 Parametric Budget

Parametric budgets have been developed in which costs are expressed as functions of variables, whereas particular values were used in the pilot study. Once such parametric budgets have been constructed expressing the mathematical relationship between costs and causal variables a recalculation of costs can be readily carried out for new values of the variables. The parametric budgets formed a stepping stone to computer programs subsequently developed for simulation models where instructions in the program are in the form of equations relating variables and actual values of the variables are fed in as data. The connection between an equation in a computer program intended to measure costs or revenue and a corresponding parametric budget is very strong. [18]

The empirical work carried out in the pilot study was related to discrete values of the relevant parameters. Discrete values used were: the number of adult sheep in a drought (for each of three droughts); the "maximum" number of adult sheep in a drought; a number of levels of demand per sheep in the drought for NDR grain, operative before the central point of the wheat intake period; a number of levels of demand per sheep in the drought, operative after grain intake; and grain input composed of a quantity of grain per sheep in the drought (when there is a drought) plus a quantity of grain per sheep in the "maximum" drought. In the parametric budget these were expressed as variables in equations estimating costs.

In development of the parametric budgets as in the pilot study the year is split into two parts by a point of time during the wheat intake period. Droughts are assumed to be declared 12 weeks before this point of time and to remain "declared" for 40 weeks after this point of time. This total period of 52 weeks is taken to extend from the beginning of one September to the beginning of the following September. Years are measured from September to August instead of the normal January to December. It is assumed initially that enough grain is put into the NDR to cover the maximum drought length (no stockout is possible) for both periods of the drought year.

Parametric Budget of Costs From the Beginning of Drought Year I to Wheat Intake (a period of 12 weeks from the beginning of September.)

Quantity of grain in stock at the beginning of drought year I = AA cwt.[7]

Number of adult sheep in the declared drought in year I = NAS(I)

Actual number of weeks NDR grain demanded at 5 lb. per sheep per week = ADL' weeks

Cost per cwt of wheat = $\$ C_1$

Variable cost of storage per cwt-week = $\$ C_2$

Rate of interest per \$-week = $C_3\%$

Average intrastate transport cost to the drought per cwt. of wheat = $\$ C_4$

Cost of feed[8], year I = $NAS(I)*ADL'*5/112)C_1$

$= P'C_1$, where P'= the number of cwt. of wheat demanded from NDR from September to wheat intake.

Cost of intra-state transport = $P'C_4$

Cost of storage = $(P'/2 * ADL')C_2 + (AA - P')12C_2$

$= Q'C_2$

Cost of interest = $Q'\ C_1\ C_3$

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(7) The notation could obviously be simplified but is here kept consistent as far as possible with subsequent computer programs. A glossary of the notation used most frequently through this study has been given.

(8) See Figure 3.2

Parametric Budget of Costs From Wheat Intake in Drought Year I to the end of Drought Year I (a period of 40 weeks)

Quantity of grain in stock just after grain intake in year I = AB cwt.

= (AA- P') + GI,

where GI = grain intake into NDR

Number of weeks NDR grain demanded at 5 lb. per week per sheep from wheat intake to the end of the year = ADL weeks

Cost of feed, year I = NAS(I) * ADL * 5/112) C_1

= PC_1 , where P = the number of cwt. of wheat demanded from wheat intake to the end of August.

Cost of intra-state transport = P C_4

Cost of storage = (P/2 * ADL) C_2 + (AB - P) 40 C_2

= Q C_2

Cost of interest = Q C_1 C_3

Total costs during the drought year I equal the sum of costs of feed, transport, storage and interest over the twelve months from September to August.

The assumption has been made so far in this development of the parametric budget that opening stocks of grain, both at the beginning of the drought year and just after wheat intake, are sufficient to fully meet demands in the following period. This assumption can be easily relaxed.

The less restrictive assumptions are made that grain demanded from NDR in a given State can exceed stocks in that State but that excess demand can be always met by importing grain from another State, and that this grain is imported as required and transported direct to drought areas. The cost of obtaining this grain apart from the cost of the grain itself is taken as the interstate transport cost. The cost of stockout is here interstate transport cost.

Interstate transport cost per cwt. of imported grain	$= C_5$
The interstate transport cost of importing grain from September, year I, to wheat intake	$= C_5(p^1 - AA)$, if $P^1 > AA$
	$= 0$, if $P^1 \leq AA$
The interstate transport cost of importing grain from wheat intake, year I, to the end of year I	$= C_5(P - AB)$, if $P > AB$
	$= 0$, if $P \leq AB$

Non-Drought Year Costs

When a drought is not declared in September there is no cost of feed or transport.

Cost of storage through the year $= AA * 52\ C_2$

Cost of interest through the year $= AA * 52\ C_1C_3$

The parametric budgets outlined, or a slight modification of them for droughts not assumed to be "declared" for 12 months from September, would enable a quick assessment of costs in a given year. They could also be useful in assessing the effect on costs of changes in some of the pertinent parameters. This could be accomplished by partial differentiation with respect to the parameter of interest. For example, change in "total" costs during a drought year given a change, ΔC_4, in estimated intra-State transport cost equals $(P + P^1)\ \Delta C_4$. Similar results obtain for the other parameters.

3.1.4 Inventory Analysis

Whereas parametric budgets may be used to give flexibility in estimating costs, inventory analysis [19] may be used to select inventory policies which are in some sense optimal. Attention is given here to the possibility of applying inventory analysis in the context of an NDR.

The parametric budgets just outlined give a method of estimating costs where a given level of demand for NDR grain is associated with given opening stocks of grain. The opening stocks are as at points of time at the beginning of the drought year and just after wheat intake. These opening stocks are subject to control, by putting grain into the NDR or by reducing the level of such grain. In particular this applies to the level of grain in the NDR just after grain intake at which point of time the level of grain in the NDR can be readily increased (or reduced).

Inventory analysis may be applicable where demand per sheep for NDR grain is not taken as a given figure but subject to a probability distribution which is known. Where the probability distribution of demand is known inventory analysis may furnish information as to the level of opening stocks of NDR grain which would minimize expected costs.

If suitable information were available regarding the probability distribution of demand per sheep for NDR grain, inventory analysis would be applied to "optimize" the opening stock of grain just after wheat intake. Here "to optimize" means to minimize the expected costs during the period from grain intake to the end of the drought year. The number of sheep in the declared drought area is known when the grain is being put aside, so to know the probability distribution of demand on the NDR it is necessary to know only the probability distribution of demand per sheep.(9)

The ensuing inventory analysis follows fairly directly from the parametric budget with the inclusion of probability and expected costs.

Let i be the level of demand per sheep where i can take any of the discrete values from 1 to N with probability p_i. Suppose the opening stock of wheat just after wheat intake is h, where h can vary from 1 to N. The unit for both i and h is a week's ration at 5 lb. per week.

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(9) It would be more difficult to apply this type of analysis to the period form drought declaration to wheat intake. Grain for this period is put down from the previous wheat intake before the drought has been declared. Demand for NDR grain during this period is derived from the interaction of the probability distribution of the number of sheep in a drought, and the probability distribution of demand for NDR grain per sheep.

Expected cost of feed supplied from within-State $= NAS(I)*(\sum_{i=1}^{h-1} p_i i + \sum_{i=h}^{N} p_i h)*(5/112)C_1$

Expected cost of storage[10] $= NAS(I)*(h - \sum_{i=1}^{h-1} p_i i - \sum_{i=h}^{N} p_i h)*(5/112)40C_2 \geq 0$

Expected cost of interest[10] $= NAS\ (I)*(h - \sum_{i=1}^{h-1} p_i i - \sum_{i=h}^{N} p_i h)*(5/112)40C_1C_3$

Expected cost of stockout $= \sum_{i=h}^{N} p_i (i - h)*(5/112)C_5*NAS(I)$, where C_5 is now interstate transport cost plus cost of feed per cwt. of imported grain

Expected transport cost on feed supplied from within-State $= NAS(I)*(\sum_{i=1}^{h-1} p_i i + \sum_{i=h}^{N} p_i h)*(5/112)C_4$

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(10) These are approximations as they measure storage cost and interest only on the portion of h which is not run down by demand.

Let $E(C_{h+1})$ = the expected total cost where the level of inventory is h+1

$$E(C_{h+1}) = NAS(I)*\{\sum_{i=1}^{h} p_i i + \sum_{i=h+1}^{N} p_i (h+1)\} *(5/112)* (C_1 + C_4)$$

$$+ NAS(I)*\{(h+1) - \sum_{i=1}^{h} p_i i - \sum_{i=h+1}^{N} p_i (h+1)\}* (5/112)*40(C_2 + C_1C_3)$$

$$+ \sum_{i=h+1}^{N} p_i \{i - (h+1)\} *(5/112)NAS(I)*C_5$$

$$= (5/112)NAS(I)*\left[\sum_{i=1}^{h} p_i i\{(C_1 + C_4) - 40(C_2+C_1C_3)\}\right.$$

$$+ \sum_{i=h+1}^{N} p_i (h+1) \{(C_1 + C_4) - 40(C_2 + C_1C_3)\}$$

$$\left. + (h+1)40(C_2+C_1C_3) + \sum_{i=h+1}^{N} p_i (i - (h+1))*C_5\right]$$

$$E(C_{h+1}) - E(C_h) = (5/112)NAS(I)*$$

$$\left[\{\sum_{i=1}^{h} p_i i - \sum_{i-1}^{h-1} p_i i\} * \{(C_1 + C_4) - 40(C_2 + C_1C_3)\}\right.$$

$$+\{\sum_{i=h+1}^{N} p_i (h+1) - \sum_{i=h}^{N} p_i (h)\}*\{(C_1 + C_4) - 40(C_2+C_1C_3)\}$$

$$+ \{(h+1) - h\} 40(C_2 + C_1C_3)$$

$$\left. + \sum_{i=h+1}^{N} p_i (i - (h+1)) C_5 - \sum_{i=h}^{N} p_i (i-h)C_5\right]$$

$$= (5/112)\ NAS(I) \Big[p_h h \{(C_1+C_4) - 40(C_2+C_1C_3)\}$$

$$+ (\sum_{i=h+1}^{N} p_i - p_h h)\ \{(C_1+C_4) - 40(C_2+C_1C_3)\}$$

$$+ 40\ (C_2+C_1C_3) - \sum_{i=h+1}^{N} p_i C_5 \Big]$$

$$= (5/112)\ NAS(I) * \Big[40(C_2+C_1C_3) +$$

$$\{(C_1+C_4) - 40(C_2+C_1C_3) - C_5\} * \sum_{i=h+1}^{N} p_i \Big]$$

It follows that $E\ (C_{h+1}) > E\ (C_h)$

if $40(C_2+C_1C_3) + \{(C_1+C_4) - 40(C_2+C_1C_3) - C_5\} * \sum_{i=h+1}^{N} p_i > 0$

i.e. $\sum_{i=h+1}^{N} p_i > \dfrac{40(C_2+C_1C_3)}{40(C_2+C_1C_3) + C_5 - (C_1+C_4)}$

Similarly, $E(C_{h+1}) < E(C_h)$

if $40(C_2+ C_1C_3) + \{(C_1+C_4) - 40(C_2+C_1C_3) - C_5\} \sum_{i=h+1} p_i < 0$

A. Optimal Inventory Zero

The optimal level of inventory will be zero on the basis of the costs considered, if:

(I) $(C_1+C_4) - 40(C_2+C_1C_3) - C_5$ is positive.

In this case,

$$40(C_2+C_1C_3) + \{(C_1+C_4) - 40(C_2+C_1C_3) - C_5\} \sum_{i=h+1}^{N} p_i$$

is positive for all values of h from zero to N.

(II) $(C_1+C_4) - 40(C_2+C_1C_3) - C_5$ is negative, but

$40(C_2+C_1C_3) + \{(C_1+ C_4) - 40(C_2+C_1C_3) - C_5\} \sum_{i=h+1}^{N} p_i$, which for convenience can be called $A + B \sum_{i=h+1}^{N} p_i$, is positive for $h = 0$.

B. Optimal Inventory Greater than Zero

If $A + B \sum_{h+1}^{N} p_i$ is negative for $h = 0$, this expression indicates that h should be increased to reduce costs. Such an increase in h will increase the algebraic size of $A + B \sum_{i=h+1}^{N} p_i$ through the decrease in absolute size of the positive factor $\sum_{i=h+1}^{N} p_i$. If $A + B \sum_{i=h+1}^{N} p_i$ changes from negative to positive for $0 < h < N$ this is the optimal inventory level. If not, the optimal inventory level is N.

If B and $A + B \sum_{i=h+1}^{N} p_i$ are negative where h = 0, to minimize expected cost one would seek to locate an inventory level h such that with the given probability distribution of demand:

$$\sum_{i=h+1}^{N} p_i > \frac{40(C_2+C_1C_3)}{40(C_2+C_1C_3) + C_5 - (C_1+C_4)}$$

and

$$\sum_{i=h}^{N} p_i < \frac{40(C_2+ C_1C_3)}{40(C_2+C_1C_3) + C_5 - (C_1+ C_4)}$$

This identifies a value of h such that $E\{C_{h+1}\} > E\{C_h\} < E\{C_{h-1}\}$. So, if one is dealing with demand for NDR grain for a drought already declared so that sheep numbers are known, the above formula will enable the "optimal" opening stock of NDR grain to be determined. It is necessary to know the probability distribution of demand for NDR grain per sheep in the drought, although the formulae developed do not depend on any particular shape of this probability distribution. The formulae allow a quick re-calculation of the optimal inventory level for a change in the cost parameters. The costs associated with non-optimal, for instance near-optimal, policies can be readily calculated by use of the parametric budget.

3.1.5 General

The development of the pilot study, parametric budget and an inventory model gave insight into the problem. These models were not used in empirical analysis except that of the pilot study, and the empirical results of the pilot study were superseded by the subsequent simulations. However, apart from assisting in development of the simulation models used in this study these "developmental" models could have intrinsic value and could perhaps be given empirical content.

3.2 Simulation Models

The technique used for the major part of the analysis of NDR costs was simulation. This is a technique which readily accommodates situations which are dynamic (in the sense that one is interested in changes in variables through time) and, or, probabilistic. The problem of the economic feasibility of an NDR clearly has both these characteristics. Dynamic programming also can be applied to problems with these characteristics. No attempt was made to apply this technique to the aggregative study of NDR costs,[11] partly because of Powell's difficulties in finding a dynamic programming model which was operable, but also because the problem seemed to possess other characteristics which suggested the application of simulation.

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(11) It was examined in connection with on-farm strategies at the level of the individual, but not used.

In particular an important part of the problem to be investigated seemed to be the level of demand for NDR grain per sheep. This level of demand is unknown before the advent of an NDR. Levels of demand for grain which occurred in some recent droughts have been examined.[10] However demand for grain per sheep depends on stocking rates, areas of improved pasture and on selection on the farm of within-drought strategies. It thus seemed desirable to carry out an exploratory analysis of costs for a number of levels of demand for NDR grain per sheep. Simulation is particularly well adapted to exploratory work of this kind. A further consideration was the fact that (because of a number of factors) it seemed possible that an NDR could conceivably have to give attention to problems of availability of grain supply as well as to levels of demand. This situation certainly does not apply at the time of writing, when there are large stocks of grain held in Australia and elsewhere. However it seemed desirable to include consideration of this factor in the analysis as a possible future contingency.

Whereas the parametric budgets allow ready costing in the drought year or a non-drought year for given opening stocks of grain and demands per sheep, the simulation models give such a costing over a continuous run of years. A number of levels of demand per sheep are included and opening stocks of grain are determined within the model.

Apart from estimates of costs the simulation models also give information regarding the levels of grain input into the NDR, storage capacity required, and the levels of stockouts. Experiments are carried out to study the behaviour of different grain input policies, where performance is measured according to the above criteria, for a variety of demands per sheep.

As indicated in the inventory model, levels of opening stock are of particular interest in studying the performance of an NDR. In the simulations, rules have been developed governing the input of grain into the NDR and the disposal of unused grain. These two factors together with the demand for grain as a drought feed determine what quantities of grain are held in the NDR at various times.

The following equations were developed to determine the level of input of grain in any year I.[12]

$$Q(I) = D * NAS(I) + E * MNAS \quad (3.5)$$

or

$$Q(I) = UL - CW(I) \quad (3.6)$$

whichever is less;[13]

where, Q(I) is the number of bushels put into the NDR in

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(12) The grain referred to here is wheat. In some of the simulations applied to Queensland, sorghum is made the main grain but with wheat as a secondary part of the NDR. The grain input rules varied slightly for the sorghum-wheat system.

(13) Grain input calculations in most of the actual simulations were limited to equation 3.5.

year I;

D is the number of bushels put into the NDR per adult sheep in the drought area in year I;

NAS(I) is the number of adult sheep in a first decile drought area in year I, based on 1964 sheep numbers;

E is the number of bushels put into NDR per "maximum number of adult sheep";

MNAS is the "maximum number of adult sheep", taken in the simulations as the largest number of sheep, based on 1964 sheep numbers, in an area located as being in a first decile drought during the period 1936-1965;

UL is the upper limit set on the number of bushels in the NDR, which upper limit is here assumed constant through time;

CW(I) is the number of bushels of "carryover wheat" at the time of wheat intake in year I.

If the three control variables D, E and UL are to be considered, the quantity of wheat in year I will be given by equation (3.5) or equation (3.6), whichever gives the lower level of Q(I). In a non-drought year the level of NAS(I) is zero, which affects the level of Q(I) obtained in equation (3.5). If only the control variables D and E are being considered, then of course equation (3.6) is not relevant.

The reasons for selecting D, E and UL as control variables were heuristic. The putting aside of a component equal to E * MNAS was done partially with the idea of supplying whatever demand might occur in the period before the next grain intake. To illustrate with reference to non-summer-rainfall areas, grain put into the NDR in accordance with the component E * MNAS in year I (measured in these areas from September to September) would tend to be available if a drought were declared at the beginning of the year I + 1, that is in the following September. Such a drought, if one is declared could be of any size up to the "maximum", i.e. MNAS. Accordingly part of the reason for including a component E * MNAS has been to help meet any demand between the coming September and the subsequent wheat intake.

This component was also thought of as being likely to stabilize, to some extent, grain input requirements for the NDR. For given values of E and MNAS this component is a constant from year to year. In this it contrasts with the component D * NAS(I) which can vary from zero when NAS(I) is zero to D * MNAS in the year when NAS(I) equals MNAS. Apart from reducing the variance of grain supply the component E * MNAS causes at least this quantity of grain to be put aside every year. This tends to reduce the necessary grain intake into NDR in drought years when, depending on the location and extensiveness of the drought, production of grain could be well below average. The component, D * NAS(I), on the other hand allows the quantity put into NDR each year to vary with NAS(I), the number of adult sheep in the drought, if any. This reduces the opportunity cost and the direct costs, that is the chemical costs, etc., associated with preserving the grain.

These two components conflict with each other. The component, E * MNAS, reduces the variance of grain intake into NDR but increases carrying costs. The second has the opposite tendencies. The analysis carried out in this study considers a number of combined levels of D and E and examines the performance of the resulting NDR policies. In this it is thought that the opposing tendencies can very likely be balanced to obtain policies which meet criteria of effectiveness imposed by decision makers connected with such a scheme.

The third component in equations 3.5 and 3.6 which helps determine the level of intake into NDR in any year is UL. Without this component the quantity put aside in any year is independent of the quantity of grain which is already held in the NDR at the time. As indicated by equations (3.5) and (3.6) this upper limit will only be effective in any year when the level of Q(I) if determined from equation (3.6) alone is less than the level of Q(I) if determined from equation (3.5) alone.

3.2.1 Components of the Simulation Models

The basic empirical analysis in the simulation of various NDR policies contained the following components, where a State (New South Wales, Victoria, etc.) formed the area of enquiry:

(1) The maps contained in Gibbs and Maher's publication [14] were used to identify "first decile droughts" over the 30 year period 1936 to 1965. A listing was taken of those shires which were in each drought.

(2) A listing was developed for each State, using information supplied by the relevant grain bulk-handling authority, of those shires which contained official silos.

(3) Estimates were made of the average cost of transporting wheat from shires which contain official silos to those affected by drought. As a first approximation to this a number of droughts were selected from those occurring during the 30 year period and transportation costs estimated from a central point in the nearest shire containing official silos. The droughts selected were chosen to represent large (in terms of sheep numbers), medium, and small droughts. Transportation costs have been estimated as a cost of rail transport from "silo shires" to a central point in the "drought shires" if this is possible by rail. Otherwise transport cost is taken from the "silo shire" to a railway station as close as possible to the "drought shire" with the remaining transportation cost to the centre of the "drought shire" estimated as road transport.

(4) Using sheep numbers as at 31st March 1964 (i.e. before the recent large droughts of 1965-66 and 1967-68) the listing of drought shires developed in (1) was converted to a time series of adult sheep in droughts over the period 1936-1965.

(5) Droughts as identified by Gibbs and Maher were related to rainfall below the first decile point in calendar years. Whenever such a drought was identified in a Gibbs and Maher map for a given calendar year this was treated in the simulation as being declared a drought as at 1st September[14] of that year. Implicit in the ensuing analysis was the idea that declaration of a drought made NDR grain available if called on. A guarantee of the availability of the grain was to be maintained for 12 months from the declaration date.[15]

(6) It could not be known with certainty what the level of demand for the NDR grain would be, with such demand dependent on weather but also on farmers' decisions regarding such things as stocking rates, improved pastures, and alternative or complementary drought strategies. Hence simulation runs were made with various levels of assumed demand.

(7) In the computer programs used for these simulation runs, a demand level for NDR grain was measured in terms of the number of weeks full maintenance ration at an assumed 5 lb. of wheat per week[17].

(8) The simulation runs divided the drought years from September to September into two sections, September to December, the period "before grain intake" and December to

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(14) Other dates of drought declaration were used for Queensland.

(15) The meeting of such guarantees would depend on grain being available as required either from within-State supplies or from imports from other localities in Australia.

September, the period "after grain intake".[16] The rationale of such a division is related to the fact that the time at which grain can be put aside for the NDR in any year is obviously during grain intake. The quantity of grain put aside at this time varies in the simulation according to the number of sheep in any drought current at that time. This can be related to demand from December to September. However the demand for grain in any period before grain intake, here taken to be from September to December, has to be supplied from grain already in the NDR.

(9) For a given demand level, the simulated quantity of grain put into the NDR in the grain intake period of any year has been varied between years and between 30 year "runs". In a given 30 year run D and E are fixed at selected values between zero and 1 bushel, and the quantity of grain put into the NDR in year I is given by:

$$Q(I) = D * NAS(I) + E * MNAS.$$ [17]

With given values of D and E grain input varies between years with variation in the size of NAS(I). In

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(16) Actually grain intake into the official storage extends over a number of months, being influenced by receival facilities, grain supply, and the length of the harvesting period. The use of a point of time over-estimates costs attributable to the NDR.

(17) This is identical to Equation 3.5 and is based on two control variables, D and E. The third control variable UL of Equation 3.6 was not used in the simulations in general. The three control variables were included in an "optimizing" simulation programme which automatically searched for a combination of levels of D, E and UL which would minimize cost. These simulation runs in searching for the minimum cost put UL at an ineffectively high level. Most of the simulation runs were based on only the two control variables, D and E.

non-drought years, NAS(I) equals zero, and grain input equals E * MNAS.

For each of a number of assumed demand levels per sheep (weeks of maintenance ration per adult sheep) a number of combinations of D and E are "run" through the 30 year period. The computer outputs obtained from a given demand level and D and E combinations can be examined in a search for suitable D and E combinations.

(10) The thirty-year runs included approximately 15 droughts in each enquiry area. This has been suggested by Hillier and Lieberman [40 P.464] to be a "satisfactory" number of observations in a simulation run.

Initial stocks of inventory were put at zero which appears to contradict recommended practice in simulations. [41] However in most enquiry areas the first year of the simulation, 1936, was not a drought year. At the time of the first drought a "relatively typical" inventory level would have accumulated.

(11) Computer output for each year (September to September) was split-up into the two periods, September to December, and December to September. This output includes the value of grain demanded for declared droughts; the transport cost for within-State transportation to the declared droughts; the opportunity cost of capital tied up in the grain; the physical costs of storage; grain intake requirements each year for the NDR; the peak storage capacity required each year at grain intake; the level of stockouts and of resultant interstate transport of grain.

(12) Interstate transport cost of grain has been measured from the grain area in the supplying State to a central point in the receiving State as an approximation to the average cost of getting this grain direct to the drought area. An alternative system would be to transport this grain first to silos in the receiving State, and then allow extra intra-State transport costs to the drought area. In the simulation for the importing State, no storage cost or opportunity cost is charged on imported grain. No guarantee is assumed regarding the supply of this grain and it is assumed to be called on if fortuitously available. This lack of guarantee in supply would need to be considered in selecting a within-State NDR policy in view of imports which might be required.

(13) A "pool" is defined as grain intake from a single harvest. Depending on whether the computer is simulating a "2-pool" or a "3-pool" NDR scheme, grain is held in the NDR for a maximum of 20 months or 32 months; the grain could contain combined grain from two successive wheat intakes in the 2-pool system or 3 successive wheat intakes in the 3-pool system. Demands for grain during the 30 year run are assumed to be supplied from the older pools first, and this is simulated in the model. This means that grain frequently is not retained in the NDR for the maximum period allowed in the model. This is particularly so if the levels of D and E which are operative in the particular computer run are parsimonious with grain supply relative to demand.

(14) Such grain as is retained for the allowed maximum period is sold. The returns from sale are not included in the model. It is assumed that the statistically expected price obtained for the wheat on sale after being in the NDR is the same as that for wheat put onto the market in the normal way without having been retained in the NDR. The rationale of this is that with suitable chemical treatment and storage facilities grain can be stored for such periods without significant physical deterioration.[18] The assumption would be violated however if there were a trend in the price of wheat. No speculative element regarding future wheat prices has been included in the model.

(15) The price of wheat used in the simulation runs has been varied but the relevant price is the price alternatively available for the wheat at the margin which is taken to be the unsubsidized export price.

(16) Parameters used in the model are: the price of wheat; the cost per quantity-time unit of storing wheat; the opportunity cost per value-time unit; within-State transport cost per unit of quantity; between-States transport cost per unit of quantity.

(17) In the model as constructed three probability distributions are distinguished. These are the probability distribution of demand per sheep in a drought, the probability distribution of the number of sheep in a drought, and the probability distribution of the interval between

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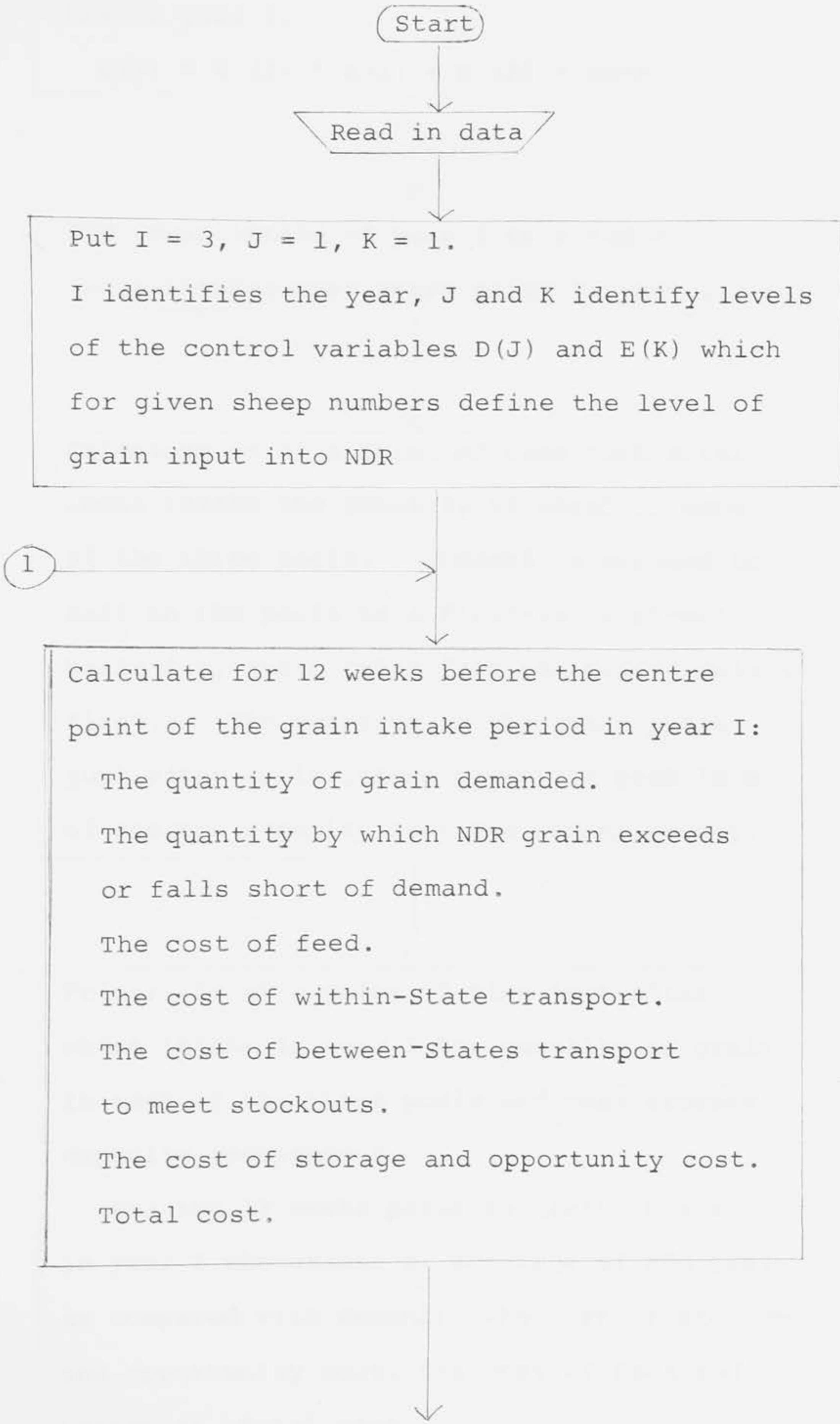
(18) Supported by correspondence from grain bulk-handling authorities in all mainland states.

droughts. All of these are related to an enquiry area, that is the particular State. In most of the simulations one of these probability distributions, the probability distribution of the demand for NDR grain per sheep, is replaced through a 30 year run by a constant demand per sheep to represent the expected value. (This parameter is varied between runs as mentioned earlier.) The other two probability distributions are represented by a historical series using 1964 sheep numbers with historical drought locations and areas.

3.2.2 Flow Diagram

Computer programs were developed to "run" simulations with the characteristics outlined. A number of variations of the "basic" simulation model were developed. For purposes of description the basic simulation model can be described in the following terms: wheat is the grain considered in the NDR; drought years extend from September to September; 2 grain input control variables D and E are considered; the model is a 3-pool model; the demand per sheep is constant over each run of 30 years; a variety of combinations of demand per sheep and of D and E are considered. The computer program allowed ready variation of these characteristics. A flow diagram which broadly outlines the computer program for the "basic" simulation is given below.

Flow Diagram 1.



Calculate the level of grain intake into NDR in year I:

Q(I) = D (J) * A(I) + E (K) * MNAS

↓

Add grain intake of year I to a sum of grain intakes over years prior to year I.

↓

Calculate as at a point of time just after wheat intake the quantity of wheat in each of the three pools. (Demand is assumed to call on the pools on a first-in first-out basis i.e. grain taken from the older pools first.) The quantity in the three pools just after grain intake gives the peak level of storage capacity required during year I.

↓

Print: As at a point of time just after wheat intake in year I the quantity of grain in each of the three pools and peak storage capacity requirement.

For the 12 weeks prior to grain intake in year I the excess or shortage of NDR grain as compared with demand; the cost of storage and opportunity cost, the cost of feed and transport, total cost.

↓

Calculate for the 40 weeks after the centre point of grain intake in year I:

The quantity of grain demanded.

The quantity by which NDR grain exceeds or falls short of demand.

The cost of feed.

The cost of within-State transport.

The cost of between-State transport to meet stockouts.

The cost of storage and opportunity cost.

Total cost.

↓

Print:

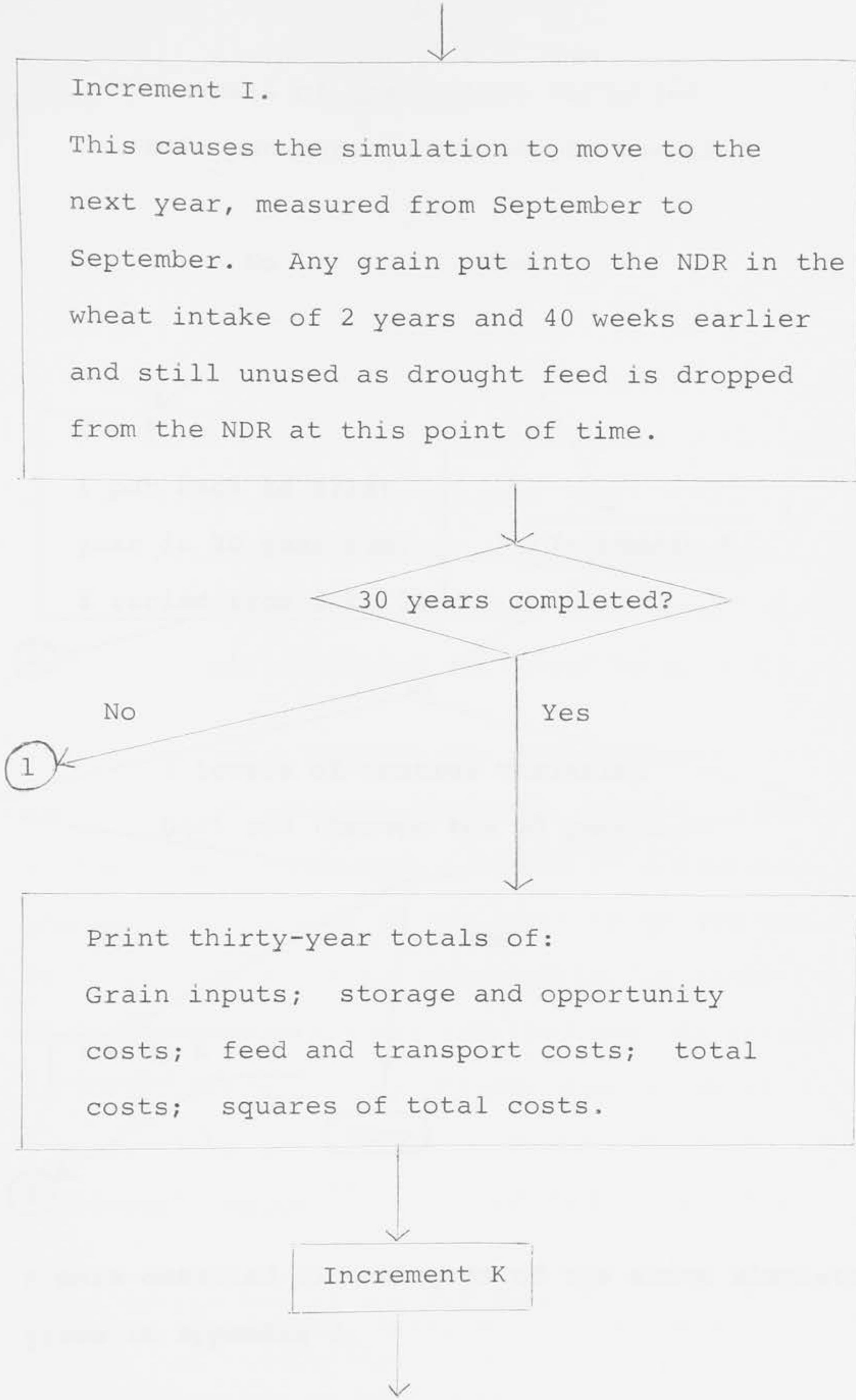
<u>As at a point of time 40 weeks after the centre point of grain intake in year I</u>:

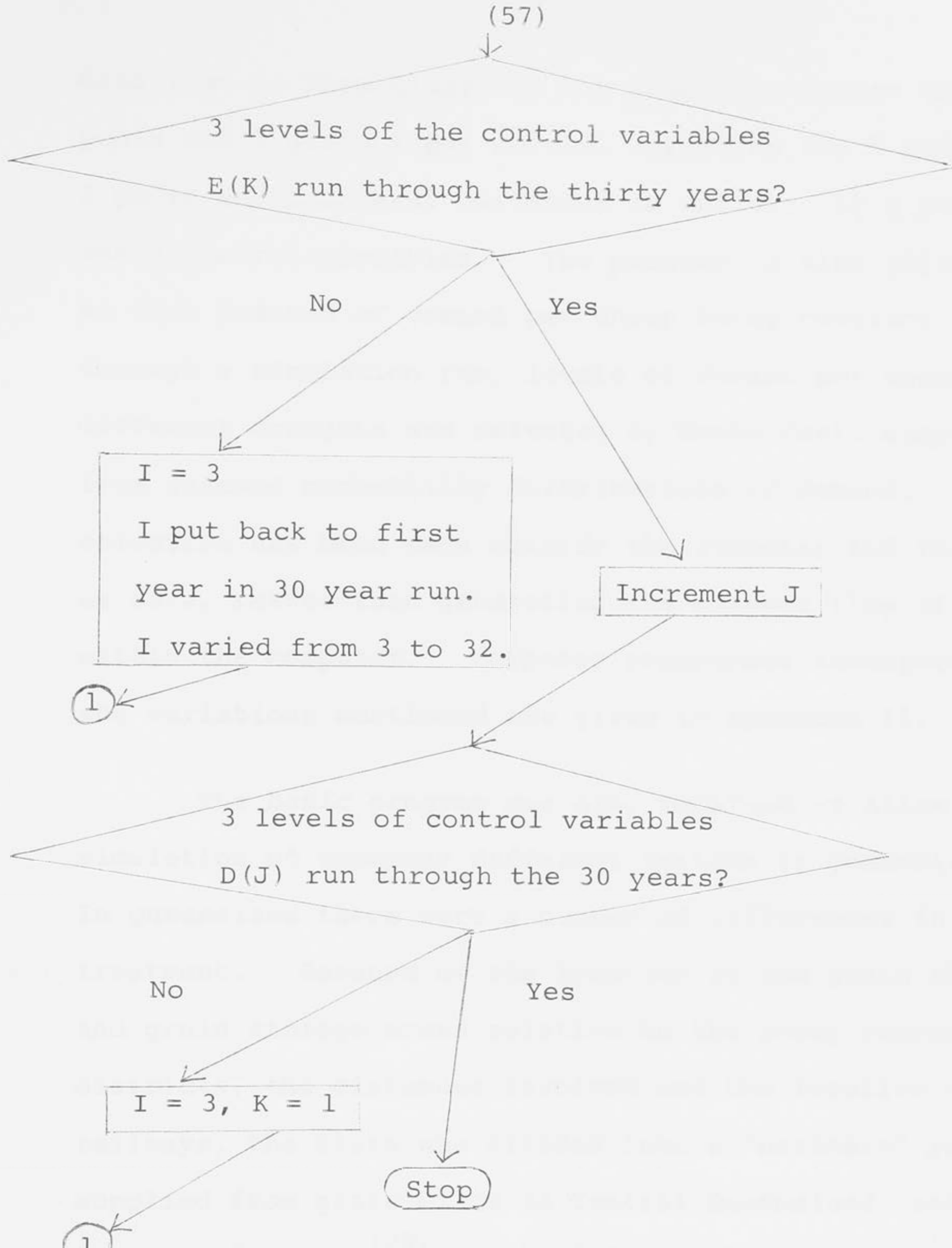
The quantity of grain in each of the three pools.

<u>For the 40 weeks after grain intake in year I</u>:

The excess or shortage of NDR grain as compared with demand; opportunity cost and the cost of storage; the cost of feed and transport; total cost.

↓


Increment I.
This causes the simulation to move to the next year, measured from September to September. Any grain put into the NDR in the wheat intake of 2 years and 40 weeks earlier and still unused as drought feed is dropped from the NDR at this point of time.
30 years completed?
No
1
Yes
Print thirty-year totals of:
Grain inputs; storage and opportunity costs; feed and transport costs; total costs; squares of total costs.
Increment K



A more detailed flow diagram of the above simulation is given in Appendix I.

3.2.3 Related Simulation Models

Computer programs were developed to incorporate variations in the assumptions of Flow Diagram 1. These include programs which perform operations similar to those described in Flow Diagram 1 but where the system has 3 pools and 3 grain input control variables (D, E and UL); 2 pools and 2 control variables (D and E); or 2 pools and 3 control variables. The program is also adjusted so that instead of demand per sheep being constant through a simulation run, levels of demand per sheep in different droughts are selected by Monte Carlo sampling from assumed probability distributions of demand. This selection has been made outside the computer and fed in as data, rather than generating the assumed flow of demand within the computer. Computer programmes incorporating the variations mentioned are given in Appendix II.

The basic program was also modified to allow simulation of somewhat different systems in Queensland. In Queensland there were a number of differences in treatment. Because of the location of the grain growing and grain storage areas relative to the sheep rearing districts, the distances involved and the location of railways, the State was divided into a "northern" region,[19] supplied from grain silos in Central Queensland, and a "southern" region[20] supplied from silos in southern

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(19) Consisting of the Far West Division, Central West Division, North West Division and the shires of Banana, Fitzroy and Livingstone in the Rockhampton Division.

(20) Consisting of the Downs, South West and Roma Divisions, and shires of Beaudesert and Morton in the Moreton Division, the shires of Kingaroy and Wondai in the Maryborough Division, and the shire of Taroom in the Rockhampton Division.

Queensland. Because of the distances involved, transport costs in Queensland for grain supplied from within the area of enquiry, "Northern" Queensland or "Southern" Queensland, were measured for each drought individually.[21]

Simulations were run from the two zones outlined, based on a 3-pool, 2-control variable (D and E) system using wheat as the grain. Because Queensland is a summer rainfall area, with most of the years' rain falling from November to March, droughts in this system were assumed to be declared 12 weeks after the centre point of wheat intake, that is about the end of March. The simulations were run over 30 years as before and similar print-outs obtained from the computer.

However in Queensland a substantial proportion of wheat produced is premium wheat. Also there has been a strong upward trend in the production of sorghum. A committee examining the possibility of mitigating droughts in Queensland has suggested that storage of grain in official silos for this purpose seemed desirable. The types of grain recommended were sorghum and wheat. [30 P.22, P.31, P.101]

Because of the importance attached to sorghum as a possible drought feed another system was devised and simulated which gave emphasis to this grain, while also using wheat. In this instance the "year" was taken to

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(21) A detailed discussion of the methods used to estimate transport costs for Queensland and other States is given in Appendix VI.

be from June to June, so that drought declaration in June is made to coincide with sorghum intake. Adherence to "years" from March to March as used in the system based on wheat only would have caused the year to be broken into three parts by the sorghum intake in winter and the wheat intake in summer. Because the programming to include the three segments would have been unduly complicated for any extra advantages obtained the "year" was made from June to June.(22) Demand for NDR grain per sheep, costs, stockouts, grain intake and storage requirements were related each year to two periods of 26 weeks. Sorghum was assumed to be kept for a maximum of 12 months and wheat for a maximum of 18 months, drawing on two wheat crops.

The programs outlined so far give a mapping of a system's performance for different combinations of input control variables and demand. For a given demand situation it would be possible to select the grain input policy from those considered which seemed preferable in terms of costs, grain input requirements, storage capacity requirements, and stockouts. However there was no attempt in programs outlined so far to find a combination of levels of the input control variables which would determine "optimal" policy. The levels of control variables to be examined were determined in advance and fed into the computer as data.

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(22) Costs throughout would be affected only marginally by altering the timing of drought declaration within the calendar years identified as drought by Gibbs and Maher. This is discussed further in the section dealing with sensitivity tests, section 3.2.10.

In order to learn more about the response of NDR cost to grain input policy and because such a programme could be of use if an NDR scheme were implemented, a program was developed which would search for the least-cost grain input policy. Once again the basic program of Flow Diagram 1 has been used, but incorporating "steepest ascent" methods (in this case "steepest descent" as the costs are to be minimized) as outlined by Wilde[20]. The program has been developed for the situation where a constant level of demand per sheep is used, but is readily adaptable to two or three pool, and two or three control variable situations.

The characteristics of the program are these. Assume given levels of demand per sheep for both the twelve weeks prior to wheat intake and 40 weeks after wheat intake. An initial level for each of the control variables, D(J), E(K), and UL(L), is fed in as data. For this combination of demand and control variables the average cost per sheep is calculated for the 30 year period. The level of D(J) is altered slightly and the average cost per sheep for the 30 year period is calculated for this new set of levels of the control variables. This is repeated for each of the control variables, varying one at a time and leaving the other two at their initial levels. These calculations enable an estimate to be made of the slope of the cost function with respect to each of the three control variables at the point representing the initial values of D(J), E(K) and UL(L). These three slopes determine the direction of steepest descent. The program then selects a new set of levels of D(J), E(K), and UL(L) in this direction. The process is then repeated. The maximum number of such iterations to be allowed in a single computer run is stipulated as data input. The computer program for optimizing in the three pool, three control variable case together with a flow diagram and related discussion is given in Appendix III.

3.2.4 Empirical Analysis - General

Following the procedures outlined, empirical analysis has been carried out for New South Wales, Victoria, South Australia, Queensland and the southern portion of Western Australia. In all of these States 3-pool models were run. It was decided to single out one State, New South Wales, for more intensive study. Queensland because of its summer rainfall, premium wheat and sorghum production, was also a special case.

Using a factorial design incorporating various levels of D and E, New South Wales was studied using both a 3-pool and a 2-pool system. Also, in order to make a closer approximation to the least cost combination of control variables "steepest descent" programmes were applied. This was done with two control variables (D and E) and the three control variables (D, E and UL). Optimization was carried out with respect to one demand combination only, 8 weeks' demand per sheep before grain intake, and 12 weeks' demand after grain intake.

3.2.5 Details of Empirical Analysis - New South Wales[23]

Based on the numbers and geographical distribution of sheep as at 31st March, 1964, the sheep which would have been in first decile drought areas during the period 1936-1965 are shown in Table 3.2. The series for New South Wales is included. Parameters used for New South Wales were a constant within-State transport cost of $3.50 per ton of wheat applied to all droughts; opportunity cost allowed at the rate of 10% per year on the value of wheat held in the NDR; physical storage cost of 40 cents per ton per year; prices of wheat of $60 and $45 per ton; interstate transport, in this case taken as $17 per ton, being an average of $15 per ton from Victoria to New South Wales and $19 per ton from South Australia to New South Wales.[24]

Costs calculated in the computer runs were reduced to a per sheep-fed basis by dividing by cumulated number of sheep involved in first decile droughts in New South Wales over the thirty years. Average cost per sheep-fed for New South Wales with wheat at $60 per ton, D and E the control variables and various demand levels are shown in Table 3.3. This is for a 3-pool model.

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(23) Some New South Wales shires were included in the Victorian NDR system. For reasons and details see Appendix VI.

(24) See Appendix VI for computation of transportation costs for all States.

Table 3.2

Number of sheep which would have been in first decile droughts based on sheep numbers and distribution as at 31st March, 1964.

1936-65

Drought Year[(a)]	QLD	NSW	VIC	SA	WA	TOTAL
			THOUSANDS			
1936	-	-	-	-	1,765	1,765
37	557	10,752	1,697	142	526	13,674
38	623	8,618	16,731	-	1,111	27,083
39	-	81	-	-	-	81
40	811	38,410	22,313	5,448	12,339	79,321
1941	-	190	-	-	-	190
42	-	-	-	-	-	-
43	-	810	7,893	1,206	66	9,975
44	3,991	36,195	12,962	716	6,745	60,609
45	-	1,368	78	-	245	1,691
1946	6,065	7,287	-	-	54	13,406
47	-	-	-	-	-	-
48	1,698	-	-	198	875	2,771
49	-	-	-	-	1,482	1,482
50	-	-	809	1,270	694	2,773
1951	1,989	1,387	-	19	-	3,395
52	2,918	-	-	-	875	3,793
53	-	599	-	-	-	599
54	-	-	866	522	2,168	3,556
55	-	-	-	-	-	-
1956	-	-	-	-	-	-
57	5,219	24,879	950	3,273	-	34,321
58	-	-	-	-	-	-
59	572	-	1,719	8,288	1,755	12,334
60	18	1,674	-	-	-	1,692
1961	2,441	-	99	4,689	130	7,359
62	-	-	-	-	143	143
63	213	-	1,960	1,304	-	3,477
64	-	-	-	414	-	414
65	5,159	28,203	9,009	4,796	-	47,167

(a) First decile droughts in calendar years as identified by Gibbs and Maher.

Table 3.3

Average cost per sheep-fed, wheat price \$60 per ton, 3 pool model, opportunity cost 10%, New South Wales, 1936-65.

		4			8			12			=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL[1]
				D O L L A R S							
0.17	0	1.32	2.01	2.69	2.01	2.69	3.38	2.69	3.38	4.06	
	0.17	1.51	2.12	2.79	2.11	2.76	3.45	2.77	3.43	na	
	0.33	1.98	2.44	3.01	2.47	2.97	3.57	3.00	3.58	na	
	0.67	2.92	3.41	3.90	3.44	3.93	4.39	3.96	4.42	na	
0.33	0	1.27	1.96	2.64	1.96	2.64	3.33	2.64	3.33	4.02	
	0.17	1.56	2.17	2.83	2.08	2.73	3.40	2.73	3.39	na	
	0.33	2.03	2.50	3.07	2.53	2.99	3.55	3.02	3.56	4.19	
	0.67	2.98	3.47	3.96	3.50	3.99	4.45	4.02	4.48	4.95	
0.67	0	1.36	2.03	2.71	1.86	2.55	3.23	2.54	3.23	3.92	
	0.17	1.68	2.26	2.93	2.17	2.76	3.42	2.68	3.31	na	
	0.33	2.15	2.62	3.17	2.65	3.11	3.66	3.14	3.58	4.15	
	0.67	3.09	3.59	4.08	3.62	4.11	4.57	4.13	4.60	5.06	
1.00	0	1.46	2.13	2.79	1.95	2.61	3.30	2.46	3.14	3.83	
	0.17	1.80	2.37	3.02	2.28	2.86	3.52	2.77	3.35	4.01	
	0.33	2.27	2.74	3.28	2.76	3.22	3.75	3.25	3.70	4.25	
	0.67	3.20	3.70	4.19	3.73	4.22	4.68	4.25	4.70	5.18	

Note

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand level.

Table 3.4

Average cost per sheep-fed, wheat price $45 per ton, 3 pool model, opportunity cost 10%, New South Wales, 1936-65.

			4			8			12	=ADL
D	E	4	8	12	4	8	12	4	8	12=ADL[1]
					DOLLARS					
0.17	0	1.05	1.60	2.16	1.60	2.16	2.71	2.16	2.71	3.26
	0.17	1.15	1.64	2.17	1.63	2.16	2.71	2.16	2.70	na
	0.33	1.51	1.87	2.32	1.89	2.27	2.74	2.31	2.76	na
	0.67	2.24	2.61	2.98	2.64	3.01	3.36	3.03	3.38	na
0.33	0	1.01	1.56	2.11	1.56	2.11	2.66	2.11	2.66	3.21
	0.17	1.19	1.68	2.20	1.60	2.13	2.65	2.12	2.65	na
	0.33	1.55	1.91	2.36	1.94	2.28	2.73	2.31	2.73	3.25
	0.67	2.28	2.66	3.03	2.68	3.05	3.40	3.07	3.43	3.79
0.67	0	1.06	1.60	2.15	1.45	2.00	2.55	2.00	2.55	3.10
	0.17	1.28	1.74	2.28	1.66	2.12	2.66	2.05	2.56	na
	0.33	1.64	2.01	2.44	2.03	2.38	2.81	2.40	2.74	3.19
	0.67	2.37	2.75	3.12	2.78	3.14	3.50	3.16	3.52	3.88
1.00	0	1.13	1.68	2.21	1.52	2.05	2.60	1.90	2.45	3.01
	0.17	1.37	1.83	2.34	1.75	2.20	2.73	2.11	2.58	3.11
	0.33	1.74	2.10	2.53	2.11	2.46	2.88	2.48	2.83	3.27
	0.67	2.41	2.84	3.21	2.86	3.23	3.68	3.25	3.60	3.97

Note

Costs per sheep-fed are underlined for lowest cost policy of those tabulated for each demand level.

Table 3.5

Average cost per sheep-fed, wheat price $60 per ton, 2-pool model, opportunity cost 10%, New South Wales, 1936-65.

			4			8			12		=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL[1]
						DOLLARS					
0.17	0	1.32	2.01	2.69	2.01	2.69	3.38	2.69	3.38	4.06	
	0.17	1.39	2.05	2.72	2.03	2.69	3.37	2.69	3.35	na	
	0.33	1.59	2.22	2.87	2.16	2.79	3.43	2.79	3.42	na	
	0.67	2.15	2.65	3.25	2.68	3.17	3.77	3.20	3.71	na	
0.33	0	1.27	1.96	2.64	1.96	2.64	3.33	2.64	3.33	4.02	
	0.17	1.43	2.08	2.74	2.00	2.66	3.34	2.64	3.32	na	
	0.33	1.63	2.26	2.90	2.16	2.78	3.42	2.76	3.40	4.05	
	0.67	2.19	2.69	3.28	2.71	3.21	3.80	3.23	3.72	4.32	
0.67	0	na	na	na	1.86	2.55	3.23	2.54	3.23	3.92	
	0.17	1.51	2.16	2.82	2.02	2.67	3.33	2.59	3.24	na	
	0.33	1.71	2.33	2.99	2.23	2.85	3.50	2.75	3.37	4.00	
	0.67	2.27	2.77	3.36	2.79	3.29	3.88	3.32	3.80	4.40	
1.00	0	na	na	na	na	na	na	2.46	3.14	3.83	
	0.17	na	na	na	na	na	na	na	na	na	
	0.33	na	na	3.07	na	na	3.58	na	3.44	4.10	
	0.67	na	na	3.44	na	na	3.95	na	3.88	4.48	

Note

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand level.

Table 3.6

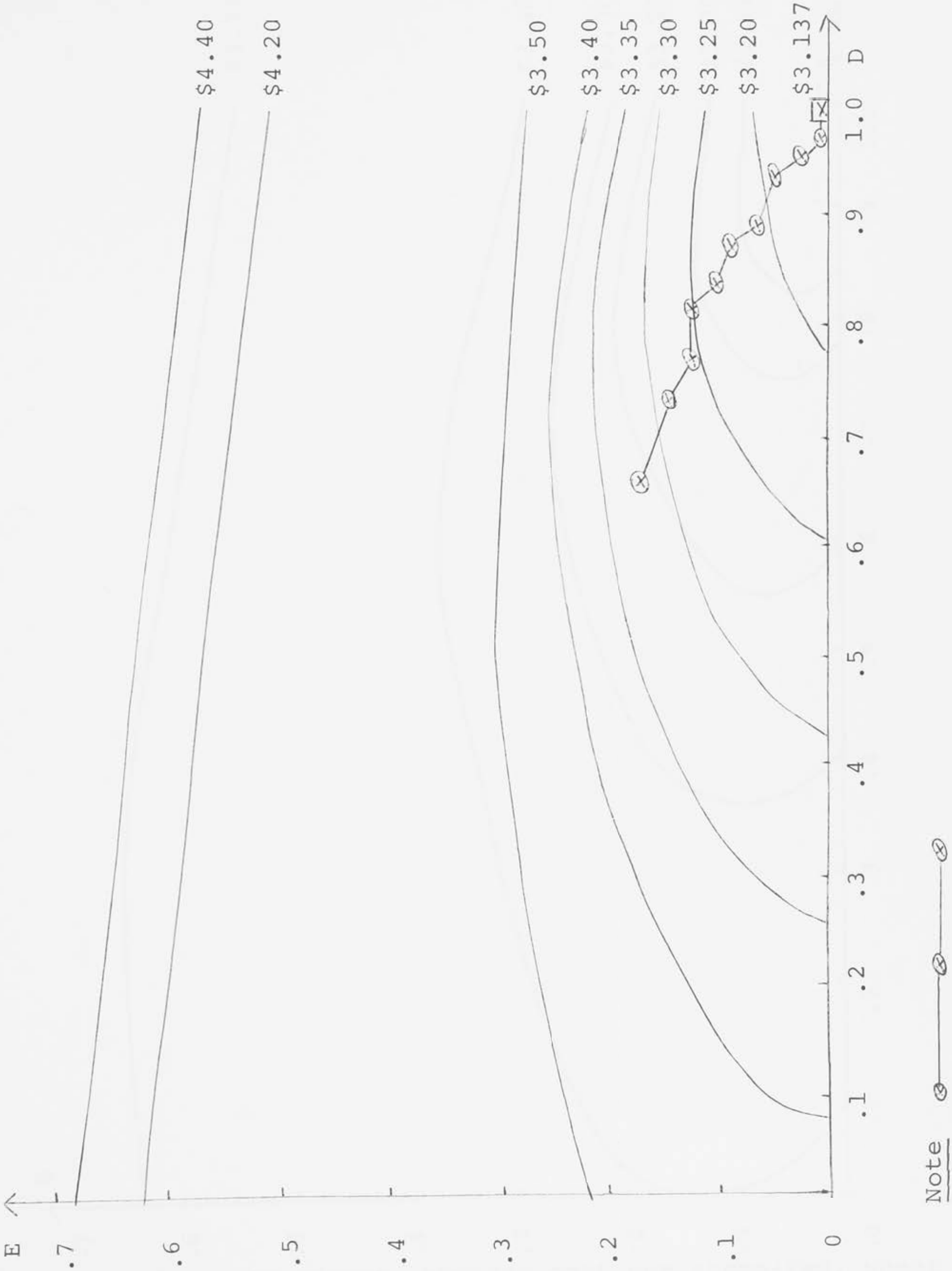
Average cost per sheep-fed, wheat price $45 per ton, 2-pool model, opportunity cost 10%, New South Wales 1936-65.

			4			8			12		=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL[1]
						DOLLARS					
0.17	0	1.05	1.60	2.16	1.60	2.16	2.71	2.16	2.71	3.26	
	0.17	1.07	1.60	2.13	1.58	2.12	2.65	2.10	2.64	na	
	0.33	1.21	1.71	2.23	1.66	2.17	2.67	2.15	2.66	na	
	0.67	1.64	2.03	2.50	2.05	2.43	2.89	2.44	2.85	na	
0.33	0	1.01	1.56	2.11	1.56	2.11	2.66	2.11	2.66	3.21	
	0.17	1.10	1.62	2.15	1.55	2.08	2.62	2.06	2.60	na	
	0.33	1.24	1.74	2.26	1.65	2.15	2.66	2.12	2.64	3.15	
	0.67	1.67	2.06	2.53	2.08	2.46	2.92	2.47	2.84	3.31	
0.67	0	na	na	na	1.45	2.00	2.55	2.00	2.55	3.10	
	0.17	1.16	1.68	2.22	1.55	2.08	2.61	1.99	2.52	na	
	0.33	1.31	1.80	2.33	1.71	2.21	2.72	2.10	2.59	3.10	
	0.67	1.74	2.12	2.59	2.14	2.52	2.98	2.54	2.91	3.38	
1.00	0	na	na	na	na	na	na	1.90	2.45	3.01	
	0.17	na	na	na	na	na	na	na	na	na	
	0.33	na	na	2.39	na	na	2.78	na	2.65	3.18	
	0.67	na	na	2.64	na	na	3.02	na	2.97	3.43	

Note

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Figure 3.3

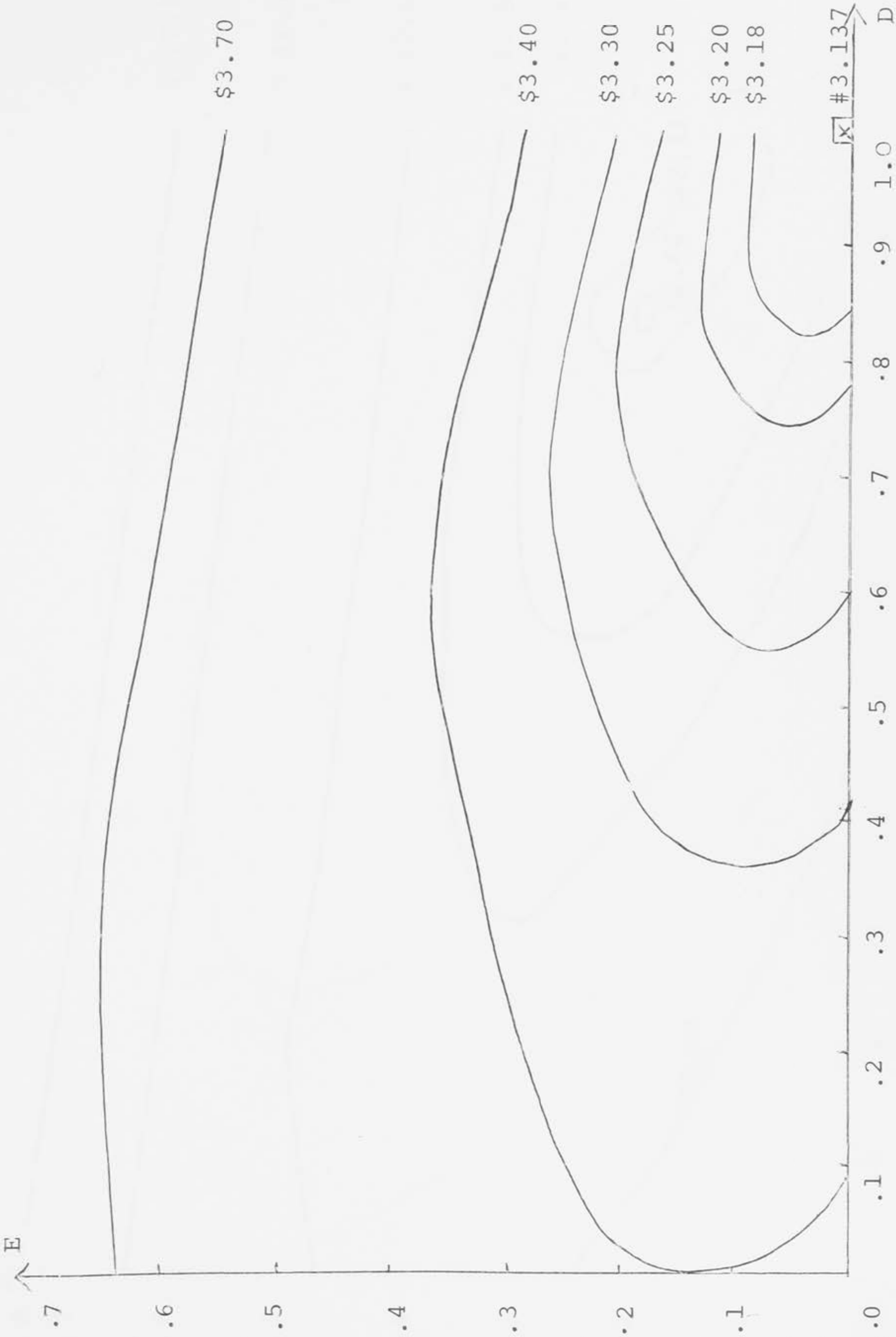


Represents the path traced by the "optimizing" program.

Iso-cost curves, average cost per sheep-fed, wheat price $60 per ton, 3 pool model, opportunity cost 10%, New South Wales, 1936-65.

ADL = 12, ADL^1 = 8.

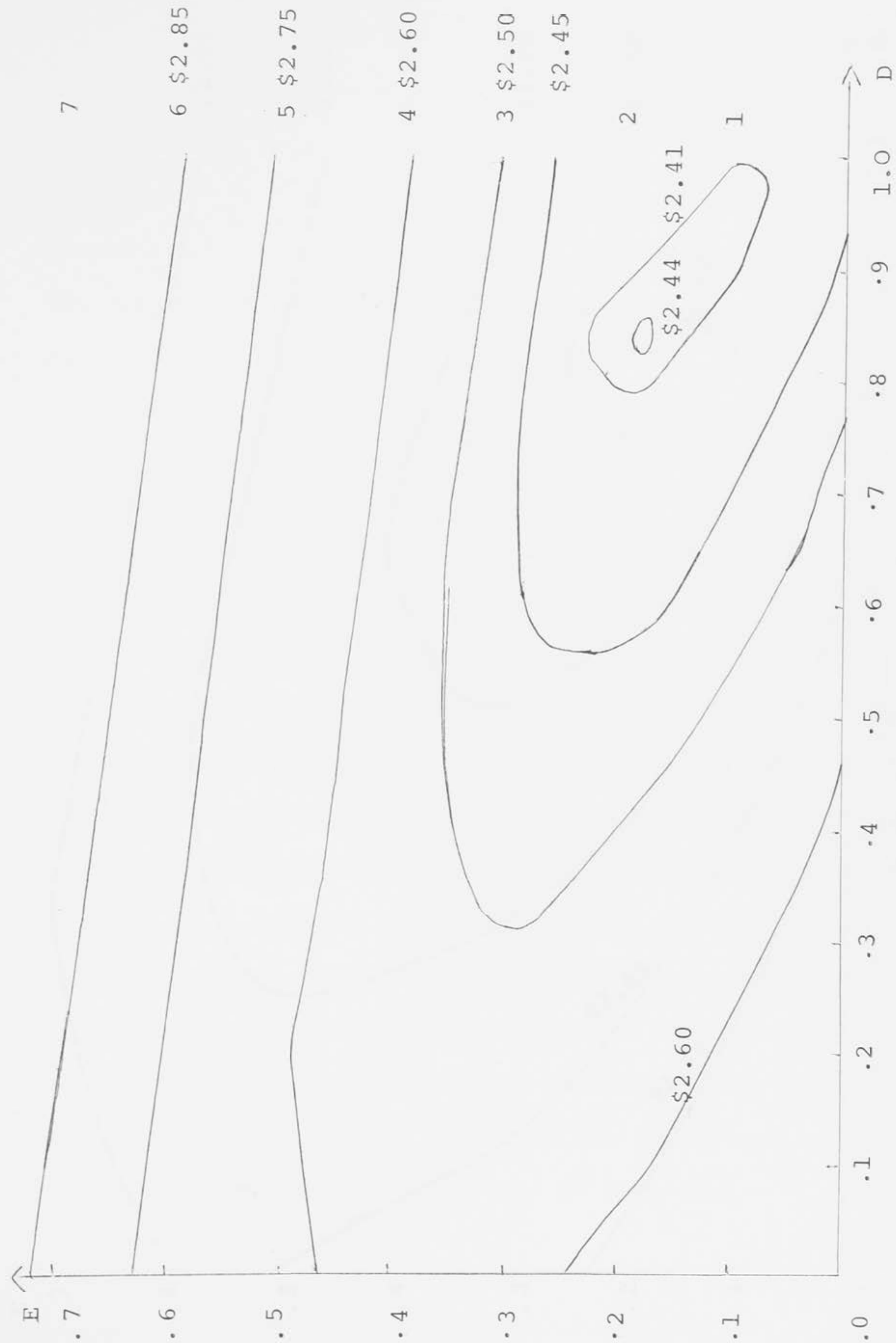
Figure 3.4



Iso-cost curves, average cost per sheep-fed, wheat price $60 per ton, 2 pool model, opportunity cost 10%, New South Wales, 1936-65.

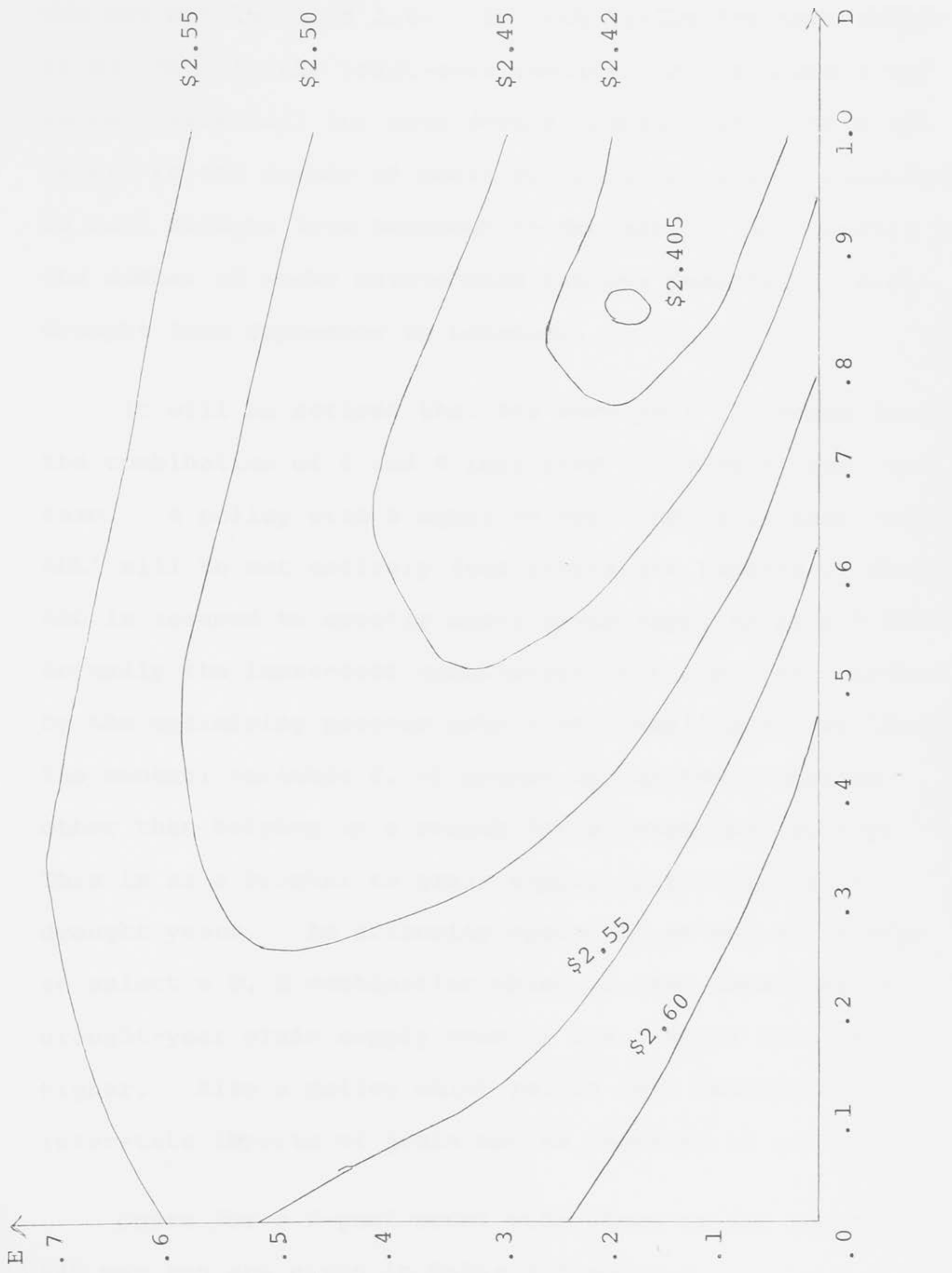
ADL = 12, ADL^1 = 8

Figure 3.5



Iso-cost curves, average cost per sheep-fed, wheat price $45 per ton, 3 pool model, opportunity cost 5%, New South Wales, 1936-65,
ADL = 12, ADL^1 = 8

Figure 3.6



Iso-cost curves, average cost per sheep-fed, wheat price \$45 per ton, 2 pool model, opportunity cost 5%, New South Wales, 1936-65.

$ADL = 12$, $ADL^1 = 8$

Similar calculations, but with wheat at $45 per ton, are set out in Table 3.4. In both tables the cost underlined identify the least-cost combinations of D and E (of those considered) for each demand combination. Here ADL refers to the number of weeks maintenance rations demanded in each drought from December to September; ADL' refers to the number of weeks maintenance rations demanded in each drought from September to December.

It will be noticed that for each pair of demand levels the combination of D and E indicated includes E equal to zero. A policy with E equal to zero indicates that demand ADL' will be met entirely from interstate imports if demand ADL is assumed to exactly equal grain supplied by D * NAS(I). Actually the least-cost combination of D and E as selected by the optimizing program puts E at a small positive level. The control variable E, of course has another function other than helping in a search for a least-cost policy. This is as a bolster to grain supply, particularly in drought years. An authority operating an NDR may prefer to select a D, E combination which is less demanding on drought-year grain supply even if the average cost is higher. Also a policy which relies less heavily on interstate imports of grain may be regarded as preferable.

Costs for a 2-pool model with wheat at $60 per ton and $45 per ton are given in Table 3.5 and 3.6.

Iso-cost curves were developed from costs of the type outlined in Tables 3.2, 3.3, 3.4 and 3.5, using additional values of D and E as required. These are set out in

Figures 3.3, 3.4, 3.5 and 3.6. All of these relate to a demand level of 8 weeks' full maintenance ration from September to December and 12 weeks' full maintenance ration from December to September. Figure 3.3 assumes a wheat price of $60 per ton and a three pool policy and Figure 3.4 a wheat price of $60 per ton and a 2-pool policy. In both Figure 3.3 and 3.4 the opportunity cost is allowed at 10%. Figures 3.5 and 3.6 represent a situation with lower storage costs. Here the price of wheat is taken at $45 per ton and opportunity cost allowed at 5%. Figure 3.5 is based on a 3-pool policy, and Figure 3.6 on a 2-pool policy.

With lower wheat price and opportunity cost the least-cost combination has a higher value of D and E. This is of course as would be expected. Also as might be expected a given D, E combination has a lower average cost if a 2-pool policy is followed rather than a 3-pool policy, due to the lower storage costs. (However due to the extra grain which tends to be on hand there is less risk of stockouts with the 3-pool policy).

The iso-cost curves shown indicate the possibility of choice between strategies. Except for the optimal combination of D and E a range of combinations of D and E exist which lead to the same average cost per sheep. Different D, E combinations would however tend to have different characteristics relative to grain intake, storage and stockouts.

For the "2 control variable" case the grain intake requirement for any value of NAS(I) is easily calculated from (3.5)

$$GI = D * NAS(I) + E * MNAS \qquad (3.5)$$

For given values of D, E and MNAS equation (3.5) represents a straight line relating GI to NAS(I). Hence if a particular D, E policy were under consideration its grain intake characteristics can be readily determined. In particular the peak grain intake will occur when the NAS(I) is a maximum, that is, when there is a "large" drought, which may seem a debilitating characteristic of the model. However the crucial question is what this level of grain intake is as compared with likely grain supply in such a year. Also, although the largest grain intake requirement will take place in the largest drought, the level of this peak is subject to control in the D, E combinations. If selection of D, E combinations fail to meet overall requirements regarding costs, grain intake, storage and stockouts there is the possibility of considering extra control variables, for example a specifically set upper limit on grain held.

For a selected combination of D and E, grain intake using the formula of equation (3.5) is independent of demand per sheep for NDR grain. In the particular system being studied storage requirements, unlike grain intake, are correlated with past occurrences in the system. They are affected by past flows of grain both into and out of the system. The system causes storage requirements, unlike grain intake requirements, to be dependent on present and past levels of demand per sheep on NDR grain.

Table 3.7

Peak Storage Requirements

3 pool model, New South Wales, 1936-65.

ADL = 12, ADL^1 = 8[a]

Thousand Bushels

		D			
		0.17	0.33	0.67	1.00
	0	6,530	12,675	25,735	38,410
	0.17	19,527	19,845	32,264	44,940
E	0.33	37,964	38,282	43,982	59,528
	0.67	77,142	77,460	91,803	106,871

ADL[a] and ADL^1 run at constant levels in the series of droughts. Subsequently tested further by selecting demand per sheep stochastically around ADL = 12 and ADL^1 = 8 for D = 0.67, E = 0.33.

Table 3.8

Peak Storage Requirements

3 pool model, New South Wales, 1936-65

ADL = 4, ADL[1] = 4[(a)]

Thousand Bushels

		D			
		0.17	0.33	0.67	1.00
	0	6,530	12,675	na	na
	0.17	19,727	22,332	38,349	53,895
E	0.33	43,221	50,397	65,646	80,447
	0.67	83,717	89,905	104,825	119,625

ADL[(a)] and ADL[1] run at constant levels in the series of droughts.

In order to see what level of storage would be required by the application of 2 control variable NDR's, tables were drawn up relating various D, E levels per sheep. Tables 3.7 and 3.8 give within-State peak storage requirements in New South Wales for various D, E combinations for demand levels of (12, 8) and (4, 4)[25], selected to represent high and low levels of demand per sheep.

Data for these tables were readily obtainable from computer output using the series of sheep numbers in droughts from 1936-1965 based on 1964 sheep numbers. Because of auto-correlation through time which would influence storage capacity requirements in this system a number of runs were carried out with the series of sheep numbers as before, but with demand per sheep selected stochastically round expected values of (12, 8). Probability distributions with a relatively wide range were selected in order to test the results obtained from the assumed static demands per sheep.[26] A grain intake combination was chosen where D = 0.67 bushels per sheep and E = 0.33 bushels per sheep. The range of peak storage requirements during the 10 runs of 30 years varied from 40.5 million bushels to 50.4 million bushels. This

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(25) Where the first element in the vectors represent the number of weeks' full maintenance ration per sheep after grain intake, and the second element the number of weeks full maintenance ration before grain intake.

(26) Demands were selected stochastically from two symmetrical triangular distributions ranging from 4 to 20 with a mean of 12, and from 4 to 12 with a mean of 8.

compared with the peak storage requirement over one 30 year run for a constant demand per sheep of (12, 8) of 43 million bushels.

Similar stochastic runs have not been carried out with regard to other cells in Tables 3.7 and 3.8. However the a priori implication seems to be that given the variety of possible D, E combinations and the general order of peak storage requirements compared with official storage capacity in New South Wales of approximately 200 million bushels,(27) it should be possible to select policies which are feasible in terms of storage.

3.2.6 Details of Empirical Analysis - Victoria(28)

As for New South Wales the 30 year series of adult sheep in droughts in Victoria is given in Table 3.2. Parameters used for Victoria were a within-State transport cost from official silo areas to drought areas of $2 per ton; opportunity cost of 10% per year on the value of wheat held in the NDR; physical storage cost of 40 cents per ton per year; prices of wheat of $60 and $45 per ton; interstate transport cost of $13 per ton. The latter was an average of the estimated transport cost between Victoria

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(27) There is the question of type of storage and the length of time the grain is to be stored. However this also does not seem likely to prove a debilitating factor, and there is the possibility of the 2-pool system which is less demanding on type of storage because of the shorter period the grain is held.

(28) Some New South Wales shires were included in the Victorian NDR system. For reasons and details see Appendix VI.

and New South Wales of $15 per ton of wheat and between Victoria and South Australia of $11 per ton.

Table 3.9

Average cost per sheep-fed, wheat price $60 per ton, 3 pool model, opportunity cost 10%, Victoria, 1936-65.

			4			8			12	=ADL
D	E	4	8	12	4	8	12	4	8	12=ADL[1]
					DOLLARS					
0.17	0	1.26	1.91	2.57	1.91	2.57	3.21	2.57	3.21	3.87
	0.17	1.60	2.18	2.80	2.17	2.78	3.41	2.80	3.42	na
	0.33	2.16	2.62	3.16	2.64	3.14	3.71	3.16	3.72	na
	0.67	3.26	3.76	4.25	3.78	4.27	4.76	4.30	4.78	na
0.33	0	1.23	1.88	2.53	1.88	2.53	3.19	2.53	3.19	3.84
	0.17	1.65	2.21	2.83	2.16	2.77	3.39	2.77	3.40	na
	0.33	2.21	2.67	3.20	2.70	3.15	3.72	3.18	3.72	4.31
	0.67	3.32	3.81	4.30	3.84	4.33	4.82	4.36	4.85	5.28
0.67	0	1.29	1.94	2.59	1.80	2.45	3.10	2.45	3.10	3.75
	0.17	1.79	2.28	2.89	2.23	2.91	3.41	2.74	3.35	na
	0.33	2.33	2.81	3.28	2.84	3.26	3.80	3.28	3.74	4.31
	0.67	3.44	3.93	4.43	3.96	4.45	4.95	4.48	4.98	5.41
1.00	0	1.37	1.99	2.65	1.86	2.51	3.16	2.38	3.03	3.69
	0.17	1.91	2.38	2.94	2.37	2.86	3.47	2.81	3.38	3.99
	0.33	2.45	2.93	3.40	2.96	3.39	3.87	3.42	3.84	4.38
	0.67	3.55	4.05	4.54	4.08	4.57	5.07	4.60	5.10	5.55

Note

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.10

Average cost per sheep-fed, wheat price $45 per ton, 3 pool model, opportunity cost 10%, Victoria, 1936-65.

		4			8			12			=ADL
D	E	4	8	12	4	8	12	4	8	12	$=ADL^1$
						DOLLARS					
0.17	0	0.99	1.51	2.03	1.51	2.03	2.54	2.03	2.54	3.07	
	0.17	1.22	1.68	2.17	1.67	2.15	1.65	2.17	2.65	na	
	0.33	1.65	1.99	2.43	2.01	2.40	2.85	2.41	2.85	na	
	0.67	2.49	2.87	3.25	2.89	3.26	3.63	3.29	3.65	na	
0.33	0	0.96	1.48	2.00	1.48	2.00	2.52	2.00	2.52	3.04	
	0.17	1.25	1.69	2.18	1.65	2.14	2.62	2.14	2.62	na	
	0.33	1.69	2.04	2.44	2.06	2.30	2.85	2.42	2.85	3.31	
	0.67	2.54	2.91	3.29	2.94	3.31	3.68	3.33	3.70	4.03	
0.67	0	0.99	1.50	2.02	1.39	1.90	2.42	1.90	2.42	2.94	
	0.17	1.36	1.74	2.22	1.70	2.22	2.62	2.09	2.57	na	
	0.33	1.78	2.14	2.50	2.17	2.49	2.90	2.50	2.86	3.29	
	0.67	2.63	3.00	3.39	3.03	3.40	3.78	3.42	3.80	4.13	
1.00	0	1.07	1.54	2.06	1.43	1.95	2.46	1.83	2.35	2.87	
	0.17	1.45	1.82	2.25	1.81	2.18	2.66	2.14	2.57	3.07	
	0.33	1.87	2.24	2.59	2.26	2.59	2.95	2.61	2.92	3.34	
	0.67	2.71	3.10	3.47	3.12	3.49	3.87	3.52	3.89	4.23	

Note

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.11

Peak Storage Requirements

3 pool model, Victoria, 1936-65

$ADL = 12$, $ADL^1 = 8$ [(a)]

Thousand Bushels

		D 0.17	0.33	0.67	1.00
	0	3,793	7,363	14,950	22,313
E	0.17	11,623	11,914	18,743	26,106
	0.33	22,333	22,624	23,433	31,969
	0.67	45,092	45,383	56,133	69,018

ADL [(a)] and ADL^1 run at constant levels in the series of droughts. Subsequently tested further by selecting demand per sheep stochastically around $ADL = 12$ and $ADL^1 = 8$ for $D = 0.67$, $E = 0.33$.

Simulations were carried out for Victoria using the 3-pool, 2 control variable system only. Costs per sheep-fed were obtained using constant demands per sheep and given in Tables 3.9 and 3.10, for wheat prices of $60 and $45 per ton.

Costs in these tables for Victoria are of the same "general order" as for New South Wales in spite of the different sequence of sheep numbers in droughts. Policies involving E at zero level are consistently lower in Victoria. In these policies grain is put into NDR only when there is a declared drought and so there is less carryover. In this case the lower costs in Victoria are at least partially caused by the lower within-State transportation costs. Cells in the table associated with policies with positive levels of both D and E are sometimes lower in Victoria and sometimes higher.

Peak storage requirements observed in a 30 year run for Victoria with different D, E combinations and various levels of NDR demand per sheep are given in Table 3.11. As a "test" of the peak storage requirements observed where demand per sheep was taken to be constant through the 30 years, ten stochastic runs were made with probability distributions centred around demands of (12, 8) for D = 0.67 bushels per sheep and E = 0.33 bushels per sheep. The range of peak storage requirements over the 30 years varied from 23.8 million bushels to 31.2 million bushels. This compared with the peak storage requirement, estimated by using constant demands of (12,8), D = 0.67 and E = 0.33, of 23.4 million bushels. The crude estimates of peak storage capacity given by assuming constant demands per sheep through a 30 year run is perhaps justified when official storage available in Victoria is capable of long-term storage amounts to over 100 million bushels.

3.2.7 Details of Empirical Analysis - South Australia.

The relevant series of sheep numbers in droughts once again is given in Table 3.2. Parameters used for South Australia were a within-State transportation cost of wheat transported from silos to droughts of $1.50 per ton; opportunity cost of 10% per year on the value of wheat held in the NDR; physical storage cost of 40 cents per ton per year; interstate transport cost of $15 per ton, being an average of $11 per ton from Victoria to South Australia and $19 per ton from New South Wales to South Australia.

Simulation runs were carried out for South Australia with a 3-pool, 2 control variable system and with various levels of demand per sheep taken as constant through a 30 year run. Average costs per sheep-fed are given in Table 3.12 for various combinations of D and E and of demand per sheep, where the price of wheat is $60 per ton. Comparing the costs in Table 3.12 with costs in Table 3.3 it appears that costs per sheep-fed are lower in South Australia than in New South Wales for zero levels of E but for any given level of D tend to become higher than in New South Wales as E is increased. With significant tests these are only prima facie conclusions, however the important point of comparison is perhaps that if low-cost policies can feasibly be chosen in each State, the cost per sheep-fed over a given number of weeks is similar in South Australia to New South Wales. For example, if demand per sheep is 8 weeks in the period after grain intake and 4 weeks in the period before grain intake and a policy with D = 0.67 and E = 0.17 is used, the estimated cost per sheep-fed is $2.17 in New South Wales and $2.22 in South Australia. Costs corresponding to those of Table 3.12 but with a wheat price of $45 per ton are given in Table 3.13.

Peak storage requirements for a demand level of (12,8) and various grain input policies are given in Table 3.14. A series of 10 runs with demand chosen stochastically round expected levels of 12 weeks after grain intake, and 8 weeks before grain intake, and a grain input policy with D = 0.67 and E = 0.33 lead to a range of peak storage requirements varying from 9.6 million bushels to 13 million bushels. This compares with the peak storage requirement when demand per sheep is static at (12,8) and the same grain input policy is used, of 10.4 million bushels. The bulk storage available which is suitable for long-term storage is about 85 million bushels.

Table 3.12

Average cost per sheep-fed, wheat price $60 per ton, 3 pool model, opportunity cost 10%, South Australia, 1936-65.

		4			8			12			=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL[1]
					DOLLARS						
0.17	0	1.29	1.96	2.62	1.96	2.62	3.29	2.62	3.29	3.96	
	0.17	1.54	2.09	2.73	2.08	2.70	3.34	2.71	3.34	na	
	0.33	2.05	2.52	3.03	2.55	2.99	3.55	3.00	3.55	na	
	0.67	3.04	3.53	4.03	3.56	4.06	4.53	4.09	4.56	na	
0.33	0	1.24	1.90	2.57	1.90	2.57	3.24	2.57	3.24	3.91	
	0.17	1.62	2.13	2.76	2.08	2.67	3.31	2.68	3.31	na	
	0.33	2.11	2.59	3.08	2.61	3.05	3.56	3.08	3.55	4.12	
	0.67	3.10	3.59	4.09	3.62	4.12	4.60	3.15	4.63	5.09	
0.67	0	1.30	1.94	2.60	1.80	2.47	3.15	2.47	3.14	3.81	
	0.17	1.76	2.25	2.83	2.22	2.72	3.32	2.66	3.24	na	
	0.33	2.23	2.72	3.19	2.75	3.21	3.66	3.24	3.67	4.15	
	0.67	3.22	3.72	4.22	3.75	4.25	4.74	4.28	4.77	5.23	
1.00	0	1.41	2.05	2.67	1.89	2.51	3.17	2.39	3.06	3.73	
	0.17	1.89	2.36	2.94	2.37	2.83	3.40	2.82	3.29	3.90	
	0.33	2.36	2.86	3.32	2.88	3.35	3.81	3.38	3.84	4.24	
	0.67	3.35	3.85	4.34	3.87	4.37	4.87	4.40	4.90	5.36	

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.13

Average cost per sheep-fed, wheat price $45 per ton, 3 pool model, opportunity cost 10%, South Australia, 1936-65.

			4			8			12	=ADL
D	E	4	8	12	4	8	12	4	8	12 = ADL[1]
						DOLLARS				
0.17	0	1.02	1.55	2.09	1.55	2.09	2.62	2.09	2.62	3.16
	0.17	1.17	1.60	2.10	1.59	2.09	2.59	2.09	2.59	na
	0.33	1.56	1.92	2.30	1.94	2.27	2.71	2.28	2.72	na
	0.67	2.32	2.69	3.07	2.72	3.09	3.45	3.11	3.47	na
0.33	0	0.97	1.51	2.04	1.51	2.04	2.58	2.04	2.58	3.11
	0.17	1.23	1.63	2.12	1.58	2.05	2.55	2.06	2.55	na
	0.33	1.61	1.97	2.35	1.99	2.31	2.72	2.34	2.70	3.15
	0.67	2.37	2.74	3.11	2.76	3.14	3.50	3.16	3.52	3.87
0.67	0	1.01	1.51	2.04	1.39	1.92	2.47	1.92	2.46	3.00
	0.17	1.34	1.72	2.17	1.69	2.07	2.55	2.03	2.48	na
	0.33	1.70	2.07	2.42	2.10	2.44	2.78	2.46	2.79	3.16
	0.67	2.46	2.84	3.21	2.86	3.24	3.61	3.26	3.63	3.98
1.00	0	1.08	1.58	2.07	1.44	1.94	2.47	1.84	2.37	2.91
	0.17	1.44	1.80	2.25	1.79	2.16	2.60	2.14	2.50	2.99
	0.33	1.80	2.18	2.51	2.18	2.54	2.89	2.57	2.92	3.21
	0.67	2.56	2.94	3.28	2.93	3.33	3.71	3.35	3.73	4.08

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.14

Peak Storage Requirements

3 pool model, South Australia, 1936-65

ADL = 12, ADL^1 = 8[a]

Thousand Bushels

		D			
		0.17	0.33	0.67	1.00
	0	1,409	2,735	5,553	8,288
	0.17	4,129	4,160	6,962	9,697
E	0.33	8,412	8,618	10,426	14,241
	0.67	16,865	17,767	21,713	26,510

ADL[a] and ADL^1 run at constant levels in the series of droughts. Subsequently tested further by selecting demand per sheep stochastically around ADL = 12 and ADL^1 = 8 for D = 0.67, E = 0.33.

3.2.8 Details of Empirical Analysis - Western Australia

The analysis of Western Australia was confined to the portion in the south of the State including all of Western Australia except the Divisions of Kimberley and Pilbara. This was larger than the area considered in the pilot study. The series of sheep numbers is included in Table 3.2. Parameters for Western Australia were a within-State transportation cost of wheat from silos to drought areas of $1.00 per ton;(29) opportunity cost of 10% per year on the value of wheat held in the NDR; physical storage cost of 40 cents per ton per year; interstate transportation cost of $23 per ton.

Costs per sheep for various combinations of grain input and demand per sheep are given in Table 3.15. Compared with New South Wales costs are lower in Western Australia where E equals zero. Again, costs are higher in Western Australia than in New South Wales for grain input policies which include positive levels of E. For values of E of 0.17 bushels per sheep or higher, costs

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(29) This is considerably lower than the figure used in the pilot study because of the different assumptions used to estimate transportation costs. Throughout the simulations grain is assumed to be transported only from the nearest "silo shire" to each drought shire. In the pilot study restriction on supply was assumed to force transportation from other than the nearest "silo shire". The assumption that grain was obtained only from the nearest "silo shire" seemed a reasonable first approximation when within-State transport cost is, in States other than Queensland, only a small fraction of the total cost. The effects of increasing transportation costs are included in subsequent sensitivity analysis.

estimated for Western Australia are higher than for South Australia, Victoria or New South Wales. Corresponding costs where the price of wheat is $45 per ton are given in Table 3.16.

Table 3.15
Average cost per sheep-fed, wheat price $60 per ton, 3 pool model, opportunity cost 10%, Western Australia, 1936-65.

			4			8			12		=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL[1]
					DOLLARS						
0.17	0	1.31	2.00	2.68	2.00	2.68	3.37	2.68	3.37	4.05	
	0.17	1.82	2.37	2.99	2.37	2.96	3.58	2.97	3.58	na	
	0.33	2.59	3.05	3.61	3.06	3.57	4.12	3.58	4.12	na	
	0.67	4.15	4.64	5.15	4.65	5.16	5.63	5.17	5.63	na	
0.33	0	1.25	1.94	2.62	1.94	2.62	3.31	2.62	3.31	4.00	
	0.17	1.89	2.43	3.05	2.39	2.95	3.58	2.95	3.56	na	
	0.33	2.65	3.12	3.67	3.13	3.59	4.14	3.60	4.14	4.69	
	0.67	4.21	4.71	5.21	4.72	5.23	5.69	5.23	5.70	6.16	
0.67	0	1.34	2.01	2.70	1.81	2.49	3.19	2.49	3.18	3.87	
	0.17	2.02	2.55	3.18	2.48	3.02	3.65	2.98	3.53	na	
	0.33	2.78	3.25	3.80	3.26	3.73	4.27	3.74	4.19	4.73	
	0.67	4.34	4.84	5.34	4.85	5.35	5.82	5.36	5.83	6.30	
1.00	0	1.45	2.11	2.77	1.90	2.57	3.25	2.39	3.07	3.76	
	0.17	2.15	2.69	3.30	2.61	3.15	3.77	3.08	3.61	4.22	
	0.33	2.91	3.38	3.91	3.39	3.86	4.38	3.87	4.32	4.84	
	0.67	4.47	4.97	5.47	4.97	5.48	5.95	5.49	5.96	6.43	

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.16

Average cost per sheep-fed, wheat price $45 per ton, 3 pool model, opportunity cost 10%, Western Australia, 1936-65.

			4			8			12		=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL^{1}
						DOLLARS					
0.17	0	1.12	1.72	2.32	1.72	2.32	2.92	2.32	2.92	3.52	
	0.17	1.38	1.84	2.36	1.83	2.33	2.86	2.33	2.85	na	
	0.33	1.94	2.33	2.80	2.33	2.74	3.19	2.74	3.18	na	
	0.67	3.17	3.55	3.94	2.55	3.94	4.29	3.94	4.30	na	
0.33	0	1.04	1.64	2.24	1.64	2.24	2.84	2.24	2.84	3.45	
	0.17	1.44	1.89	2.41	1.83	2.29	2.83	2.29	2.81	na	
	0.33	2.02	2.38	2.84	2.38	2.74	3.18	2.73	3.19	3.63	
	0.67	3.22	3.60	3.99	3.61	3.99	4.34	3.99	4.35	4.70	
0.67	0	1.08	1.66	2.27	1.45	2.05	2.65	2.05	2.65	3.25	
	0.17	1.54	1.98	2.51	1.89	2.34	2.85	2.27	2.73	na	
	0.33	2.12	2.48	2.92	2.48	2.75	3.28	2.84	3.19	3.62	
	0.67	2.32	3.70	4.09	3.71	4.09	4.44	4.09	4.45	4.80	
1.00	0	1.16	1.72	2.31	1.49	2.09	2.69	1.88	2.48	3.09	
	0.17	1.64	2.07	2.60	1.99	2.42	2.95	2.33	2.77	3.28	
	0.33	2.22	2.58	3.01	2.85	2.95	3.36	2.94	3.29	3.71	
	0.67	3.42	3.80	4.18	3.80	4.19	4.54	4.19	4.55	4.90	

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.17.

Number of sheep which would have been in first decile droughts in North and South Queensland, based on sheep numbers and distribution as at 31st March, 1964.

1936-65

Drought[(a)] Year	South Q'ld	North Q'ld	Drought[(a)] Year	South Q'ld	North Q'ld
	,000			,000	
1936	-	-	1951	1,804	185
37	557	-	52	-	2,918
38	518	104	53	-	-
39	-	-	54	-	-
40	811	-	55	-	-
1941	-	-	1956	-	-
42	-	-	57	5,119	100
43	-	-	58	-	-
44	3,991	-	59	208	364
45	-	-	60	18	-
1946	5,443	622	1961	-	2,441
47	-	-	62	-	-
48	-	1,698	63	-	213
49	-	-	64	-	-
50	-	-	65	1,928	3,231

(a) First decile droughts in calendar years as identified by Gibbs and Maher.

3.2.9 Details of Empirical Analysis - Queensland[30]

The series of sheep numbers of sheep in first decile droughts in Queensland as a whole are given in Table 3.2. The series of sheep numbers in first decile droughts in the area assumed to be served from central Queensland silos and in the area assumed to be served from south Queensland silos are given in Table 3.17.

Wheat and sorghum prices in the Queensland simulations were both taken at $45 per ton. Transportation costs associated with stockouts in the "north Queensland system" from Brisbane to the drought area were taken as $0.45 per bushel plus $0.4010 per bushel. This is the estimated cost of $0.45 per bushel to transport wheat from Brisbane to silo areas in central Queensland plus an average cost of $0.4010 per bushel to transport wheat from silo areas in central Queensland to drought areas. Transportation costs associated with transport of grain from interstate to drought areas in the "south Queensland system" were taken at $0.45 per bushel. An opportunity cost of 10% and storage cost of 40 cents per ton-year were allowed as in the other States. Intrastate transportation costs for both Queensland areas were estimated for each brought and fed into the simulations accordingly.

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(30) Discussion in this section is confined to systems which combine sorghum and wheat. Interstate imports are confined to wheat only.

Table 3.18

Average cost per sheep-fed, 3 pool model, wheat only, wheat price \$45 per ton, opportunity cost 10%, "North" Queensland, 1936-65.

			4			8			12		=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL[1]
0.17	0	1.29	1.98	2.66	1.98	2.66	3.35	2.66	3.35	4.03	
	0.17	1.36	1.95	2.60	1.95	2.58	3.23	2.58	3.23	na	
	0.33	1.68	2.17	2.75	2.19	2.70	3.28	2.71	3.29	na	
	0.67	2.32	2.83	3.32	2.85	3.34	3.84	3.37	3.86	na	
0.33	0	1.22	1.91	2.59	1.91	2.59	3.28	2.59	3.28	3.96	
	0.17	1.39	1.98	2.62	1.91	2.51	3.17	2.52	3.17	na	
	0.33	1.71	2.20	2.78	2.22	2.69	3.26	2.71	3.26	3.87	
	0.67	2.35	2.86	3.35	2.88	3.37	3.87	3.40	3.89	4.37	
0.67	0	1.25	1.94	2.63	1.76	2.45	3.13	2.45	3.14	3.82	
	0.17	1.46	2.02	2.66	1.95	2.52	3.15	2.46	3.06	na	
	0.33	1.77	2.27	2.82	2.29	2.76	3.32	2.78	3.26	3.80	
	0.67	2.41	2.92	3.42	2.94	3.44	3.94	3.46	3.96	4.44	
1.00	0	1.30	1.98	2.67	1.80	2.49	3.17	2.32	3.00	3.69	
	0.17	1.52	2.08	2.70	2.02	2.57	3.18	2.51	3.06	3.68	
	0.33	1.84	2.33	2.88	2.36	2.82	3.39	2.85	3.33	3.86	
	0.67	2.48	2.99	3.48	3.01	3.51	4.01	3.52	4.02	4.50	

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.19

Average cost per sheep-fed, 3 pool model, wheat only, wheat price $45 per ton, opportunity cost 10%, "South" Queensland, 1936-65.

		4			8			12			=ADL
D	E	4	8	12	4	8	12	4	8	12	=ADL[1]
						DOLLARS					
0.17	0	1.13	1.60	2.16	1.60	2.16	2.71	2.16	2.71	3.26	
	0.17	1.15	1.66	2.17	1.65	2.16	2.69	2.17	2.69	na	
	0.33	1.48	1.85	2.34	1.87	2.30	2.79	2.31	2.80	na	
	0.67	2.10	2.51	2.92	2.53	2.94	3.32	2.96	3.34	na	
0.33	0	1.00	1.55	2.10	1.55	2.10	2.65	2.10	2.65	3.20	
	0.17	1.19	1.68	2.20	1.62	2.13	2.65	2.14	2.66	na	
	0.33	1.52	1.89	2.38	1.92	2.29	2.78	2.31	2.77	3.30	
	0.67	2.14	2.55	2.96	2.57	2.98	3.36	3.00	3.39	3.75	
0.67	0	1.06	1.60	2.16	1.45	2.00	2.55	2.00	2.55	3.10	
	0.17	1.28	1.74	2.25	1.65	2.14	2.66	2.07	2.59	na	
	0.33	1.60	1.98	2.43	2.00	2.36	2.83	2.38	2.73	3.23	
	0.67	2.22	2.63	3.04	2.65	3.06	3.45	3.08	3.47	3.84	
1.00	0	1.12	1.65	2.20	1.50	2.05	2.60	1.90	2.45	3.01	
	0.17	1.36	1.80	2.31	1.74	2.18	2.71	2.10	2.59	3.11	
	0.33	1.68	2.06	2.50	2.08	2.45	2.88	2.47	2.82	3.29	
	0.67	2.30	2.71	3.12	2.73	3.15	3.53	3.16	3.56	3.93	

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.20

Average cost per sheep-fed, wheat price $45 per ton, sorghum price $45 per ton, model allowing 2 pools of wheat and 1 pool of sorghum, opportunity cost 10%, "North" Queensland, 1936-65.

				4			8			12 =ADL	
DW	EW	DS	4	8	12	4	8	12	4	8	12 =ADL[1]
						DOLLARS					
0.17	0.17	0.33	1.26	1.82	2.47	1.82	2.45	3.11	2.47	3.11	3.77
		0.67	1.31	1.83	2.39	1.81	2.36	3.01	2.36	3.00	3.66
		1.00	1.35	1.88	2.40	1.85	2.38	2.93	2.35	2.91	3.56
	0.33	0.33	1.43	1.95	2.51	1.93	2.48	3.11	2.55	3.11	3.76
		0.67	1.48	2.00	2.52	1.98	2.50	3.05	2.48	3.03	3.66
		1.00	1.52	2.04	2.57	2.02	2.55	3.07	2.52	3.05	3.60
0.33	0.17	0.33	1.28	1.79	2.41	1.83	2.40	3.06	2.49	3.05	3.71
		0.67	1.32	1.85	2.36	1.82	2.34	2.96	2.37	2.94	3.60
		1.00	1.37	1.89	2.41	1.87	2.39	2.91	2.37	2.89	3.50
	0.33	0.33	1.45	1.97	2.49	1.95	2.47	3.07	2.56	3.08	3.70
		0.67	1.49	2.01	2.54	1.99	2.51	3.03	2.49	3.01	3.62
		1.00	1.53	2.06	2.58	2.04	2.56	3.08	2.54	3.06	3.58
0.67	0.17	0.33	1.31	1.83	2.34	1.86	2.37	2.94	2.51	3.03	3.60
		0.67	1.35	1.88	2.39	1.85	2.37	2.89	2.40	2.92	3.48
		1.00	1.40	1.92	2.44	1.90	2.42	2.94	2.40	2.92	3.44
	0.33	0.33	1.48	2.00	2.52	1.98	2.50	3.01	2.59	3.11	3.62
		0.67	1.52	2.05	2.57	2.02	2.54	3.06	2.52	3.04	3.56
		1.00	1.56	2.09	2.61	2.07	2.59	3.11	2.57	3.09	3.61

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.21

Average cost per sheep-fed, wheat price $45 per ton, sorghum price $45 per ton, model allowing 2 pools of wheat and 1 pool of sorghum, opportunity cost 10%, "South" Queensland, 1936-65.

				4			8			12	=ADL
DW	EW	DS	4	8	12	4	8	12	4	8	12 =ADL[1]
						DOLLARS					
0.17	0.17	0.33	1.08	1.54	2.06	1.53	2.05	2.59	2.06	2.58	3.13
		0.67	1.12	1.55	2.01	1.53	1.99	2.52	1.99	2.50	3.04
		1.00	1.17	1.60	2.03	1.58	2.01	2.47	1.99	2.45	2.97
	0.33	0.33	1.24	1.67	2.12	1.65	2.11	2.63	2.16	2.62	3.15
		0.67	1.29	1.72	2.15	1.70	2.13	2.58	2.11	2.56	3.08
		1.00	1.33	1.76	2.20	1.74	2.18	2.60	2.15	2.58	3.04
0.33	0.17	0.33	1.09	1.52	2.03	1.55	2.02	2.54	2.08	2.55	3.09
		0.67	1.14	1.57	2.00	1.55	1.97	2.49	2.00	2.47	3.00
		1.00	1.18	1.62	2.05	1.59	2.02	2.45	2.00	2.43	2.94
	0.33	0.33	1.26	1.69	2.11	1.67	2.09	2.60	2.17	2.60	3.12
		0.67	1.30	1.74	2.16	1.72	2.14	2.57	2.12	2.55	3.05
		1.00	1.35	1.78	2.21	1.76	2.19	2.62	2.17	2.60	3.02
0.67	0.17	0.33	1.13	1.55	1.98	1.58	2.01	2.47	2.11	2.54	3.00
		0.67	1.17	1.60	2.03	1.58	2.01	2.43	2.03	2.46	2.93
		1.00	1.12	1.65	2.08	1.63	2.06	2.48	2.04	2.46	2.89
	0.33	0.33	1.29	1.72	2.15	1.70	2.12	2.55	2.21	2.63	3.06
		0.67	1.34	1.77	2.20	1.75	2.18	2.60	2.15	2.58	3.00
		1.00	1.38	1.81	2.25	1.79	2.23	2.65	2.20	2.63	3.06

Note:

Costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Average costs per sheep-fed in the system using wheat only are given in Table 3.18 for "northern Queensland" and Table 3.19 for "southern Queensland". Because the more relevant system is probably the one including sorghum, analysis of stockouts and storage requirements is not given for the system based on wheat only.

Average costs per sheep-fed in the system using both sorghum and wheat are given in Table 3.20 for "northern Queensland" and Table 3.21 for "southern Queensland".

A direct comparison between costs in Queensland and those in New South Wales cannot be made because of the difference between the systems simulated. However in spite of the increased transport costs included in the Queensland system the cost per sheep-fed in the Queensland sorghum-wheat system which was simulated compares quite well with that of the different system simulated in New South Wales.[31]

3.2.10 Sensitivity Analysis

While planning the simulation models attention was given to constructing models which would allow sensitivity analysis to be carried out simply. The models have in general been constructed to simplify estimation of the

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(31) The use of a combination of winter grain with a summer grain as compared with one grain only would allow some extra scope for cost reduction. Other things being equal, this would allow reduction in the length of time grain needs to be held in the NDR, because suitable crops are harvested twice a year instead of only once a year. This could apply to any State where suitable crops were available.

the effects on average costs per sheep-fed of changes in price parameters. In most of the models the average cost of feed per sheep-fed, with wheat at $45 per ton was obtainable from the average cost per sheep-fed for wheat at $60 per ton, for given grain input-demand combinations. This avoided the need for computer re-runs to make estimates at the different prices. This did not apply to Queensland systems with their between-year variations in transportation costs.

In order to facilitate sensitivity analysis and presentation of the results over the large number of combinations of grain input and demand which were considered, the total cost has been split into two components only - the cost of feed and "other costs". "Other costs" include opportunity cost, the physical storage cost, within-State transportation cost, and between-State transportation cost.

The sensitivity analysis has been confined to New South Wales and Queensland but is readily applicable to the other States. Table 3.4 presents average cost per sheep-fed in New South Wales using a 3-pool system and with wheat valued at $45 per ton. Each column in Table 3.4 represents the same demand per sheep. This demand is always met in the model either from the NDR grain held within the State or from imported grain. So the quantity supplied and fed is assumed equal to the quantity demanded. The figures in each column are equal to the cost of the feed demanded, which is constant down the column, plus other costs. The cost of feed associated with each column is readily calculated from the number of weeks feed (at 5lb. per week) and the price of the grain.

Elimination of the cost of feed from Table 3.4 gives costs other than feed. A split-up of the costs of Table 3.4 into feed costs and non-feed costs is given in Table 3.23.

The fact that at a given wheat price the cost of feed is fixed for a given demand level means that minimum cost policies are less sensitive than others to a given percentage variation in non-feed costs. For example, if the policy D = 0.67 and E = 0.17 is used where demand per sheep is (8, 12), that is 8 weeks after grain intake and 12 weeks before grain intake, costs other than direct feed costs are $\$\frac{0.65}{20}$ per sheep per week. To increase costs by one cent per sheep-week non-feed costs would need to increase from 65 cents to 85 cents which is an increase of about 31%.

Tables 3.22, 3.24, 3.25, 3.26 and 3.27 give a similar split-up of costs given originally in earlier Tables. In general where lower cost policies are considered a considerable margin for error in non-feed costs can be allowed before there is a substantial change in costs per sheep-week. This also holds in States other than New South Wales and Queensland.

A feature of the NDR simulations which is obviously fairly arbitrary is the timing of the declaration of droughts.

Table 3.22

Average cost per sheep-fed, wheat price $60 per ton, 3 pool model, opportunity cost 10%, New South Wales, 1936-65. Costs are divided into cost of wheat and other ("non-feed") costs.

		4			8			12			=ADL
		4	8	12	4	8	12	4	8	12	=ADL[1]
		DOLLARS									
Wheat Cost		1.07	1.61	2.14	1.61	2.14	2.68	2.14	2.68	3.21	
D	E										
0.17	0	0.25	0.40	0.55	0.40	0.55	0.70	0.55	0.70	0.85	
	0.17	0.44	0.51	0.65	0.50	0.62	0.77	0.63	0.75	na	
	0.33	0.91	0.83	0.87	0.86	0.83	0.89	0.86	0.90	na	
	0.67	1.85	1.80	1.76	1.83	1.79	1.71	1.82	1.74	na	
0.33	0	0.20	0.35	0.50	0.35	0.50	0.65	0.50	0.65	0.81	
	0.17	0.49	0.56	0.69	0.47	0.59	0.72	0.59	0.71	na	
	0.33	0.96	0.89	0.93	0.92	0.85	0.87	0.88	0.88	0.98	
	0.67	1.91	1.86	1.82	1.89	1.85	1.77	1.88	1.80	1.74	
0.67	0	0.29	0.42	0.57	0.25	0.41	0.55	0.40	0.55	0.71	
	0.17	0.61	0.65	0.79	0.56	0.62	0.74	0.54	0.63	na	
	0.33	1.08	1.01	1.03	1.04	0.97	0.98	1.00	0.90	0.94	
	0.67	2.02	1.98	1.94	2.01	1.97	1.89	1.99	1.92	1.85	
1.00	0	0.39	0.52	0.65	0.34	0.47	0.62	0.32	0.46	0.62	
	0.17	0.71	0.76	0.88	0.67	0.72	0.84	0.63	0.67	0.80	
	0.33	1.20	1.11	1.14	1.13	1.08	1.07	1.11	1.02	1.04	
	0.67	2.13	2.09	2.05	2.12	2.08	2.00	2.11	2.03	1.97	

Note:

"Non-feed" costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.23

Average cost per sheep-fed, wheat price $45 per ton, 3 pool model, opportunity cost 10%, New South Wales, 1936-65. Costs are divided into cost of wheat and other ("non-feed') costs.

		4			8			12		=ADL
		4	8	12	4	8	12	4	8	12=ADL[1]
		DOLLARS								
Wheat Cost		0.80	1.21	1.61	1.21	1.61	2.01	1.61	2.01	2.41
D	E									
0.17	0	0.25	0.39	0.55	0.39	0.55	0.70	0.55	0.70	0.85
	0.17	0.35	0.43	0.56	0.42	0.55	0.70	0.55	0.69	na
	0.33	0.71	0.66	0.71	0.68	0.66	0.73	0.70	0.75	na
	0.67	1.44	1.40	1.37	1.43	1.40	1.35	1.42	1.37	na
0.33	0	0.21	0.35	0.50	0.35	0.50	0.65	0.50	0.65	0.80
	0.17	0.39	0.47	0.59	0.39	0.52	0.64	0.51	0.64	na
	0.33	0.75	0.70	0.75	0.73	0.67	0.72	0.70	0.72	0.84
	0.67	1.48	1.45	1.42	1.47	1.44	1.39	1.46	1.42	1.38
0.67	0	0.26	0.39	0.54	0.24	0.39	0.54	0.39	0.54	0.69
	0.17	0.48	0.53	0.67	0.45	0.51	0.65	0.58	0.55	na
	0.33	0.84	0.80	0.83	0.82	0.77	0.80	0.79	0.73	0.78
	0.67	1.57	1.54	1.51	1.57	1.53	1.49	1.55	1.51	1.47
1.00	0	0.33	0.47	0.60	0.31	0.46	0.59	0.31	0.44	0.60
	0.17	0.57	0.62	0.73	0.54	0.59	0.72	0.50	0.57	0.70
	0.33	0.94	0.89	0.92	0.90	0.85	0.87	0.87	0.82	0.86
	0.67	1.61	1.63	1.60	1.65	1.62	1.67	1.64	1.59	1.56

Note:

"Non-feed" costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.24

Average cost per sheep-fed, wheat price $60 per ton, 2 pool model, opportunity cost 10%, New South Wales, 1936-65. Costs are divided into costs of wheat and other ("non-feed") costs.

		4			8			12		=ADL
		4	8	12	4	8	12	4	8	12 =ADL[1]
		DOLLARS								
Wheat Cost		1.07	1.61	2.14	1.61	2.14	2.68	2.14	2.68	3.21
D	E									
0.17	0	0.25	0.40	0.55	0.40	0.55	0.70	0.55	0.70	0.85
	0.17	0.32	0.44	0.58	0.42	0.55	0.69	0.55	0.67	na
	0.33	0.52	0.61	0.73	0.55	0.65	0.75	0.65	0.74	na
	0.67	1.08	1.04	1.11	1.07	1.03	1.09	1.06	1.03	na
0.33	0	0.20	0.35	0.50	0.35	0.50	0.65	0.50	0.65	0.81
	0.17	0.36	0.47	0.60	0.39	0.52	0.66	0.50	0.64	na
	0.33	0.56	0.65	0.76	0.55	0.64	0.74	0.62	0.72	0.84
	0.67	1.12	1.08	1.14	1.10	1.07	1.12	1.09	1.04	1.11
0.67	0	na	na	na	0.25	0.41	0.55	0.40	0.55	0.71
	0.17	0.44	0.55	0.68	0.41	0.53	0.65	0.45	0.56	na
	0.33	0.64	0.72	0.85	0.62	0.71	0.82	0.61	0.69	0.79
	0.67	1.20	1.16	1.22	1.18	1.15	1.20	1.18	1.12	1.19
1.00	0	na	na	na	na	na	na	0.32	0.46	0.62
	0.17	na	na	na	na	na	na	na	na	na
	0.33	na	na	0.93	na	na	0.90	na	0.76	0.89
	0.67	na	na	1.30	na	na	1.27	na	1.20	1.27

Note:

"Non-feed" costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.25

Average cost per sheep-fed, wheat price \$45 per ton, 2 pool model, opportunity cost 10%, New South Wales, 1936-65. Costs are divided into cost of wheat and other ("non-feed") costs.

		4			8			12			=ADL
		4	8	12	4	8	12	4	8	12	=ADL[1]
		DOLLARS									
Wheat Cost		0.80	1.21	1.61	1.21	1.61	2.01	1.61	2.01	2.41	
D	E										
0.17	0	0.25	0.39	0.55	0.39	0.55	0.70	0.55	0.70	0.85	
	0.17	0.27	0.39	0.52	0.37	0.51	0.64	0.49	0.63	na	
	0.33	0.41	0.50	0.62	0.45	0.56	0.66	0.54	0.65	na	
	0.67	0.84	0.82	0.89	0.84	0.82	0.88	0.83	0.84	na	
0.33	0	0.21	0.35	0.50	0.35	0.50	0.65	0.50	0.65	0.80	
	0.17	0.30	0.41	0.54	0.34	0.47	0.61	0.45	0.59	na	
	0.33	0.44	0.53	0.65	0.44	0.54	0.65	0.51	0.63	0.74	
	0.67	0.87	0.85	0.92	0.87	0.85	0.91	0.86	0.83	0.90	
0.67	0	na	na	na	0.24	0.39	0.54	o.39	0.54	0.69	
	0.17	0.36	0.47	0.61	0.34	0.40	0.60	0.38	0.51	na	
	0.33	0.51	0.59	0.72	0.50	0.60	0.71	0.49	0.58	0.69	
	0.67	0.94	0.91	0.98	0.93	0.91	0.97	0.93	0.90	0.97	
1.00	0	na	na	na	na	na	na	0.29	0.44	0.60	
	0.17	na	na	na	na	na	na	na	na	na	
	0.33	na	na	0.78	na	na	0.77	na	0.64	0.77	
	0.67	na	na	1.03	na	na	1.01	na	0.96	1.02	

Note:

"Non-feed" costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.26

Average cost per sheep-fed, wheat price $45 per ton, sorghum price $45 per ton, model based on 2 pools of wheat and 1 pool of sorghum, opportunity cost 10%, "North" Queensland, 1936-65. Costs are divided into cost of wheat and sorghum, "feed" cost, and other, "non-feed" cost.

			4			8			12 =ADL		
			4	8	12	4	8	12	4	8	12 =ADL[1]
			DOLLARS								
Feed Cost			0.80	1.21	1.61	1.21	1.61	2.01	1.61	2.01	2.41
DW	EW	DS									
0.17	0.17	0.33	0.46	0.61	0.86	0.61	0.84	1.10	0.86	1.10	1.36
		0.67	0.51	0.62	0.78	0.60	0.75	1.00	0.75	0.99	1.25
		1.00	0.55	0.67	0.79	0.64	0.77	0.92	0.74	0.90	1.15
	0.33	0.33	0.63	0.74	0.90	0.72	0.87	1.10	0.94	1.10	1.35
		0.67	0.68	0.79	0.91	0.77	0.89	1.04	0.87	1.02	1.25
		1.00	0.72	0.83	0.96	0.81	0.94	1.06	0.91	1.04	1.19
0.33	0.17	0.33	0.48	0.58	0.80	0.62	0.79	1.05	0.88	1.04	1.30
		0.67	0.52	0.64	0.75	0.61	0.73	0.95	0.76	0.93	1.19
		1.00	0.57	0.68	0.80	0.66	0.78	0.90	0.76	0.88	1.09
	0.33	0.33	0.65	0.76	0.88	0.74	0.86	1.06	0.95	1.07	1.29
		0.67	0.69	0.80	0.93	0.78	0.90	1.02	0.88	1.00	1.21
		1.00	0.73	0.85	0.97	0.83	0.95	1.07	0.93	1.05	1.17
0.67	0.17	0.33	0.51	0.62	0.73	0.65	0.76	0.93	0.90	1.02	1.19
		0.67	0.55	0.67	0.78	0.64	0.76	0.88	0.79	0.91	1.09
		1.00	0.60	0.71	0.83	0.69	0.81	0.93	0.79	0.91	1.03
	0.33	0.33	0.68	0.79	0.91	0.77	0.89	1.00	0.98	1.10	1.21
		0.67	0.72	0.84	0.96	0.81	0.93	1.05	0.91	1.03	1.15
		1.00	0.76	0.88	1.00	0.86	0.98	1.10	0.96	1.08	1.20

Note:

"Non-feed" costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

Table 3.27

Average cost per sheep-fed, wheat price $45 per ton, sorghum price $45 per ton, model based on 2 pools of wheat and 1 pool of sorghum, opportunity cost 10%, "South" Queensland, 1936-65. Costs are divided into cost of wheat and sorghum, "feed" cost, and other "non-feed" cost.

			4			8			12 =ADL		
			4	8	12	4	8	12	4	8	12 =ADL[1]
			DOLLARS								
Feed Cost			0.80	1.21	1.61	1.21	1.61	2.01	1.61	2.01	2.41
DW	EW	DS									
0.17	0.17	0.33	<u>0.28</u>	0.33	0.45	<u>0.32</u>	0.44	0.58	0.45	0.57	0.72
		0.67	0.32	0.34	0.40	0.32	0.38	0.51	<u>0.38</u>	0.49	0.63
		1.00	0.37	0.39	0.42	0.37	0.40	0.46	0.38	0.44	0.56
	0.33	0.33	0.44	0.46	0.51	0.44	0.50	0.62	0.55	0.61	0.74
		0.67	0.49	0.51	0.54	0.49	0.52	0.57	0.50	0.55	0.67
		1.00	0.53	0.55	0.59	0.53	0.57	0.59	0.54	0.57	0.63
0.33	0.17	0.33	0.29	<u>0.31</u>	0.42	0.34	0.41	0.53	0.47	0.54	0.68
		0.67	0.34	0.36	0.39	0.34	<u>0.36</u>	0.48	0.39	0.46	0.59
		1.00	0.38	0.41	0.44	0.38	0.41	0.44	0.39	<u>0.42</u>	0.53
	0.33	0.33	0.46	0.48	0.50	0.46	0.48	0.59	0.56	0.59	0.71
		0.67	0.50	0.53	0.55	0.51	0.53	0.56	0.51	0.54	0.64
		1.00	0.55	0.57	0.60	0.55	0.58	0.61	0.56	0.59	0.61
0.67	0.17	0.33	0.33	0.34	<u>0.37</u>	0.37	0.40	0.46	0.50	0.53	0.59
		0.67	0.37	0.39	0.42	0.37	0.40	<u>0.42</u>	0.42	0.45	0.52
		1.00	0.42	0.44	0.47	0.42	0.45	0.47	0.43	0.45	<u>0.48</u>
	0.33	0.33	0.49	0.51	0.54	0.49	0.51	0.54	0.60	0.62	0.65
		0.67	0.54	0.56	0.59	0.54	0.57	0.59	0.54	0.57	0.59
		1.00	0.58	0.60	0.64	0.58	0.62	0.64	0.59	0.62	0.65

<u>Note</u>:

"Non-feed" costs per sheep-fed are underlined for the lowest cost policy of those tabulated for each demand combination.

In most of the States the simulations assumed a drought declaration 40 weeks after the centre of the previous wheat intake in a first decile drought year. In Queensland the declaration date was taken in one set of simulations (based on wheat only) as 12 weeks after the centre of the wheat intake, and in another set (based on wheat and sorghum) as 26 weeks after the centre of the wheat intake.

Tables 3.22 to 3.27 again indicate the lack of sensitivity of the average costs to changes in the dates of drought declaration. The estimated costs in Table 3.23 are based on droughts declared 12 weeks before wheat intake and lasting for 40 weeks after wheat intake. If a new system were applied which has the same parameters, same values of D and E and the same levels of ADL' and ADL as the system of Table 3.23 but with droughts declared at different times, the difference in costs between the two systems would be limited. Because ADL' and ADL, D and E are the same, opening stocks of grain at drought declarations and at grain intakes would be the same. The cost of feed and transport (including stockouts) would be the same. Differences in costs would be confined to differences between the cost of storage and interest during droughts and between droughts. Costs other than feed costs in Table 3.23 include cost of transport as well as the cost of storage and interest. Using the same example as before with D = 0.67, E = 0.17 and demand per sheep of (8, 12) the change in timing of drought declaration would need to cause an increase of considerably more than

31% in the cost of storage and interest to cause a one cent per sheep-week change in overall cost.

It would be relatively simple to allow the timing of drought declaration to be a random variable with a Monte Carlo selection of the drought declaration in computer runs. However in view of the small effect on average costs per sheep of the timing of drought declarations within first decile calendar years this has not been done.

The simulations throughout were based on sheep numbers and geographical distribution as at 31st March, 1964. This was selected in preference to later years for which data were available at the time the simulations were being undertaken because of the possible effects on sheep numbers of large droughts which occurred during the following few years. However it is obviously of interest to ascertain what effects changes in sheep numbers subsequent to 1964 would have on results obtained.

A change in sheep numbers, provided there is no change in geographical distribution of sheep, would not affect the cost estimates if the price parameters were unchanged. If sheep numbers increase by 50% in New South Wales over 1964 numbers, the simulation runs as constructed would give the same average cost per sheep-fed. Each year the grain intake is determined by the formula,

$$Q(I) = D * NAS(I) + E * MNAS \qquad (3.5)$$

With a 50% rise in sheep numbers both NAS(I) and MNAS would increase by 50% so that grain intake in each year of the

30 year run would increase by this proportion. For a given level of demand per sheep for NDR grain the total quantity of grain demanded in each drought would also increase by 50% because each first decile drought in the 30 year run would now involve 50% more sheep.

So the flow of grain inventories and of grain fed during the 30 years would increase by 50%. Total cost increases by 50% but so does the number of sheep-fed. Cost per sheep-fed remains the same. Grain intake and storage requirements increase by 50%.

The above was based on the premise that price parameters were unchanged by the increase in sheep numbers. This would not be so if the change in sheep numbers affected the price of grain, or if the extra storage requirements necessitated obtaining grain from more distant storage localities in droughts.

3.2.11 General

The NDR simulations discussed in this chapter have enabled empirical calculations of costs, grain inputs, storage capacity requirements, and imports from other States for a range of levels of demand per sheep and of grain input policies.

The scheme is broadly like an insurance policy with grain guaranteed to be available if demanded during certain periods of time. The periods of grain availability have been tied to first decile droughts. This method of identification meets the requirement where historical data was to be considered, of being unaffected by changes between current practices (stocking rates, improved pasture levels, etc.) and past practices. Also a fair correspondence between droughts declared in this way and "popular" droughts had been observed. However the simulation model could be readily adapted to study the costs etc. associated with droughts occurring in a particular locality with relative frequencies other than one year in ten.

Everist [22] has indicated that it is possible to "distinguish between absolute drought and partial drought and between acute drought and chronic drought".

In terms of plants and crops, absolute drought is a period when "as a direct result of lack of rainfall ... all plants die (except those with very deep root systems) ...". A "partial drought ... is a period when insufficient soil moisture is available to sustain production from the pastures or crops which normally grow in a particular region".

Also in terms of plants and crops an "acute drought occurs when there is a continuous or almost continuous period without effective rainfall sufficiently long in duration to prevent growth of plants ... ", whereas, "chronic drought is a prolonged period when productivity is below normal as a result of shortage or abnormal distribution of rainfall".

Clearly the use of first deciles as drought indicators would tend to exclude chronic droughts. First decile droughts measured over calendar years are by definition relatively short periods when rain is well below average, rather than "a prolonged period when productivity is below normal as a result of shortage or abnormal distribution of rainfall". The "first decile" method of identification seems to be in sympathy with the type of drought Everist has classified as "acute".

The empirical work done indicates the actuarial effect of using a relatively large area, that is a State, as the area of enquiry. Whereas first decile droughts occur in only one year in ten in individual locations, they occur about one year in two in the States as a whole. This has obvious implications regarding the length of time grain has to be stored between droughts.

With the rate of occurrence of droughts in the States, least-cost policies tend to have a small positive level of E indicating the desirability cost-wise of storing a small amount of grain between years. As required, additional grain was imported from other States. It should be noted here though that if each State simultaneously assumes that a proportion of its grain requirements in a drought will be imported from other States there may be some conflict in State policies. To assist in avoiding this the range of grain input policies considered allows each State to decide what level of grain imports it will assume. For this reason and to guard against possible small drought year grain supplies, E may be chosen at a higher level than the least-cost level would indicate. On the other hand whereas rainfalls in Australia tend to be positively correlated for locations near to each other, for locations suitably far apart negative correlations occur. So that if an individual State is willing to import grain from far enough away, for example from Western Australia to the eastern States, this would tend to increase the probability that grain would be available for imports. The simulations carried out here however have assumed that grain where imported is obtained from neighbouring States only.

The simulations have not included the effects of short-term forecasts which would possibly be carried out if an NDR scheme were implemented. Demand per sheep has remained constant in any one 30 year simulation, but varied between runs. This is not intended to imply that it is expected that demand per sheep for NDR grain will be exactly the same in every drought. Rather, the assumption is that if demand per sheep varies randomly in different droughts around an expected value, the long-term average cost estimated by using this expected value in each drought will be similar to the cost estimated by using the randomly occurring values of demand per sheep. This assumption would hold exactly if costs were a perfectly linear function of the level of demand per sheep. [23 P 89]. As the cost of grain fed for a given grain price is a constant multiple of the level of demand per sheep and grain fed is an important component of overall costs, this linearity has been assumed as an approximation. A number of Monte Carlo runs where demand per sheep varied randomly around an expected value gave a number of estimates of long-term average costs which were distributed "reasonably well" about the long-term average cost extimated by using expected demand per sheep through the 30 year run. If the costs are split into the components, "feed costs" and "non-feed costs", the long term expected cost of feed is a linear component. "Non-feed costs" as a group are not linear. The use of the expected value only rather than varying demands per sheep between droughts will induce an error in the estimation of this component of cost. However the sensitivity tests indicate that for a range of D and E a substantial error can be accommodated in this component of cost without greatly affecting the average cost per sheep-fed.

The above constitutes a defence of cost estimates obtained by using a constant demand per sheep in each drought instead of varying demands per sheep in each drought. The reason for wanting to use expected value as a surrogate for the probability distribution as a whole is that (a) this saves many computer runs which would be required if demand per sheep were selected randomly from a probability distribution, and (b) the probability distribution of demand per sheep is in any case not currently known.

The simulations carried out use a constant combination of D and E against a given level of demand per sheep. No attempt has been made to actually estimate what the long-term demand per sheep would be, or to simulate the effects of short-term forecasts applied separately to individual droughts. However the range of expected demands per sheep considered in the simulations were influenced by the level of demands for wheat observed in the drought survey conducted by the Bureau of Agricultural Economics [10]. This drought was recognised as a very severe drought when demand for supplementary feed could be expected to be high and it occurred at a time when wheat was in very plentiful supply. So in a sense the demand per sheep for wheat observed in this drought is "maximal". However because of the possibility of substitution between drought strategies (for example feeding wheat instead of hay) and because of possible changes in management practices (for example in stocking rates), the range of demands per sheep considered goes well above the demand per sheep as observed in the B.A.E. survey.

The simulations have given estimates of costs for a variety of combinations of wheat input and of demand per sheep (see for example Table 3.22). If the long-run expected demand per sheep is known these tables indicate the cost per sheep-fed for various grain input policies. They also allow estimates of the cost per sheep for given grain input policies if the long-run expected demand used to select grain input turns out to be incorrect.

Possibly instead of basing grain input policies on long-run expected demands the decision may be taken to carry out short-term forecasts of demand per sheep at the beginning of each drought. Such forecasts would take advantage of current knowledge regarding pasture condition, levels of on-farm fodder supplies, and so on. Instead of maintaining constant levels of D and E (or of D, E and UL if three control variables are used) grain intake each year could be adjusted according to the demand per sheep for NDR grain expected for the given drought.

The short-term forecasts envisaged here are forecasts of demand per sheep in an existing drought rather than forecasts of the timing and location of droughts. Such a forecast could be taken advantage of in selecting the level of D in the grain input equation:

$$Q(I) = D * NAS(I) + E * MNAS \qquad (3.5)$$

If a forecast in year I gives a probability distribution of demand for NDR grain per sheep, from grain intake in year I to the end of the drought, formulae of the type derived in the section on inventory analysis could be used to minimize cost over the period of the drought.

The actual reduction in costs which might be obtained from such short-term forecasts would depend on the distribution of demands per sheep which might obtain if an NDR scheme were implemented and on the accuracy in forecasting them. This kind of information could be developed if an NDR were implemented. In the meantime the simulation runs based on a number of different long-run expected demands per sheep give a first approximation to the costs involved. If the policy of meeting all demands for NDR grain is followed, feed costs are fixed by demand levels, the area of possible cost reduction through short-term forecasting is limited to non-feed costs. To be worthwhile the costs of carrying out such forecasts should be less than the benefits obtained.

CHAPTER 4

Measurement of the Benefits of a National Drought Reserve of Grain

In this chapter the discussion covers some of the theoretical background to personal on-farm decision-making in droughts and some of the facets in the estimation of the benefits which follow from implementation of an NDR. If an NDR were implemented the purchase of NDR grain would be one of a number of alternative drought strategies available to the individual grazier. Where an individual grazier purchases NDR grain it is likely that he would consider this with other strategies. Attention is given first to development of a number of models relevant to strategy selection under uncertainty. This is followed by a discussion of the imputing of a value to sheep as distinct from accepting the market price. Finally quantitative estimates and comparisons are made with regard to various drought strategies.

4.1 Some Models Relevant to the Comparison of Within-drought Strategies

In developing models of within-drought decision making by the grazier a number of possible strategies have been considered. These are: feed sheep NDR grain, sell sheep which are to be replaced after the drought by breeding or purchase, send sheep on agistment, allow mortality. These have been considered firstly as individual strategies and then in a number of strategy combinations.

4.1.1 Sell Sheep at the Beginning of Month i

Suppose at the start of month i the grazier is prepared to place probabilities, p_j, on there being j subsequent months with insufficient feed to supply a maintenance ration to his current number of sheep, where $j = 1,\ldots\ldots,N$ and where $\sum_{j=1}^{N} p_j = 1$.

Let $\$C_i$ = the difference between the price obtained for a single sheep if sold at the beginning of month i and cost of replacing the sheep after the drought.

$\$CF$ = the cost per month of feeding sheep a maintenance ration of NDR grain, where $CF is constant throughout the drought.

$\$C_s$ = costs incurred with this selling strategy from i to N, including replacement of the sheep after N.

$$\text{Expected value of } C_s = C_i \sum_{j=1}^{N} p_j = C_i \qquad (4.1)$$

$$\text{Variance of } C_s = 0 \qquad (4.2)$$

4.1.2 Send Sheep on Agistment at the Beginning of Month i

Let $\$T_c$ = the transportation associated with sending a sheep to and from agistment.

$\$AR$ = the net cost per sheep-month of agistment rental; net of variable costs, returns or mortality while on agistment.

$\$C_a$ = the costs incurred from month i to N with this agistment strategy.

$$\text{Expected value of } C_a = T_c + \sum_{j=1}^{N} (p_j * AR * j) \quad (4.3)$$

$$\text{Variance of } C_a = \sum_{j=1}^{N} (p_j * AR^2 * j^2) - (\sum_{j=1}^{N} p_j * AR * j)^2 \quad (4.4)$$

4.1.3 Feed Sheep from the Beginning of Month i

Let \$VC = variable(1) costs per sheep-month on the property, excluding any supplementary drought feeding.

\$CF = costs incurred from i to N where a sheep is fed NDR grain.

$$\text{Expected value of } C_f = \sum_{j=1}^{N} p_j (CF + VC) j \quad (4.5)$$

$$\text{Variance of } C_f = \sum_{j=1}^{N} p_j \{(CF + VC) j\}^2 - \{\sum_{j=1}^{N} p_j (CF + VC) j\}^2 \quad (4.6)$$

4.1.4 Allow Mortality from the Beginning of Month i

Let M = the number of sheep which die per month, assuming that M is constant and $0 \leq M \leq 1$, (consistent with the other strategy models 4.1.1, 4.1.2 and 4.1.3, which were developed at the level of a single sheep).

\$C = the replacement cost per sheep lost during the drought.

$\$C_m$ = costs incurred from month i to N with this strategy.

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(1) Fixed costs are common to the different strategies and so do not affect comparisons between strategies.

$$\text{Expected value of } C_m \doteq \sum_{j=1}^{N} p_j \{(C^*M + VC)j\} , \qquad (4.7)$$

which ignores returns from dead wool and saving in variable costs caused by mortality. This is a linear function of $\sum_{j=1}^{N} p_j j$, the expected drought length.

$$\text{Variance of } C_m \doteq \sum_{j=1}^{N} p_j \{(C^*M + VC)j\}^2$$

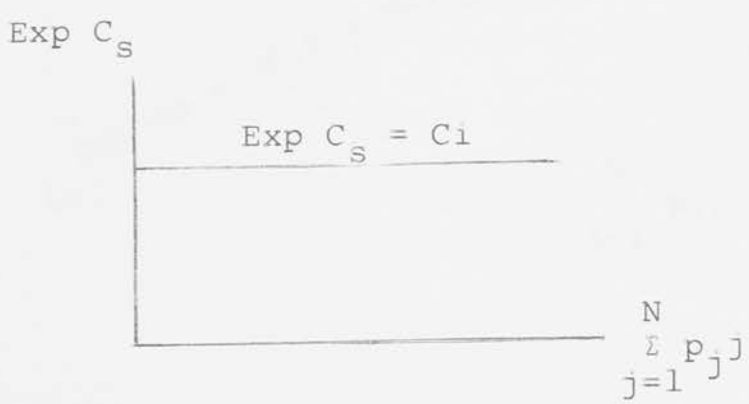
$$- [\sum_{j=1}^{N} p_j \{ (C^*M + VC)j\}]^2 \qquad (4.8)$$

4.1.5 Discussion of the Models of 4.1.1, 4.1.2, 4.1.3 and 4.1.4

The expected values of C_s, C_a, C_f, and C_m are linear functions of the expected drought length and so the complete probability distribution of drought length from month i need not be known to determine these values. The types of linear function involved are illustrated in Figures 4.1, 4.2, 4.3 and 4.4.

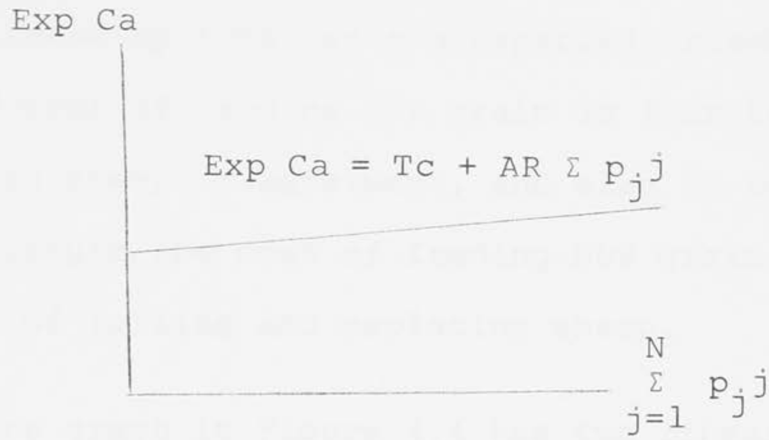
Expected Cost in Drought - Sheep Sold

FIG.4.1



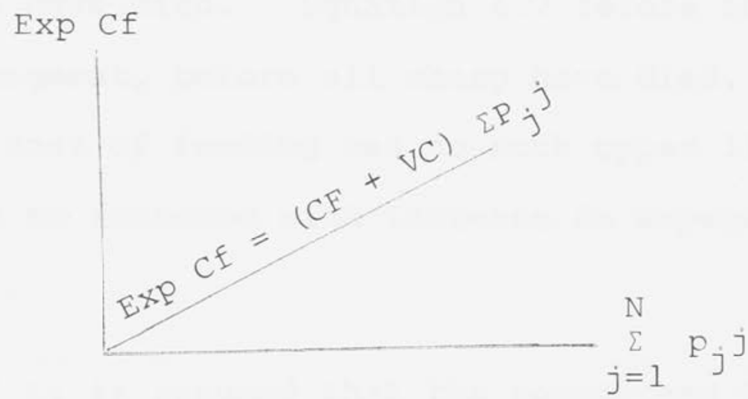
Expected Cost in Drought - Sheep Sent on Agistment

FIG.4.2



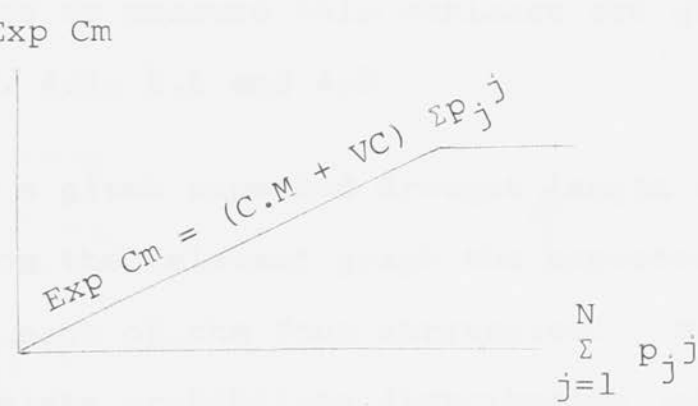
Expected Cost in Drought - Sheep Fed

FIG.4.3



Expected Cost in Drought - Sheep allowed to die

FIG.4.4



From Figures 4.1, 4.2, 4.3 and 4.4 it is obvious that at least up to a certain expected drought length the expected cost of feeding NDR grain is less than the cost of sending sheep on agistment, and also up to a certain drought length the cost of feeding NDR grain is less than the cost of selling and replacing sheep.

The graph in Figure 4.4 has two linear segments. The expected cost of mortality reaches an upper limit if the expected drought length is long enough, when all the sheep have died. Equation 4.7 refers to the upward sloping segment, before all sheep have died. The expected cost of feeding has no such upper limit and continues to increase with increase in expected drought length.

If it is assumed that the parameters C_i, T_c, AR, CF, VC, C and M are known and the probability distribution of drought length is known, variance in costs is associated with variance in actual drought length.[(2)] The formulae to measure this variance are given in equations 4.2, 4.4, 4.6 and 4.8.

For a given expected drought length it is possible to read from the relevant graph the expected cost associated with each of the four strategies. With knowledge of the complete probability distribution (which would have a particular expected drought length) it is possible to place a confidence interval round the expected cost.

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(2) Officer and Dillon used these criteria, expected value and variance, in their study of the combination "on-farm fodder reserves - purchased feed". [9]

The above discussion has been carried out in terms of a single sheep. However the argument would readily apply to a group of sheep, for example a portion of a flock, if the parameters used - for example, the value of C_i, the difference between selling price and replacement cost of a sheep - apply to them as a group. The expected values for a group of N sheep are N times those for the individual sheep, and the variances for the group are N^2 times those for the individual sheep.

The strategies outlined so far are all applied as single strategies in the same month i. In practice graziers in a drought tend to use combinations of strategies. In view of this an analysis has been made of expected costs and variances of costs, where combinations of strategies are applied and where decisions can be made at one point of time in a drought to act at a later stage.

4.1.6 Feed-sell as a Combined Strategy

If a decision is made at the beginning of month i to sell a sheep at the beginning of month i, the cost per sheep has an expected value of C_i and a variance of zero.

If a decision is made at the beginning of month i to sell a sheep k months later, where k varies from 1 to N, if there is still a drought, and to give it NDR grain in the meantime, if there is still a drought, the cost per sheep has an expected value at the beginning of month i of

$$\sum_{j=1}^{k-1} p_j \{(VC + CF)\, J\} + \{(VC + CF)k + C_{k+i}\} \sum_{j=k}^{N} p_j = A$$

The variance of this cost per sheep is

$$\sum_{j=1}^{k-1} p_j \{(VC + CF)j\}^2 + \{(VC + CF)k + C_{k+i}\}^2 \sum_{j=k}^{N} p_j - A^2$$

4.1.7 Mortality-sell as a Combined Strategy

If a decision is made at the beginning of month i to sell a sheep k months later, where k varies from 1 to N, (if there is still a drought), without supplementary drought feed in the meantime, the cost per sheep has an expected value of approximately

$$\sum_{j=1}^{k-1} p_j \{(C^*M + VC)j\} + \{(C^*M + VC)k + C_{k+i}\} \sum_{j=k}^{N} p_j = B$$

and a variance of approximately

$$\sum_{j=1}^{k-1} p_j \{(C^*M + VC)j\}^2 + \{(C^*M + VC)k + C_{k+i}\}^2 \sum_{j=k}^{N} p_j - B^2$$

4.1.8 Feed-agistment as a Combined Strategy

If a decision is made at the beginning of month i to send a sheep on agistment at the beginning of month i the cost per sheep has an expected value of

$$T_c + AR \sum_{k=1}^{N} p_j = T_c + AR$$

and a variance of zero.

If a decision is made at the beginning of month i to send a sheep on agistment k months later, (if there is still a drought), and to give the sheep NDR grain in the meantime (if there is still a drought), the cost per sheep has an expected value of

$$\sum_{j=1}^{k-1} p_j\,(CF + VC)j + \sum_{j=k}^{N} p_j\,\{T_c + AR(j-k+1) + (CF + VC)k\}$$

$$= C$$

and a variance of

$$\sum_{j=1}^{k-1} p_j\,\{(CF + VC)j\}^2 + \sum_{j=k}^{N} p_j\{T_c + AR(j-k+1) + (CF+VC)k\}^2$$

$$- C^2$$

4.1.9 Mortality-agistment as a Combined Strategy

If a decision is made at the beginning of month i to send a sheep on agistment k months later (if there is still a drought), without supplementary drought feed in the meantime, the cost per sheep has an expected value of approximately

$$\sum_{j=1}^{k-1} p_j\,\{(C*M+VC)j\} + \sum_{j=k}^{N} p_j\{T_c + AR(j-k+1) + C*M+VC)k\}$$

$$= D$$

and a variance of

$$\sum_{j=1}^{k-1} p_j\,\{(C*M + VC)j\}^2 + \sum_{j=k}^{N} p_j\{T_c + AR(j-k+1) + (C*M+VC)k\}^2$$

$$-D^2$$

4.1.10 Net Cash Outflow

The above discussion has dealt with costs and returns as distinct from cash flows. However it can be assumed that all of the costs and returns represented by the model are also cash flows, except post-drought replacement of sheep where this is undertaken by breeding sheep.

The models developed can be used to estimate expected net cash outflows (or inflow) and the variance of net cash outflow (or inflow). Where necessary the parameter influenced by post-drought cost of replacement is adjusted to make the immediate post-drought cash outflow equal to zero, if replacement is by breeding rather than by purchase. In the models developed this would affect strategies (either single or combined) which include loss of sheep through mortality or through within-drought sales. Parameters affected are C_i, the difference between the price obtained for a sheep if sold at the beginning of month i of the drought and the cost of replacing the sheep after the drought, and C, the replacement cost per sheep lost in the drought.

Net cash outflow and associated increase in indebtedness of graziers has been an important feature in recent droughts. [25P.48] Where upper limits are placed on the tolerable level of net cash outflow, the variance as well as the expected value is of particular importance.

4.2 Flock Recovery and the Evaluation of Sheep

A feature of the recent, 1965/6 and 1967/8 droughts in New South Wales and Queensland has been the apparently quick recovery in the graziers' financial position. [10 P.49] One factor contributing to this, particularly in the wheat-sheep zone, was the possibility of switching resources left unused by diminished sheep numbers to increased production of wheat. As wheat delivered to official storage facilities obtained a first advance of $1.10 per bushel a fairly quick cash return was available.(3) However the post-drought effect of drought losses of sheep, particularly of breeding sheep, seems to warrant investigation. There is the prima facie possibility that the cost of breeding replacements is higher than the cost of purchasing replacements. There is also the possibility that the cost to the nation of sheep lost may be greater than the cost to individual graziers.(4)

A simulation model was developed to study costs associated with the post-drought recovery of a flock depleted by drought.(5) A hypothetical flock of ewes is considered where at the start of the post drought recovery period there are 6 age groups. Ewes aged 5½ years, 4½ years, 3½ years, 2½ years, ewe hoggets aged 1½ years, and lambs of both sexes aged 6 months. In determining the structure of this flock two survival rates have been assumed, one being the proportion of lambs which survive from 6 months to 18 months, the other being the proportion of ewes of 18 months or more which survive the following year. The one survival rate is assumed

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(3) More recently, although the first advance still applies, growers have been issued with quotas which limit the quantity of grain to which the first advance applies.

(4) See articles by K.O. Campbell [26], B.R. Davidson,[2], and the Farm Management Guidebook by A. Wright and A.S. Watson [27].

(5) The flow diagram for this model is given in Appendix IV. The basis of this model was an article by P.F. Byrne [28]. Byrne however dealt with a flock in equilibrium, whereas by adjusting the number of ewe hoggets retained in the flock the current model simulates post-drought recovery in flock size.

for ewes of different ages. Each year in the post-drought period gross returns are "obtained" by this flock from the sale of wool and sale of sheep in the form of cast-for-age sheep, culled ewe hoggets or wether hoggets. In order to calculate a series of annual gross margins for this flock variable costs [6] have been calculated as associated with the number of sheep in this flock each year. The post-drought "performance" of this flock is compared with the post-drought "performance" of a number of flocks where each is chosen to represent a flock depleted in varying degrees by drought losses. A slight change is made in the "non-depleted" flock according to which of the depleted flocks is being compared with it. The number of lambs in the otherwise non-depleted flock is made equal to the number of lambs in the depleted flock. This simplifies later calculation of the imputed value per ewe lost in the depleted flock. Lambs in the depleted flocks are placed at 30% of the number of breeding ewes.

With an assumed annual survival rate of adult sheep of 0.96 and an assumed survival rate of sheep from 6 months to 18 months of 0.90, the structure of the "non-depleted" flocks is as in Table 4.1.

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(6) Where the reduction in sheep numbers is thought likely to cause a reduction in capital investment variable costs obviously are not the relevant ones. The models developed here study the situation where drought losses do not lead to a reduction in capital investment.

Table 4.1

Non-depleted Flocks[a]

Flock No.	Sheep Numbers by Age-Groups						
	Ewes 5½ yrs.	Ewes 4½ yrs.	Ewes 3½ yrs.	Ewes 2½ yrs.	Ewe Hoggets 1½ yrs.	Lambs both sexes 6 mnths	Flock excluding lambs
1	18.40	19.17	19.97	20.80	21.66	28.50	100
2	18.40	19.17	19.97	20.80	21.66	27.00	100
3	18.40	19.17	19.97	20.80	21.66	25.50	100
4	18.40	19.17	19.97	20.80	21.66	24.00	100

(a) The only difference between these four flocks is in the number of lambs which is made to agree with the number of lambs in the corresponding depleted flocks.

Four depleted flocks were constructed representing various levels of drought reductions or losses. Reductions considered were 5, 10, 15 and 20 per cent of the ewes. The flocks are set out in Table 4.2.

Table 4.2

Depleted Flocks

Flock No.	Sheep Numbers by Age-Groups						
	Ewes 5½ yrs.	Ewes 4½ yrs.	Ewes 3½ yrs.	Ewes 2½ yrs.	Ewe Hogget 1½ yrs.	Lambs, both sexes 6 months	Flock size[a] excl. lambs
1	17	18	19	20	21	28.50	95
2	16	17	18	19	20	27.00	90
3	15	16	17	18	19	25.50	85
4	14	15	16	17	18	24.00	80

(a) This column indicates the reduction in the number of ewes during the drought.

In a particular simulation run, one of six combinations of lambing rates and culling rates of ewe hoggets was chosen for each of the four pairs of flocks. Parameters used in the simulations were:

Lambing rates 0.80, 0.60.

Culling rates of ewe hoggets 5%, 20%, 35%.

Survival rate of adult sheep to next age group 0.96.

Survival rate of 6 month old lambs to 18 months 0.90.

Annual yield of wool per adult sheep 10 lbs.

Annual yield of wool per ewe hogget 3 lbs.

Variable cost per sheep $1.50 [7].

Price of wool $0.50 per lb.

Price of culled sheep $6.00 per head.

Discount rates per annum 5%, 6%, 7%.

Interest was focussed on lambing rate/culling rate combinations, which for the assumed survival rates of 90% and 96%, would lead to growth in the flocks being compared. Comparisons of discounted gross margins between the depleted and non-depleted flocks were made at points of time after the drought. Because of the assumed drop in lamb numbers in the "non-depleted" flock during the drought there was an initial post-drought fall in ewe numbers in this flock. The comparisons were discontinued when this flock had approximately regained its original ewe numbers of 100. Subject to this constraint the comparisons were at points of time 2 years, 4 years, 5 years and 10 years after the drought.

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(7) Byrne [29 p.49] obtained an estimate of $1.37 for variable costs associated with ewes and lambs; rounded to $1.50.

Tables 4.3, 4.4, 4.5 and 4.6 set out, for various percentages of ewes lost in droughts, the discounted reductions in gross margins per ewe lost. This figure is taken as an imputed value per ewe. The simulations carried out do not show a great variation in the imputed value for different levels of drought losses.

The model is rather crude in that the various parameters used are not made age specific. While there is a variation between age groups in parameters such as wool per head, and mortality rates (both in droughts and non-droughts) these were not explicitly allowed in the model. Within-drought depletions of 5, 10, 15 and 20 per cent were allowed fairly evenly across age-groups which implicitly made some allowance for higher mortality rates among older sheep by balancing this against the smaller number of old sheep in the equilibrium flock.

The columns of figures in Tables 4.3, 4.4, 4.5 and 4.6 are discontinued when the equilibrium flock has approximately regained its original size of 100 ewes. Continuation past this point of time down the column would represent post-drought growth over the pre-drought flock size. This has not been assumed here. A lambing rate of 80% and a 5% culling rate of ewe hoggets is associated with "recovery" of the "non-depleted" flock in two years. A depleted flock with a lambing rate of 80% and a culling rate of 5% would have a value per ewe lost of about $8 to $9. Where lambing and culling rates are 80% and 20% respectively the "non-depleted" flock has recovered in about 4 years. The value per ewe imputed over the 4 years is about \$15 to \$16. When the lambing rate is about 60%, culling rates of 20% or 35% are not conducive to recovery in the flock depleted by the model. A culling rate of 5% is associated with "recovery" in the non-depleted flock in about 5 years, the imputed value per sheep being about \$16 to \$17. A glance across corresponding rows of these tables indicates that there is very little variation within rows, where discounting is over the same time span, but there is a marked variation between rows, that is, time spans. Valuations imputed to a sheep by this method will vary according to what post-drought growth is allowed over pre-drought sheep numbers, and the time span over which the comparison is made. However those results in Tables 4.3, 4.4, 4.5 and 4.6 which represent a lambing rate of 60% and a culling rate of 5% have a particular interest. Here a value per sheep of about \$16 to \$17 has been imputed over a time span of 5 years without having assumed significant growth over the pre-drought flock. At the end of the fifth year the 4 versions of the "non-depleted" flock have 102.59, 101.55, 100.51 and 99.47 ewes respectively, compared with the pre-drought situation with 100 ewes. The lambing rate of 60% is realistic in the pastoral zone. This method of imputing values to sheep is quite realistic in this zone where there is not the same scope for allocation of resources, left unused by the loss of sheep, to alternative enterprises. The value imputed over five years of about \$16 to \$17 (based on a price of wool of 50 cents per pound) is substantively higher than the post-drought market price of sheep when wool was at approximately this price. Values over discounting spans beyond the fifth year would depend on assumptions regarding flock growth.(8)

4.3 Further Discussion of Costs and Benefits and Some Empirical Analysis

As indicated by Figures 4.1, 4.2, 4.3 and 4.4 a grazier who is basing his estimates on the criterion of expected value only, and who is considering only single strategies as distinct from combined strategies, still has a considerable range of choice. Where multiple criteria and combined strategies are included in the individual grazier's decision-making the problem becomes more complex. The measurement even ex-post of aggregate benefit in a single drought is more complex again, and to obtain an ex ante measure of aggregate benefit given probable occurrence and intensity of drought is still more difficult. Problems of this kind are common in systems analysis.[38 pp. 9-11, 42, 43]

However against the difficulties there are some more favourable elements in the problem of measuring the benefits. One is that indications of the worthwhileness or otherwise of formally implementing an NDR might be

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(8) B.R. Davidson op.cit. [2] obtains much larger estimates over a 20 year discounting period, where growth in flock size over pre-drought numbers is assumed. If the current estimates had been extended beyond 5 years, even without assumed post-drought growth over pre-drought numbers, larger estimates than $16 to $17 would have been obtained because the depleted flocks still had not recovered after 5 years.

obtainable without estimation of the actual level of ex ante aggregate benefits. For instance, if break-even points could be set above which an NDR would be worthwhile it is then sufficient to show that the benefits exceed this level. Another favourable element is related to the fact that decision-making and costs in an NDR scheme can be split into two segments. There is the group decision, with its associated costs, to hold grain in an NDR scheme. Then there are possible decisions by individual graziers, with associated costs, to purchase grain from the NDR to be fed to sheep. In the analysis of Chapter 3 the first decision is associated with physical costs (chemical costs etc.) and the opportunity cost involved in storing grain. As has been indicated, for example in the sensitivity analysis of Chapter 3, these costs are small.(9) Decisions by graziers to purchase and feed NDR grain would lead to transport costs and the cost of feed itself. These costs are higher but would not be incurred by individual graziers unless they were considered worthwhile. In the framework of this argument the question of benefits and costs can be expressed in the form: "Would the aggregate benefit obtained by graziers acting as individuals be likely to affect costs involved in the decision to purchase NDR grain by enough to also cover the costs involved in the prior decision to hold NDR grain?"

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(9) Costs which are also relevant but which have not so far been considered are what Starr and Miller [19] refer to as systemic costs. These are here the administrative costs which would be involved in implementing such a scheme. Systemic costs per bushel would decrease with the number of bushels demanded by graziers.

Table 4.3

Discounted Reduction in Gross Margin per Breeding Ewe lost in Drought

(Percentage of ewes lost in drought = 20%)

Discounted Reduction in Gross Margins per Ewe lost	Lambing Rate 0.60 Culling rate of ewe hoggets 35%	20%	5%	Lambing Rate 0.80 Culling rate of ewe hoggets 35%	20%	5%
Discounted over 2 years at:	$	$	$	$	$	$
5% per annum	NR	NR	8.44	9.39	9.10	8.67
6% per annum	NR	NR	8.39	9.34	9.06	8.63
7% per annum	NR	NR	8.35	9.29	9.01	8.59
Discounted over 4 years at:						
5% per annum	NR	NR	14.72	16.79	16.36	R
6% per annum	NR	NR	14.53	16.56	16.14	R
7% per annum	NR	NR	14.35	16.35	15.93	R
Discounted over 5 years at:						
5% per annum	NR	NR	17.64	20.53	R	R
6% per annum	NR	NR	17.34	20.19	R	R
7% per annum	NR	NR	17.06	19.82	R	R
Discounted over 10 years at:						
5% per annum	NR	NR	R	35.55	R	R
6% per annum	NR	NR	R	34.22	R	R
7% per annum	NR	NR	R	32.98	R	R

NR - No recovery of depleted flock.
R - "Non-depleted" flock recovered.

Table 4.4

Discounted Reduction in Gross Margins per Breeding Ewe lost in Drought

(Percentage of ewes lost in drought = 15%)

Discounted Reduction in Gross Margins per Ewe lost	Lambing Rate 0.60 Culling rate of ewe hoggets 35%	20%	5%	Lambing Rate 0.80 Culling rate of ewe hoggets 35%	20%	5%
Discounted over 2 years at:	$	$	$	$	$	$
5% per annum	NR	NR	8.58	9.34	9.21	8.77
6% per annum	NR	NR	8.54	9.29	9.17	8.73
7% per annum	NR	NR	8.50	9.25	9.12	8.69
Discounted over 4 years at:						
5% per annum	NR	NR	14.72	16.77	16.35	R
6% per annum	NR	NR	14.53	16.56	16.13	R
7% per annum	NR	NR	14.35	16.34	15.93	R
Discounted over 5 years at:						
5% per annum	NR	NR	17.63	20.07	R	R
6% per annum	NR	NR	17.33	19.73	R	R
7% per annum	NR	NR	17.05	19.39	R	R
Discounted over 10 years at:						
5% per annum	NR	NR	R	35.04	R	R
6% per annum	NR	NR	R	33.75	R	R
7% per annum	NR	NR	R	32.52	R	R

NR - No recovery of depleted flock.
R - "Non-depleted" flock recovered.

Table 4.5

Discounted Reduction in Gross Margins per Breeding Ewe lost in Drought

(Percentage of ewes lost in drought = 10%)

Discounted Reduction in Gross Margins per Ewe lost	Lambing Rate					
	0.60			0.80		
	Culling rate of ewe hoggets			Culling rate of ewe hoggets		
	35%	20%	5%	35%	20%	5%
Discounted over 2 years at:	$	$	$	$	$	$
5% per annum	NR	NR	8.59	9.54	9.16	8.87
6% per annum	NR	NR	8.55	9.49	9.11	8.83
7% per annum	NR	NR	8.51	9.44	9.07	8.79
Discounted over 4 years at:						
5% per annum	NR	NR	14.52	16.71	16.24	R
6% per annum	NR	NR	14.34	16.49	16.02	R
7% per annum	NR	NR	14.17	16.28	15.83	R
Discounted over 5 years at:						
5% per annum	NR	NR	17.23	19.84	R	R
6% per annum	NR	NR	16.95	19.50	R	R
7% per annum	NR	NR	16.69	19.18	R	R
Discounted over 10 years at:						
5% per annum	NR	NR	R	34.44	R	R
6% per annum	NR	NR	R	33.18	R	R
7% per annum	NR	NR	R	31.98	R	R

NR - No recovery of depleted flock.
R - "Non-depleted" flock recovered.

Table 4.6

Discounted Reduction in Gross Margins per Breeding Ewe lost in Drought

(Percentage of ewes lost in drought = 5%)

Discounted Reduction in Gross Margins per Ewe lost	Lambing Rate 0.60 Culling rate of ewe hoggets 35%	20%	5%	Lambing Rate 0.80 Culling rate of ewe hoggets 35%	20%	5%
Discounted over 2 years at:	$	$	$	$	$	$
5% per annum	NR	NR	8.80	9.94	9.36	9.18
6% per annum	NR	NR	8.76	9.88	9.32	9.12
7% per annum	NR	NR	8.72	9.84	9.28	9.08
Discounted over 4 years at:						
5% per annum	NR	NR	14.46	16.66	15.90	R
6% per annum	NR	NR	14.28	16.46	15.72	R
7% per annum	NR	NR	14.16	16.28	15.52	R
Discounted over 5 years at:						
5% per annum	NR	NR	16.92	19.46	R	R
6% per annum	NR	NR	16.66	19.16	R	R
7% per annum	NR	NR	16.42	18.88	R	R
Discounted over 10 years at:						
5% per annum	NR	NR	R	31.38	R	R
6% per annum	NR	NR	R	30.34	R	R
7% per annum	NR	NR	R	29.38	R	R

NR - No recovery of depleted flock.
R - "Non-depleted" flock recovered.

4.3.1 Ex post Comparison of Costs of Purchasing Oats and Hay with Costs of Purchasing NDR Grain.

The curves of Figures 4.1, 4.2, 4.3 and 4.4 suggest the possibility of selection between individual strategies on an ex ante basis if the expected drought length is known. The relevant expected drought lengths are those applicable to individual farms. Expected drought lengths would vary between farms. A simpler if less ideal approach to the empirical estimate of benefits of an NDR is to measure ex post what the benefits might have been if an NDR had been available in a particular drought. To this end data obtained by the B.A.E.(10) have been utilized to make some ex post comparisons of the costs associated with different drought strategies. The data related to severe droughts.

Based on observations of drought practices on a sample of 136 farms, comparisons have been made of actual expenditure by the farms on hay and oats during the drought and the cost of purchasing an "equivalent" quantity of NDR grain. "Equivalence" in this instance has been obtained by expressing the three types of feed - hay, oats and NDR grain - in terms of the number of food-units. This is on the basis of the assumption that in a drought the "content" of a feed is indicated by its energy content as distinct from proteins, etc. [17 P.5]

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(10) A special tabulation from the Australian Sheep Industry Survey data.

The approach used in this analysis was:

(1) Estimates were made of the costs per food-unit at which NDR grain would have been made available in the 1964-66 droughts in drought zones in New South Wales and Queensland.

(2) Estimates were made of the amount of money which was spent on hay and on oats at higher prices per food-unit than that of NDR grain.[11]

(3) It is assumed that with a price per food-unit of NDR grain which is guaranteed to be at a fixed level throughout the drought the individual grazier can estimate which type of feed can be purchased at the lower cost per food-unit. For this reason it is assumed in this analysis that where hay and oats were purchased at prices higher than NDR prices, the difference between this expenditure and expenditure necessary to purchase the equivalent number of food-units of NDR grain could have been saved.

(4) Estimates are obtained of what extra quantities of NDR grain would have been required if demand had been switched from hay or oats to NDR grain in those instances where the price per food-unit of the latter was the less. It is possible that the extra quantity of wheat or sorghum required was in fact available in the particular droughts being considered so the problem was in those droughts one of extension rather than availability of grain.

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(11) Food-unit contents in hay, oats and wheat were estimated using average food-unit content per unit by weight.

(5) Estimates were made of the excess expenditures on drought feeding of sheep, as distinct from cattle, in the sample of farms.

(6) From the sample, estimates were made of excess expenditure on drought feeding of sheep in the population of farms in that drought area.

The costs per food-unit of purchasing NDR grain are given in Table 4.7. These costs are comprised of the costs considered in the simulations, that is feed, storage, opportunity and transportation and are associated with various long-term expected demand levels indicated in columns 1 and 2 of Table 4.7. The costs associated with each long-run demand level are those which follow from minimum cost combinations of D and E. The price of sorghum and of wheat included in these calculations are both taken at $45 per ton. The costs per food-unit shown in Table 4.7 vary with the long-run expected demand level. The highest costs per food-unit are 4.38 cents in "North Queensland", 3.75 cents in "South Queensland" and 3.66 cents in New South Wales. The following cost comparisons apply to droughts in the Pastoral Zone of Queensland, and the Pastoral, Wheat-Sheep and High Rainfall Zones in New South Wales. The cost of 4.38 cents per food-unit has been applied to the Pastoral Zone of Queensland and the cost 3.66 cents per food-unit to all zones in New South Wales.

Frequency distributions of cost at the farm gate of purchased hay, oats and wheat[12] are given by zones in New South Wales and Queensland in Tables 4.8, 4.9 and 4.10.

A comparison between Table 4.7 and Tables 4.8, 4.9 and 4.10 indicates the proportion of those who purchased hay, oats or wheat during the drought at costs greater than the cost per food-unit of NDR grain. To assist in the comparisons, dotted lines in Tables 4.8, 4.9 and 4.10 approximately separate those costs per food-unit which were higher than the NDR costs from others. The separation is only approximate as NDR costs used, of 4.38 cents per food-unit and 3.66 cents per food-unit, do not fall exactly on the class limits of the frequency distributions.

Table 4.7

Cost per Food-unit of NDR Grain[a] [b]

Demand		North Q'ld.	South Q'ld	N.S.W.
ADL	ADL'	cents	cents	cents
4	4	4.38	3.75	3.51
	8	4.14	3.52	3.61
	12	4.06	3.44	3.66
8	4	4.19	3.54	3.36
	8	4.06	3.42	3.47
	12	4.01	3.38	3.54
12	4	4.08	3.45	3.30
	8	4.01	3.38	3.40
	12	3.98	3.34	3.48

(a) It has been assumed that both wheat and sorghum have the same number of food-units per bushel, although in fact sorghum contains 45 food-units compared to wheat's 43.2 (Averages only)
(b) The contents of this table are based on minimum cost policies as in Tables 3.20, 3.19 and 3.4 Chapter 3.

(12) Costs of wheat actually purchased, not the estimated cost of NDR wheat.

Table 4.8

Frequency distributions of cost at the farm gate per food-unit of purchased hay, by zones in New South Wales and Queensland, sample farms, 1964-66 droughts.

Cost per food-unit	N.S.W. Pastoral Zone	N.S.W. Wheat-Sheep Zone	N.S.W. High Rain-fall Zone	Q'ld. Pastoral Zone
	FREQUENCIES			
cents				
1 - 2	1	-	-	-
2 - 3	3	1	-	-
3 - 4	2	-	2	1
4 - 5	1	1	2	5
5 - 6	6	1	-	4
6 - 7	9	5	2	5
7 - 8	3	-	1	1
8 - 9	-	-	-	9
9 - 10	-	-	1	2
10 - over	2	-	1	4
Total no. in sample	27	8	9	31

Table 4.9

Frequency distributions of cost at the farm gate per food-unit of purchased oats, by zones of New South Wales and Queensland, sample farms, 1964-66 droughts.

Cost per food-unit	N.S.W. Pastoral Zone	N.S.W. Wheat-Sheep Zone	N.S.W. High Rain-fall Zone	Q'ld. Pastoral Zone
	FREQUENCIES			
cents				
1 - 2	-	-	-	-
2 - 3	3	-	-	-
3 - 4	2	-	2	1
4 - 5	6	2	1	1
5 - 6	1	1	-	-
6 - 7	3	-	-	-
7 - 8	-	-	-	-
8 - 9	-	-	-	-
9 - 10	-	-	-	-
10 - over	-	-	-	-
Total no. in sample	15	3	3	2

Table 4.10

Frequency distributions of cost at the farm gate per food-unit of purchased wheat by zones of New South Wales and Queensland, sample farms, 1964-66 droughts.

	FREQUENCIES			
Cost per food-unit	N.S.W. Pastoral Zone	N.S.W. Wheat-Sheep Zone	N.S.W. High Rain-fall Zone	Q'ld. Pastoral Zone
cents				
1 - 2	-	-	1	-
2 - 3	1	1	-	-
3 - 4	19	14	10	7
4 - 5	1	-	-	2
5 - over	-	-	-	-
Total no. in sample	21	15	11	9

Table 4.11

The amount of money spent on purchased hay at prices greater than estimated NDR prices per food-unit, compared with the estimated cost of buying the same number of food-units at NDR prices, sample farms, 1964-66 droughts.

Zone	Actual Expenditure on hay	Equivalent Expenditure on NDR grain	"Excess" Expenditure
	$	$	$
N.S.W.			
Pastoral	39,736	22,035	17,701
Wheat-Sheep	13,216	8,131	5,085
High Rainfall	10,184	5,641	4,543
Q'ld.			
Pastoral	98,628	52,391	46,237
Total	161,764	88,198	73,566

Table 4.12

The amount of money spent on purchased oats at prices greater than estimated NDR prices per food-unit, compared with the estimated cost of buying the same number of food-units at NDR prices, sample farms, 1964-66 droughts.

Zone	Actual Expenditure on oats	Equivalent Expenditure on NDR grain	"Excess" Expenditure
	$	$	$
N.S.W.			
Pastoral	19,592	14,382	5,210
Wheat-Sheep	1,716	1,268	448
High Rainfall	7,650	7,258	392
Q'ld.			
Pastoral	-	-	-
Total	28,958	22,908	6,050

Column 2 of Table 4.11 gives estimates of the amounts of money spent on the purchase of hay at prices per food-unit greater than the NDR cost; column 3 gives the cost of purchasing the "equivalent" quantity of NDR grain; and column 4 gives the excess expenditure. Comparable estimates relative to the purchase of oats are given in Table 4.12.

The B.A.E. drought survey [10 P.22] gives a split-up of fodder between sheep and cattle with "about 86% of fodder ... fed to sheep and 14% to cattle in all zones except the wheat-sheep zone where the proportions were about 69% and 31% respectively". Of the three types of purchased fodder - wheat, oats and hay - the percentage fed to cattle was allocated in this analysis as far as possible to hay and then if necessary to oats and then wheat. The basis of allocation was food-units. This reduces as far as possible the estimated quantity of hay fed to sheep. As hay more than oats was the feed which was purchased at high price per food-unit, this gives a conservative estimate of the "excess" expenditure on feed purchased for drought feeding of sheep.(13)

Using the above allocation to sheep, the estimate of "excess" expenditure on hay and oats purchased for drought feeding of sheep is given in Table 4.13. These estimates are for farms in the sample.

Table 4.13

Estimate of "excess" expenditure on oats and hay purchased for drought feeding of sheep, sample farms, 1964-66 droughts.

Zone	"Excess" Expenditure on hay	"Excess" Expenditure on oats	Total
	$	$	$
N.S.W.			
Pastoral	5,664	5,210	10,874
Wheat-Sheep	610	448	1,058
High Rainfall	-	390	390
Q'ld.			
Pastoral	38,377	-	38,377

(13) In keeping with the analysis of costs it was decided to refer this section of the study also to sheep only.

To obtain estimates for all farms in the drought areas from which the sample was drawn the ratio of farms in the population to farms in the sample was derived as shown in Table 4.14.

Table 4.14

Ratio of the number of farms in the population to the number of farms in the sample, 1964-66 droughts.

	N.S.W.			Q'ld.
	Pastoral	Wheat-Sheep	High Rainfall	Pastoral
No. of sample farms	37	26	21	52
No. of farms in the population (a)	3,761	22,361	8,677	2,992
Ratio of farms in the population to farms in the sample	101.65	860.00	413.19	57.54

(a) Source: The Australian Sheep Industry Survey, 1964-65 to 1966-67, Bureau of Agricultural Economics, Canberra, Australia, (published August, 1969).

An estimate of "excess" expenditure on hay and oats in the population of farms is given in Table 4.15. Over the zones affected by the droughts from 1964 to 1966 the "excess" expenditure was approximately $4 million.

Table 4.15

Estimate of "excess" expenditure on hay and oats on farms in drought areas in New South Wales and Queensland, 1964-66 droughts.

Zones	"Excess" expenditure on hay and oats on farms in the sample	Ratio of farms in the population to farms in the sample	Estimate of "excess" expenditure on hay and oats on farms in the population
	$		$
N.S.W.			
Pastoral	10,874	101.65	1,105,000
Wheat-Sheep	1,058	860.00	910,000
High Rainfall	390	413.19	161,000
Q'ld.			
Pastoral	38,377	57.54	2,208,000
Total			4,384,000

The total quantities of fodder purchased by farms in the sample were as shown in Table 4.16

Table 4.16

Total quantities of fodder purchased, sample farms, 1964-66 droughts.

Zone	Wheat (60 lb. bushel)	Oats (40 lb. bushel)	Hay (tons)
N.S.W.			
Pastoral	59,618	21,987	903
Wheat-Sheep	13,496	1,444	376
High Rainfall	20,248	8,415	194
Q'ld.			
Pastoral	10,953	1,536	2,702

Using the ratio of farms in the population to farms in the sample in the various zones the estimated quantities of fodder which were purchased by the population farms as a whole were as given in Table 4.17.

Table 4.17

Total quantities of fodder purchased, population farms, 1964-66 droughts.

Zone	Wheat (60 lb. bushel)	Oats (40 lb. bushel)	Hay (tons)
N.S.W.			
Pastoral	6,060,000	2,235,000	92,000
Wheat-Sheep	11,607,000	1,242,000	323,000
High Rainfall	8,366,000	3,477,000	80,000
Q'ld.			
Pastoral	630,000	88,000	155,000
Total	26,663,000	7,042,000	650,000

If oats or hay had been replaced by NDR grain as a sheep feed when the latter had a price advantage per food-unit, quantities of NDR grain would have been required in addition to the wheat actually purchased. On sample farms the estimated additional quantities of NDR grain are given in Table 4.18.

Table 4.18

Quantities of NDR grain which would have been required to replace oats or hay as a sheep feed where NDR grain had a price advantage per food-unit, sample farms and population farms, 1964-66 droughts.

Zone	Sample farms (60 lb. bushel)	Ratios of the number of population farms to sample farms	Population farms (60 lb. bushel)
N.S.W.			
Pastoral	13,608	101.65	1,383,000
Wheat-Sheep	1,419	860.00	1,220,000
High Rainfall	4,564	413.19	1,886,000
Q'ld.			
Pastoral	22,982	57.54	1,322,000
Total	42,573		5,811,000

Some points which emerge from the foregoing analysis are:

(1) At the assumed prices of $45 per ton for wheat and sorghum and using disadvantageously low levels of long-term demand for NDR grain, average costs of 4.38 cents per food-unit were attainable in Queensland and 3.66 cents per food-unit in New South Wales.

(2) The estimated NDR costs were similar to the actual costs of wheat at the farm gate in the 1964-66 droughts in New South Wales and Queensland. (Actual costs would have benefited to some extent from subsidies on transportation costs whereas NDR costs were at unsubsidized rates.)

(3) The costs were less per food-unit than actual costs at the farm gate for a considerable proportion of oats and hay purchased during the drought.

(4) Estimates from the sample of the quantity of wheat actually purchased during the drought by the total population of farms in the drought were: New South Wales, 26 million bushels; Queensland, ½ million bushels.

(5) Estimated extra purchases of NDR grain if this had been purchased to replace oats or hay as sheep feed where it had a price advantage were: New South Wales, 4.5 million bushels; Queensland, 1.3 million bushels.

(6) The estimated decrease in costs on drought affected farms was $4 million.

(7) The above estimates of replacement of oats and hay by NDR grain depends on the assumption that food-units are the important measure of the "content" of a feed in a drought. Hay, depending on the type of hay used, tends to have more protein content than wheat or sorghum. However the droughts in question have been described as very severe, [10], and in drought conditions the food-unit has been described as the relevant basis of comparison of feed. [17].

(8) To the extent that the extra wheat (and sorghum) required was available in the droughts considered, some or all of the $4 million was potentially a benefit of extension work.

If one can rely on the necessary quantities of grain being available for reasons other than maintaining a drought reserve, at the right times in the right places, it would be legitimate not to allocate storage costs and opportunity costs to the NDR. In NDR cost estimates these assumptions have not been made and in order to avoid underestimating costs, the full opportunity cost and storage cost have been attributed to the NDR.(14)

(9) The prices of the different feeds would not be independent. The price of wheat in an implemented NDR is taken to be related to the unsubsidized marginal export price, but guaranteed to be at a constant level throughout the drought.

The availability of NDR grain at a known guaranteed price could have an effect on the drought price of other feeds, for example, hay. The above analysis has taken the costs of oats and hay as actually observed without allowing for any effect on these which an NDR scheme might make. Fortunately from the point of view of the complexity of the empirical analysis carried out, the estimated NDR prices used in the analysis were similar to the actual prices paid for wheat.

If, apart from switching demand from oats and hay to NDR grain, some of the effect of an NDR was to lower the price of oats and hay this would still be a benefit to NDR users.

(10) All of the benefits discussed here could be regarded as a transfer of benefits from growers selling feed to drought affected farms.

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(14) Possible exceptions are the limited number of estimates where opportunity cost has been allowed at 5% instead of 10%.

(11) The above analysis has been confined to comparisons within the drought feeding strategy. The level of drought feeding which actually occurred was maintained while an effort was made to see whether re-allocations of the type of feed used would have reduced costs. This type of re-allocation could be made if prices were known without knowledge of drought length.

There was no attempt in the above to try and find out whether costs could have been reduced still further by substituting other strategies, for example, sending sheep on agistment or allowing mortality, for NDR feeding.

4.3.2 Comparison of the Costs of Feeding NDR Grain with Costs of Sending Sheep on Agistment.(15)

The B.A.E. "drought survey" [10 P.48] makes the comment: "The relatively large number of sheep supported on supplementary feed suggests that this practice may be more generally acceptable to graziers than is sometimes suggested. However, the most likely avenue for reduction in the number of deaths occurring in a drought would seem to be an increase in the mobility of livestock either through sales or agistment to other areas. Further study seems to be needed to examine the conditions under which such a policy would be economic and also whether it should

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(15) Based largely on a special tabulation made available by the B.A.E. from the Australian Sheep Industry Survey data.

be preferentially supported or encouraged by government policy measures."

The cost involved in agistment can be split into costs of transport to and from the agistment area and the "rental" payable for agisting the livestock on another property. As indicated in previous discussion, where agistment costs were related to statistically expected drought length, the cost of transporting sheep to and from agistment represents a fixed cost once the sheep have been sent on agistment while total agistment "rental" paid will vary with the period of agistment.

The ex post cost of agistment per sheep over x weeks (cents) $= a + bx$ (4.9)

where a = transportation costs (cents)

and b = rental (cents)

The average cost of agistment per sheep-week (cents) $= \frac{a}{x} + b$

The cost of feeding a maintenance ration of NDR grain per sheep-week (cents) $= c$

For the cost of agistment to break-even with the alternate cost of NDR feeding

$$\frac{a}{x} + b = c$$

i.e. $a = (c - b)\, x$ (4.10)

For a given value of c and of x, equation (4.10) can be used to draw a curve giving the combination of a and b, that is agistment transportation cost per sheep and agistment rental per sheep-week, for which total agistment cost over x weeks equals the cost of feeding NDR grain over the same length of time. If b is represented on the x-axis and a on the y-axis then the curve of equation (4.10) is a straight line in the top-right quadrant from (c, 0) to (0, cx). The location of the line depends on c and x only. Figure 4.5 represents a family of curves derived from equation (4.10) where c is held constant and a number of values of x taken. The fact that (c, 0) is one terminal of the break-even curves for all values of x is consistent with the fact that if transport cost is zero the break-even agistment rental equals c the cost per sheep-week of NDR feed.

Obviously the family of curves shown in Figure 4.5 can be given empirical content if c is specified. This has been done to represent the situation in New South Wales and Queensland. Estimates of c for these States are made using the same costs per food-unit as were applied in the comparisons of alternative feeding strategies, that is 3.66 cents per food-unit in New South Wales and 4.38 cents per food-unit in Queensland. The value of c in the two States is then estimated on the basis of feeding 5 lb. of wheat per week,[16] where 5.5 lb. of wheat contain

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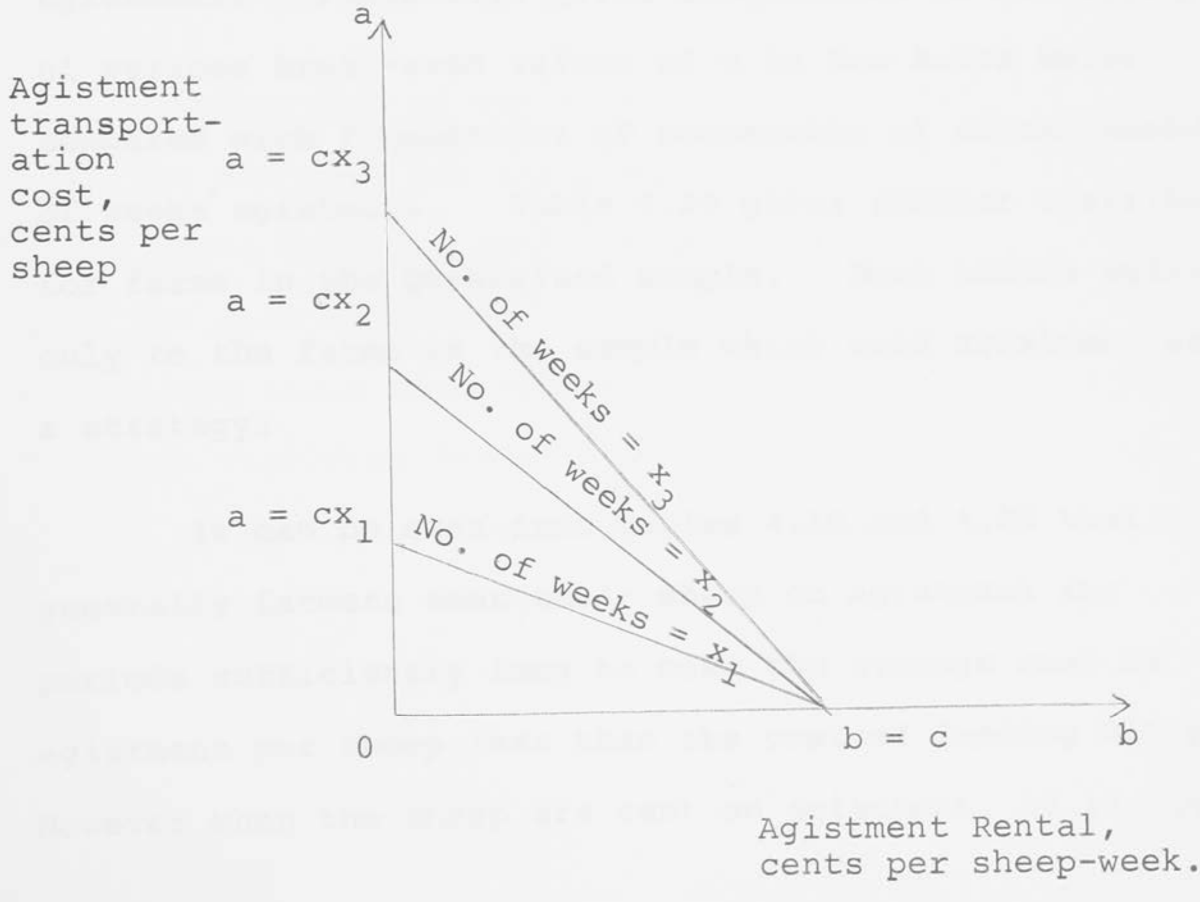
(16) Sorghum has a similar food-unit content to wheat, with 4 food-units per 5.3 lb. of grain sorghum. The use of the wheat food-unit content slightly over-estimates the cost of NDR feed per food-unit.

4 food-units. The estimates of c are 13.3 cents for New South Wales and 15.9 cents for Queensland. Referring to Figure 4.5, if $x_1 = 4$, and $c = 13.3$, the relevant break-even curve is the straight line joining $a = 53.2$ to $b = 13.3$. Any point on this line would represent a combination of a and b such that the cost of sending sheep on agistment for four weeks would just equal the cost of feeding them at 13.3 cents per sheep-week. For combinations of a and b above the line it would be cheaper to feed them and for combinations below the line it would be cheaper to send them on agistment. Similar curves can be constructed with $c = 15.9$.

Figure 4.5
"Break-even" curves showing the combinations of agistment transportation cost and agistment rental for which total agistment cost over x weeks equals the cost of feeding with NDR grain at c cents per sheep-week over x weeks.



In the 1964-66 droughts in New South Wales and Queensland, it was generally cheaper post hoc to send sheep on agistment than it would have been to feed them a maintenance ration of NDR grain. As already indicated factors affecting this were the transportation costs per sheep sent on agistment, agistment rentals per sheep-week and the number of weeks agistment. Equation (4.11) can be used to gain further insight.

$$\frac{a}{c - b} = x \qquad (4.11)$$

From equation (4.11) the "break-even" number of weeks agistment have been calculated for a and b values which occurred on sample farms and with c equal to 13.3 in New South Wales and 15.9 in Queensland. From this, a frequency distribution of the break-even number of weeks' agistment has been derived for comparison with the frequency distribution of the actual number of weeks' agistment. Table 4.19 gives frequencies of occurrence of various break-even values of x in New South Wales compared with frequencies of occurrence of actual number of weeks' agistment. Table 4.20 gives similar distributions for farms in the Queensland sample. Both tables refer only to the farms in the sample which used agistment as a strategy.

It can be seen from Tables 4.19 and 4.20 that generally farmers sent their sheep on agistment for periods sufficiently long to make the average cost of agistment per sheep less than the cost of feeding NDR grain. However when the sheep are sent on agistment, it is not known how long the drought will last. Column 2 of Table 4.19 and 4.20 indicates the length of agistment necessary to break-even with feeding NDR grain and so is a pertinent figure in the decision to send sheep on agistment or to feed them. On 8 out of 10 farms in Queensland the length of time required to break-even was 4 weeks or less, so there presumably would be a good chance when the decision was being made that the drought would continue for at least this length of time. In New South Wales the break-even period was 4 weeks or less on 7 sample farms out of 12.

Finally frequency distributions have been developed of the ex post cost per sheep-week of agistment, including both transport costs and agistment rental on the sample farms. A separate frequency distribution has been obtained for New South Wales and Queensland. Both distributions are given in Table 4.21.

Comparison of the distributions in Table 4.21 with the NDR cost per sheep-week of 13.3 cents in New South Wales and 15.9 cents in Queensland indicates that ex post one grazier in the New South Wales sample and one in Queensland would have reduced costs by buying NDR grain. The fact that from Tables 4.19 and 4.20 the break-even number of weeks agistment were fairly small suggests that this might be true of droughts generally. This assumes that the order of agistment transportation costs and rental costs observed in the 1964-66 droughts hold true generally.

Table 4.19

Frequency Distributions of the Number of Weeks' Agistment. Sample farms which sent sheep on agistment, 1964-66 droughts.

No. of weeks	N . S . W . Frequency of this value of the "break-even" agistment period	Frequency of this value of the actual agistment period
0 - 4	7	-
4 - 8	2	5
8 - 12	2	4
12 - 16	-	2
16 - 20	-	-
Over 20	1	1
Total	12	12

Note c = 13.3

Table 4.20

Frequency Distributions of the Number of Weeks' Agistment. Sample farms which sent sheep on agistment, 1964-66 droughts.

No. of weeks	Q U E E N S L A N D Frequency of this number of weeks as the "break-even" agistment period	Frequency of this number of weeks as the actual agistment period
0 - 4	8	-
4 - 8	1	-
8 - 12	-	2
12 - 16	-	-
16 - 20	1	2
Over 20	-	6
Total	10	10

Note c = 15.9

Table 4.21

Frequency distributions of the cost of agistment per sheep-week, sample farms which sent sheep on agistment, 1964-66 droughts.

Cost per sheep-week of agistment (cents)	Frequency	
	N.S.W.	Q'ld.
0 - 2	5	2
2 - 4	1	1
4 - 6	1	2
6 - 8	1	4
8 - 10	1	-
10 - 12	1	-
12 - 14	1*	-
14 - 16	-	-
16 - 18	-	1
18 - 20	-	-
Over 20	1	-
Total	12	10

*Less than 13.3 cents

Where agistment can be obtained at these costs it offers the possibility of lower costs than NDR grain. The longer the drought the greater its advantage. However there is the question of what quantity of agistment measured in say sheep-weeks is available and what quantity would be demanded by drought affected properties.

Table 14 in the B.A.E. drought survey [10 P.29-30] indicates that the number of sheep-weeks of supplementary feeding at $8 per sheep-year (approximately 15 cents per sheep-week) was much larger than the estimated number of sheep-weeks of agistment. This is in spite of the "cost advantage" as measured in this analysis of agistment over supplementary feeding. The reason could be at least partly in the supply of agistment. Obviously if all supplementary feeding were transferred to agistment when this had a "cost advantage" a much bigger supply of agistment would be called for. It could be at least partly explained by preference for supplementary feeding. This could be caused by ignorance of the "cost advantage", or because of factors not considered so far in the cost comparisons carried out. Some factors not considered in the comparisons which have been carried out between agistment and NDR feeding are outlined by the "Report of the Drought Mitigation Committee, Queensland, 1966". [30 P.19] These are as follows:

" 2.16 During the history of the livestock industries in Queensland, agistment has been one of the major weapons by which graziers have withstood drought. ... Since most droughts are limited in area of distribution, agistment can be quite effective and useful and is generally regarded as the base cost against which drought feeding can be compared.

2.17 However, the use of agistment is fraught with risk. If the recipient property is understocked and the agisted stock merely bring numbers up to normal levels, then no risk of overstocking is entailed. However, the usual situation is where a producer is stocked at full capacity and then accepts stock for agistment. This means that the weaker agisted stock suffer most with the decline of the pasture conditions and losses can occur. If the drought widens and the properties on which the stock are agisted become drought-stricken, then severe losses in the agisted stock can be expected.

2.18 Agistment is usually offered for a specified period. If the property of origin is still drought-stricken at the end of this time, an extension of agistment has to be negotiated or alternative agistment or sale has to be arranged.

2.19 Stock moving on agistment from one class of country to another can suffer severe setbacks even under normal conditions which are aggravated when they are low in condition. Predators, poison plants internal and external parasites and the control measures needed to keep them in check all place limitations on the value of agistment.

2.20 The incidence of cattle tick infectations in certain areas of the State makes the movement of stock on agistment difficult between clean and ticky areas."

As well as the above qualifications, there is the likelihood that with individual negotiations of agistment, the aggregate available supply might be a limiting factor. So even if there is a cost advantage after taking into account possibly increased risk, there could well continue to be a substantial demand for supplementary feeding. An NDR scheme could have a considerable advantage over agistment from the point of view of guaranteed aggregate available supply. However it is possible that some increase in the present level of use of agistment may with benefit occur in a drought if information were centrally available as to which properties were offering agistment, the quantities available and the costs and which properties required agistment and the quantities required. This would tend to increase the use of agistment if information and convenience in negotiating contracts are limiting factors. Possibly the information could also include some indication of stocking rates and pasture conditions on properties offering agistment as an indication of risks involved. The same information centre could also record actual costs and sheep losses in the agistment which could lead to a future quantification of the costs and risks involved in using agistment compared with feeding NDR grain. A preliminary survey could perhaps be made to see whether lack of such information is at present a limiting factor.

4.3.3 Comparison of the cost of Selling a Sheep during a drought, to be replaced after the drought, with that of Feeding NDR Grain - ex post costs.

In previous discussions of the ex ante costs the difference between the selling price of a sheep in a drought and the post drought replacement cost was taken as known and a constant. In fact the price differential would not be definitely known and it would tend to vary with drought length. However when the sheep are being sold the drought length is not known and also the relationship between the price differential and drought length may not be known in any explicit form. As there is an upper limit to the amount people would be willing to pay for replacement sheep the curve relating the price differential to drought length after rising for a certain length of time would flatten out. However, the actual shape and position of the curve before it flattens out seem uncertain.

Figure 4.6 shows hypothetical curves representing the cost of selling a sheep at time 0 and having to replace it at a higher price at the end of a drought lasting x weeks after 0, together with a straight line representing the cost of keeping the sheep and feeding it x weeks till the end of the drought.

The vertical distances between the "Feed NDR grain" curve and the "Sell sheep" curve at any point x represent the difference in costs between the two strategies over the x weeks from the time of action 0. In Figure 4.6.1 there is one value of x for which the costs for the "Feed NDR grain" strategy equal those for the "Sell sheep" strategy. That is, there is one break-even point. In Figure 4.6.2, there is none, and in Figure 4.6.3 there are two.

The slope of the "Feed NDR grain" cost curve has been estimated with values of \$0.133 in New South Wales and \$0.159 in Queensland. However if the shape of the "Sell sheep" cost curve is unknown, very little can be said about values of x which would lead to equal costs between the two strategies. However it may well be that a range of likely price differentials can be ascertained relative to droughts of "serious length". This may be represented by the fairly horizontal parts of the "sell sheep" curves in Figures 4.6.1, 4.6.2 and 3.6.3.

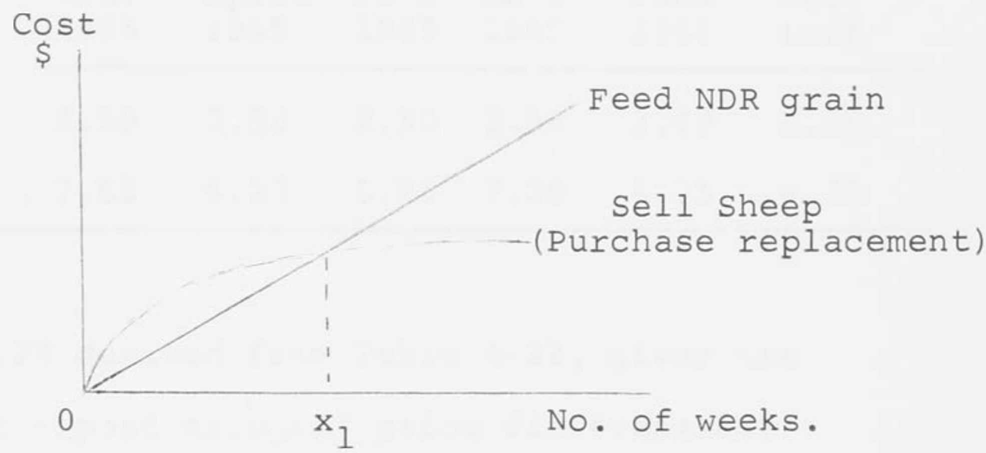
If Figure 4.6.1 represents the relationships between the curves, the "sell sheep" strategy would cost more than the "feed NDR grain" strategy if NDR feeding required was less than x_1 weeks, and vice versa, if NDR feeding required was more than x_1 weeks. In the situation represented by Figure 4.6.2, the "feed NDR grain" strategy would always cost more than the "sell sheep" strategy. In the situation of Figure 4.6.3, the "sell sheep" strategy would be the cheaper if feeding required was less than x_1 weeks, dearer if the feeding required was between x_1 weeks and x_2 weeks, and cheaper if feeding required was greater than x_2 weeks. The result in Figure 4.6.3 follows from the assumption of an S-shaped "sell sheep" cost curve. This could occur if the price differential between selling a sheep at time 0 and replacing it x weeks later increased slowly for a while, then more rapidly as the drought continued, and finally reached a ceiling. All of these situations could be studied ex ante in terms of expected cost and variance of cost if the probability distribution of x were known and also the location of the two curves.

As part of a survey of a sample of New England farms [31] data were collected of price per sheep from January 1965 to December 1966. Some of these data are reproduced in Table 4.22.

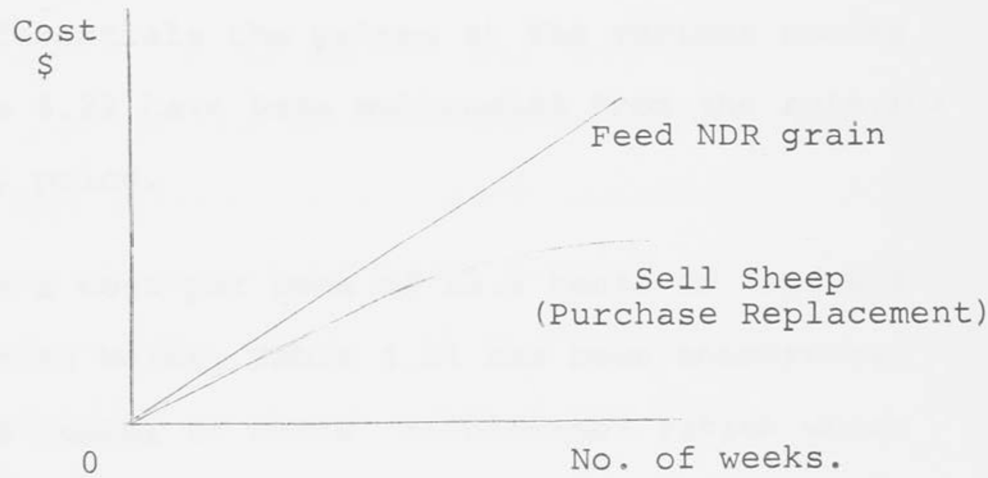
Figure 4.6

Hypothetical curves showing the cost of selling a sheep (and purchasing a replacement x weeks later) and the cost of keeping the sheep and feeding it NDR grain for x weeks.

4.6.1



4.6.2



4.6.3

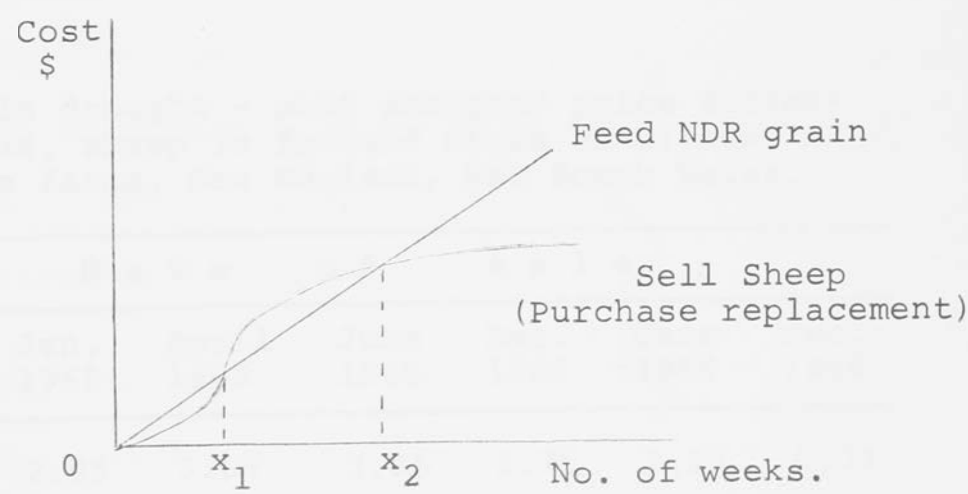


Table 4.22

Prices of sheep in forward store condition, sample farms, New England, New South Wales.

	Date of sales					
	Jan. 1965	April 1965	June 1965	Dec. 1965	June 1966	Dec. 1966
Old ewes $	3.50	2.50	2.50	3.80	3.60	5.55
Young ewes $	7.65	6.20	5.85	7.20	6.75	10.33

Table 4.23 derived from Table 4.22, gives the "within drought - post drought" price differentials for sheep sold at different stages of the drought. To obtain the differentials the prices at the various months listed in Table 4.22 have been subtracted from the relevant December, 1966, price.

Based on a cost per week of 13.3 cents to feed NDR grain in New South Wales, Table 4.24 has been constructed setting out the number of weeks' maintenance ration which would correspond to the price differentials of Table 4.23.

Table 4.23

"Within drought - post drought" price differentials, sheep in forward store condition, sample farms, New England, New South Wales.

	Date of sale					
	Jan. 1965	April 1965	June 1965	Dec. 1965	June 1966	Dec. 1966
Old ewes $	2.05	3.05	3.05	1.75	1.95	0.00
Young ewes $	2.68	4.13	4.48	3.13	3.58	0.00

Table 4.24

Number of weeks' maintenance ration whose costs equal the "within drought - post drought" price differentials of sheep sold in the months shown.

	Date of sale					
	Jan. 1965	April 1965	June 1965	Dec. 1965	June 1966	Dec. 1966
Old ewes No. of weeks	15.4	22.9	22.9	13.2	14.7	0
Young ewes No. of weeks	20.1	31.1	33.7	23.5	26.9	0

The "drought survey" carried out by the B.A.E. [10 p.24], gives expenditure on "fodder costs per sheep equivalent carried". It is pointed out that these figures "do not include the value of stored fodder fed out". In the high rainfall zone, which includes the New England area, average expenditure per property on fodder per sheep equivalent over the period 1964-65 to 1966-67 was $1.42. Comparison with the price differentials in Table 4.23 shows that this was less than any of the price differentials listed. Table 10 (op. cit. p23) shows that the value of fodder stored in the New South Wales high rainfall zone was only about one-ninth of the value of fodder purchased. The comparison would still hold if the $1.42 were increased by this proportion.

However this is not conclusive, as what one really wants to know for a post hoc assessment is how much NDR feeding would have been saved by selling a sheep at each of the dates listed. This is not obtainable from average figures. For instance, there is a relationship between the time sheep are sold and the amount of NDR feeding which would be saved. The earlier the sheep is sold the smaller is the amount of feeding needed. So, other things being equal, the sale of a sheep early in the drought would have tended to save more than $1.42 and a sheep sold late in the drought, less than $1.42. Also the figure of $1.42 and the average number of weeks' feed per sheep in the New South Wales high rainfall zone of 25.6 weeks (op. cit. p22 Table 9) indicate that sheep were not continuously fed a full maintenance ration from January 1965 to December 1966. It is not clear from this data how much feeding would have been saved by selling sheep at different times in the drought.

The argument has been put that purchased feed should be given when necessary to maintain a nucleus of the flock. The figures considered in this section, while not proving this conclusively, suggest that in the drought considered and at the prices which occurred, it could well have been cheaper to feed young ewes than sell them. The price differential for sales of young ewes at January, 1965, was more than twice the average expenditure of $1.42.

The practice as indicated in the B.A.E. report is in many cases to treat the two as complementary rather than competitive. "Less essential" sheep may be sold while the nucleus is fed; sheep to be sold may be fed to keep them in reasonable condition for sale. However more information than that given in this section would be needed to make a comparative assessment of selling sheep and feeding them.

4.3.4 Comparison of the Cost of Feeding NDR Grain with the Cost of letting sheep die.

Empirical analysis has been carried out in order to obtain insight into the economies of feeding sheep NDR grain in a drought, as compared with allowing mortality. Costs of feeding sheep NDR grain have been compared with the value of sheep which would thereby be kept alive. Data for the analysis have been obtained from results of drought feeding experiments conducted on sheep, where these results were readily available.

To convert experimental results to a form suited to current purposes, levels of mortality have been related to two causal variables; the number of food-units consumed per week, and the length of time sheep were on this ration. Mortality levels measured as the percentage of original sheep numbers which died per week, can be regarded as forming a response surface with the number of food-units per week and the length of time at this level of feeding as causal variables. In the brief analysis carried out here, two cross sections have been considered in this response surface. These have been represented in Figures 4.7 and 4.8 as curves, one where the given level of feeding is continued for six months, and one (considered very briefly) where the level of feeding is continued for three months.[17] Experimental results have been considered only for relatively young, dry sheep.

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(17) The possibility of variation through time in the number of food-units available from the pasture is ignored here as consistent with the experiments on which Figures 4.7 and 4.8 were based.

Experiments whose results have been pooled to construct these curves were not carried out with this purpose in mind and are not entirely homogeneous. However, a first approximation to the slope of this curve has been obtained which enables tentative empirical conclusions to be drawn. These empirical conclusions while tentative, seem to throw considerable light on why the feeding of sheep has recently been observed to be applied as a drought strategy.

Figure 4.7 gives an analysis of experimental results where a constant number of food-units per week were fed over a period of six months.[18] The curve MN relates the percentage mortality per week (a percentage of the initial number of sheep consuming this number of food-units) to the number of food-units per week. The slope of the line CD is determined by the ratio of the cost of NDR grain per sheep-week to the value of a sheep prevented from dying. The slope, which is negative, equals CO/OD where the monetary saving in reducing the mortality percentage by CO per week equals the cost of feeding OD units of NDR grain per week. A slope with a larger absolute size would represent a monetary saving in reduced mortality which exceeded the cost of NDR feeding. Similarly a slope of smaller absolute size than that of the line CD would represent the position where the monetary

(18) For detailed calculations see Appendix V.

saving through reduction in mortality was exceeded by the cost of NDR grain. At an NDR cost of 15 cents for 5 lbs. of wheat, one food-unit costs 4.125 cents. At $10 replacement cost for a young ewe, an increase of one food-unit per week would need to decrease mortality rate by 0.41 per cent per week to break even.

A tangent with a slope of -0.41 would touch the curve in Figure 4.7 approximately at point P. This suggests that if the number of food-units available over a period of six months is less than three per week, sheep replacement cost is $10, and the cost of NDR grain is 4.125 cents per food-unit, it would be worthwhile to increase the number of food-units per week to about three. This analysis ignores any extra labour cost and wool receipts associated with an increase in the number of food-units per week. Any labour cost incurred is likely to be associated with the decision to feed, and is not likely to vary significantly with variation in the number of food-units per week.

Extra wool receipts from extra feed though small compared with the value of a sheep saved would vary with the number of food-units per week. These if quantified could be deducted from the cost per week of NDR feed and so would change the slope of CD. The experimental evidence is that the increase in wool production per head over a 26 week period might be of the general order of 1 to 2 lb. of wool. If the price of wool is taken at 40 cents per lb. the saving is from about one and a half to three cents per week. This would cause CD to have a slope of a smaller absolute size and the point of tangency P to move to the right. It would pay, if necessary, to give supplementary NDR feed to bring the number of food-units per week to between three and four. At four units per week the experimental evidence is that the slope of MN is zero.[19]

Assume that instead of giving feed additional to that available in a drought the practice is followed of putting the sheep on a full maintenance ration and that the criteria to be used are just the cost of NDR grain at the farm and the value of the sheep saved. Mortality, if the sheep had been left on the drought affected pastures, would have had to be at a certain level or greater to make this worthwhile. If the cost of 5lb. of NDR grain per sheep-week is 15 cents and the replacement cost of a ewe is $10, this would mean that one and a half per cent of sheep fed NDR grain would need to be saved per week to break-even. From Figure 4.7, if this feeding is over six months, a mortality rate of one and a half per cent per week would occur if one and a half to two food-units were being consumed per week.

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(19) Mortality per week at four food-units per week is shown as zero. This is only an approximation, as even with an adequate maintenance ration some mortality, say five per cent per year, will still occur among young sheep. However expressed on a weekly basis, the figure would normally be small.

Figure 4.7

The relationship between the number of food-units per week and mortality per week as a percentage of initial number of sheep, 2 - 3 year old dry sheep, 6 months' period.

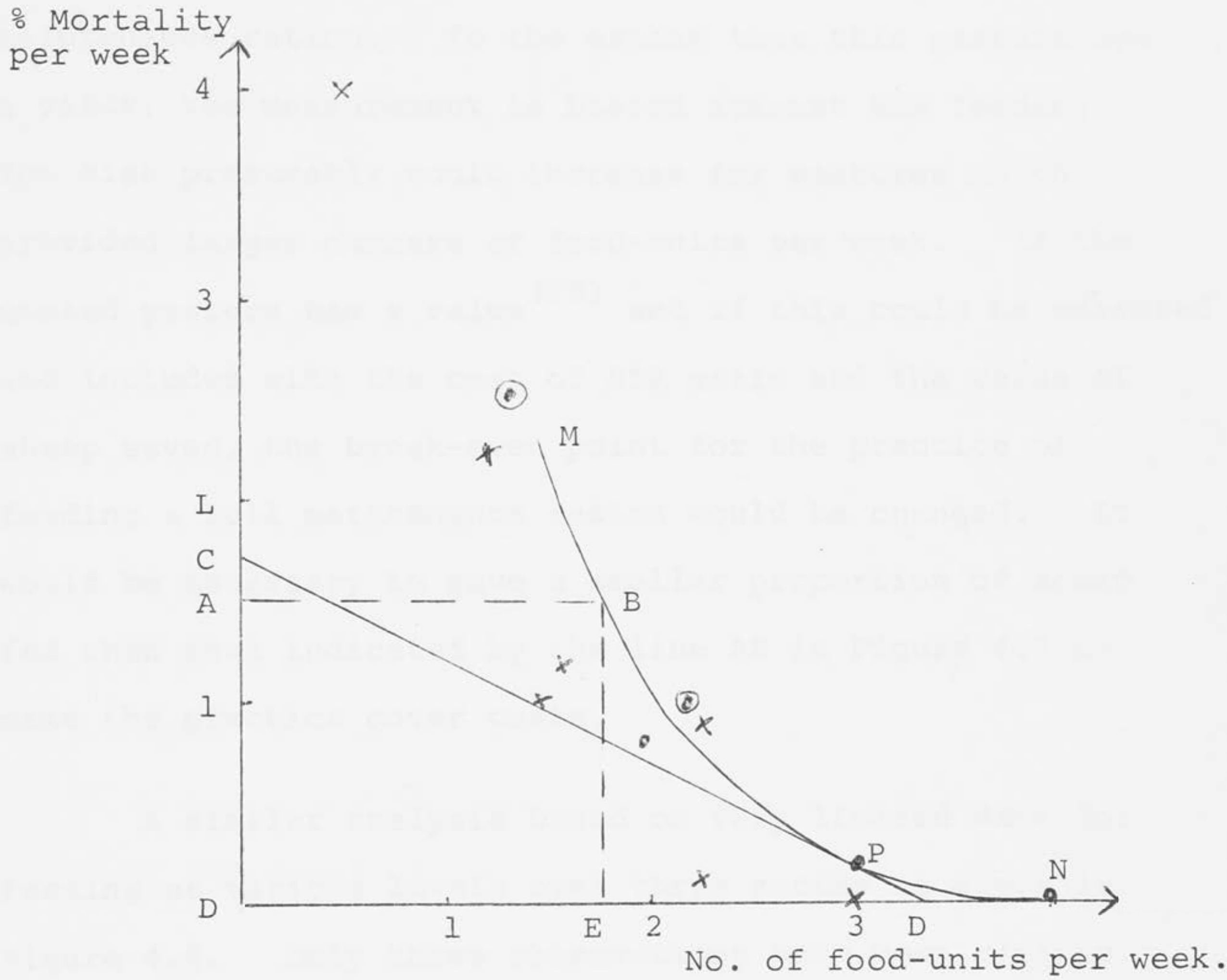
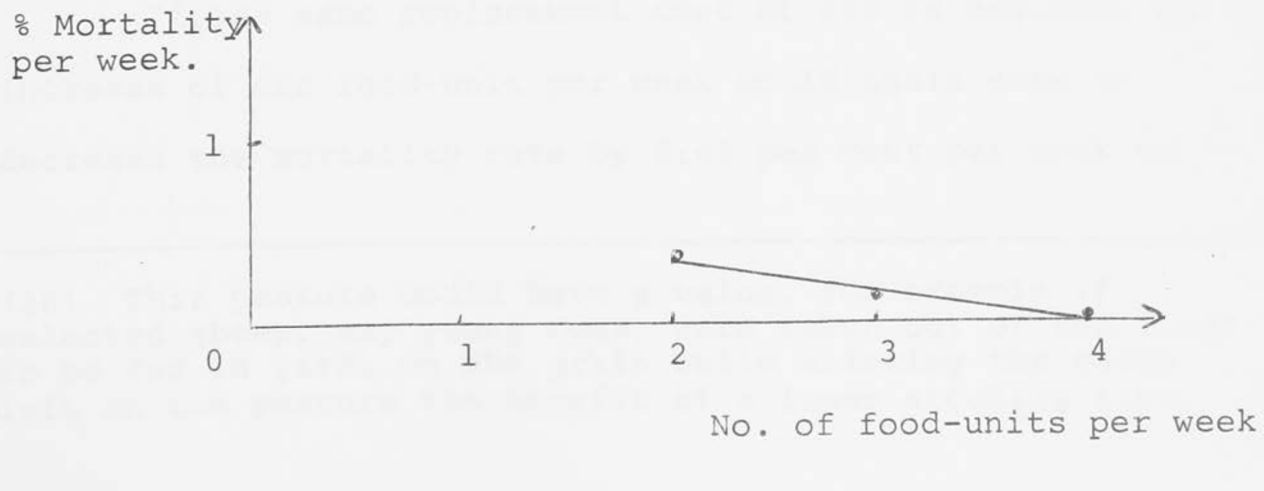


Figure 4.8

The relationship between the number of food-units per week and mortality per week as a percentage of initial number of sheep, 2 - 3 year old dry sheep, 3 months' period.



A point about this measurement however is that it compares only the cost of NDR feed and the value of sheep saved. In particular, no value is placed on pasture which is left unused as a result of putting the sheep on a full maintenance ration. To the extent that this pasture has a value, the measurement is biased against NDR feeding. The bias presumably would increase for pastures which provided larger numbers of food-units per week. If the unused pasture has a value[20] and if this could be measured and included with the cost of NDR grain and the value of sheep saved, the break-even point for the practice of feeding a full maintenance ration would be changed. It would be necessary to save a smaller proportion of sheep fed than that indicated by the line AB in Figure 4.7 to make the practice cover costs.

A similar analysis based on very limited data for feeding at various levels over three months is given in Figure 4.8. Only three observations have been plotted, for groups of sheep fed 2, 3 and 4 food-units per week. Based on this, a tentative curve, which happens on this data to be a straight line, has been drawn.

If the same replacement cost of $10 is assumed, an increase of one food-unit per week would again need to decrease the mortality rate by 0.41 per cent per week to

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(20) This pasture would have a value, for example if selected sheep, say young ewes, were taken out of the flock to be fed in yards on NDR grain while allowing the sheep left on the pasture the benefit of a lower stocking rate.

break-even. Over the range from 2 to 4 food-units, the tentative indication here is that the decrease in mortality rate per extra food-unit would not offset the extra cost of feed if the feeding is over 3 months only.

If periods of feeding are extended, eventually for any level of feeding below the maintenance level all sheep would have died. This will occur more quickly the lower the feed level. Eventually for long enough time periods, any supplementary feeding would fail to pay for itself in terms of the value of sheep saved. For example, if the pasture supplies no feed and 5 lbs. of grain are fed, the cost of NDR feed at the farm gate is about 15 cents per week. If this level of feeding is continued for approximately 67 weeks an outlay of $10 has been made. If the maintenance feeding of more than 67 weeks is needed at 5 lb. of NDR grain per week, then ex post the outlay has exceeded the value of the sheep.

Whether it will pay to feed NDR grain on a property rather than let sheep die, obviously depends on a number of factors. However, the above analysis suggests that if NDR grain is given to supplement any feed already available (including the case where this in fact means a full maintenance ration because no feed is available), then the NDR grain is likely to cost more than the value of sheep saved if feeding is for a period of 3 months, to cost less than the value of sheep saved whose feeding is continued for 6 months, and to cost more than the value of sheep after "prolonged" feeding. If it is assumed that a <u>full</u>

maintenance ration of NDR grain will be fed and if the pasture which is unused as a result of putting sheep on a maintenance ration of grain is given no value, then feeding NDR grain will only pay if the level of feed in the pasture is low enough to offer sufficient scope for preventing mortality.(21)

The above analysis is intended largely as an indication of a method by which experimental results can be analyzed to ascertain under what conditions, if any, feeding would pay. Experiments drawn on were not constructed with this form of economic analysis in mind. Analysis here was limited with respect to the effects of such things as breed of sheep, body-weights, effects of pregnancy, etc.

However if the relative shapes of the curves in Figure 4.7 are basically correct for a period (here 6 months) of sub-maintenance feeding, there is a range over which it would pay to increase the level of energy intake. This range is from zero up to the intake corresponding to the point of tangency of curves MN and CD. Over this range the slope of MN is larger in absolute size than that of CD, both slopes being negative.

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(21) In Powell's estimates [3 pp. 183-185], while the cost of feed is at full maintenance level, measuring the difference in cost between a situation with full maintenance ration and one with zero ration, the benefits of feeding are associated with a difference in mortality of 2½% per month. The difference in mortality clearly is not associated with a difference between zero ration and full maintenance ration, unless the droughts were short enough for most sheep to survive on initial body reserves. No value was placed on unused pasture feed.

A pertinent question is to what extent the curves of Figure 4.7, if valid experimentally, would apply in practice. Davidson and Martin have discussed the relationship between experimental results and results on farms for both livestock and crops. [37] The discussion found that the ratio between yields obtained on farms and in experiments decreased as the timing of operations became more important or as the scale of operations on the farm became larger. The article dealt with crop and livestock production. The author knows of no literature relating mortality on farms to mortality in experiments. If, because of the importance of the timing of operations, mortality is higher on farms for all levels of maintenance feeding, the curve of Figure 4.7 would move to the right. If the new curve has exactly the same shape as that of Figure 4.7, a new curve MN^1 could be drawn x units to the right of MN. A line CD^1 could also be drawn x units to the right of CD. This would be tangential to MN^1 at a point, say P^1, x units to the right of P. The argument applied to MN and CD is unchanged except that P^1 is associated with a higher number of food-units per week than P.

It may well be that the curve relating the level of mortality to the number of food-units, although situated to the right of MN is not parallel to it. Mortality on the farm may be higher than that in experiments, particularly over certain ranges of food-units supplied per week. A possible hypothesis here is that if this is so it would occur at smaller levels of energy when conditions were more rigorous. If this hypothesis is valid, this would increase the steepness of the slope of MN^1 to the left of P^1. This would only increase the discrepancy to the left of P^1 between the slopes of MN^1 and CD^1 and put the economic argument on firmer grounds.

The effect of this on the economic results obtained would be that on the farm it would pay to feed up to a level corresponding to P^1, where P^1 was to the right of P. That is it would pay on the parameters used to feed somewhat more than 3 food-units per week.

CHAPTER 5

Conclusions

The empirical results obtained can be considered in three parts: (1) the manipulation of grain stocks and flows at the State level and associated costs; (2) possible benefits at the farm level with some aggregation to estimates for the 1964-66 droughts in Queensland and New South Wales; and (3) the interaction of these two. Other aspects of the problem are finance and operational control of such a scheme.

5.1 National Drought Reserve Systems, and Costs and Benefits.

If low costs are taken as the sole objective the quantity which should be held between years was small, with deficits in grain supply in a particular State met by imported grain. However because of the possibility of other objectives or constraints being important, such as drought year grain supply, preference for additional autonomy within a State as far as NDR grain is concerned, and storage capacity of grain, a number of alternative policies were examined other than those at or near the least-cost policies. This gives quantitative information for a variety of policies.

Estimated NDR costs varied according to location and type of policy selected. However if the price of grain is taken as $45 per ton, policies were available at 4.125 cents and less per food-unit. These policies seem within the constraints of drought year grain supply and storage.

Apart from giving estimates of various measures of effectiveness, the models developed in the simulations gave attention to practicability. The association of the model with first decile droughts means that there is scope for simplicity in application. Accumulated rainfall in different localities can be used as an indicator of impending "drought conditions".

The models developed would apply directly to a historical series of droughts developed using criteria other than the first decile. For example, a series of second decile droughts could be studied in the same simulation model, as these would occur more frequently it is expected intuitively that storage and interests costs would be lowered. The first decile droughts have been observed to correspond fairly well with "popularly declared" droughts provided the area covered by the first decile drought is sufficiently large. However smaller droughts were retained in the sequence of first decile droughts. By definition, rainfall deficiency in affected areas is just as marked in localized first decile droughts as in larger ones; also they occur more frequently. These two factors seemed to warrant their inclusion.

A feature of the use of first decile droughts is that although droughts occur in a particular locality only once in ten years on average, a first decile drought occurs somewhere in a State as a whole much more frequently, for example, about one year in two in New South Wales.

This tends to make turnover of grain much more rapid than would be the case with a drought reserve kept on an individual farm. As a result, carrying costs (both physical costs and opportunity costs) would be reduced.

The NDR schemes purport to give a guaranteed supply during first decile droughts. Droughts in other years, for example, "chronic droughts" are assumed to be met by other means. A side effect however of an NDR based on first decile droughts would be that unused grain for the NDR would become generally available at the time chosen to relinquish grain. The effect of this would be to create some flow of the grain onto the market at a time other than the time of normal grain intake. This could be of use in meeting drought demands for grain other than those associated with first decile droughts.

Costs measured in the model, (i.e. cost of grain, transport cost, opportunity cost and the cost of storage) are on the basis that the grain will be kept in existing silos. This assumes that sufficient storage capacity is available in a "convenient" locality. In the grain silo system, silos exist alongside railway lines in the grain producing areas, as sub-terminals nearer the coast, and as terminals at the coast. The analysis envisages that grain would be held in nearby silos during an existing drought where a drought has already been declared when the grain is put into NDR, but more widely dispersed when the grain is being held to meet possible demand in later droughts.

Possible benefits of an NDR have been studied giving emphasis to the fact that any implementation of an NDR would depend on decisions made by graziers acting as individuals.[1] On recent observation it is not likely that they would try to apply the feeding of NDR grain as a single strategy, although observations in recent droughts suggest it could be the most important strategy. In studying the possible benefits of an NDR, comparisons were made of the economies of feeding NDR grain with those of adopting other strategies.

In making such comparisons, one has the difficulty that comparisons in practice have to be made on an ex ante basis and under uncertainty. Decision making depends on individual probability distributions, for example, drought length. In view of the size of the task of including numbers of individual probability distributions in a national drought reserve study, ex post analysis was made of costs associated with different strategies in the droughts from 1964 to 1966 in New South Wales and Queensland.

A comparison was made between actual outlays on feed where these were at prices per food unit higher than that estimated for NDR grain, and the outlay which would have been necessary if these purchases had been replaced by an equivalent number of food-units of NDR grain. This estimate was made first for a sample and then for the population of farms in the drought affected areas. An estimate of the reduction in expenditure which would have been brought about if NDR grain had been substituted for

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(1) A recent study by Schechter and Heady of grain storage in America, although not associated with drought feeding, was similar in approach to the current study in that it used simulation and a split-up of the problem into aggregative and "micro" components. [44]

other sheep feeds, where it had an advantage in cost per food-unit, was approximately $4 million. A feature of this type of expenditure reduction is that it should be possible to achieve it without prior knowledge of how long feeding will be necessary.[(2)]

Agistment as another strategy was also examined. Here costs can be split into costs of transporting sheep and agistment rental. These two components were put into one dimension by measuring the number of weeks' agistment which would be necessary for the total cost of agistment, that is transport cost plus rental, to break-even with the cost of feeding NDR grain over the same period. For the farms in the sample frequency distributions were obtained of the number of weeks' agistment required to break-even with feeding NDR grain. The proportion of the frequency distribution related to comparatively short agistment periods indicates that for the transport costs and rental costs observed, this strategy could be cheaper than NDR feeding in most droughts. However there remains the question of how much agistment is available together with some risks involved.

A comparison of NDR feeding with drought sales of sheep indicated that NDR feeding compared fairly well. However, for the flock as a whole, it is likely that the two strategies would both be adopted with a tendency to sell old sheep and non-breeders and to feed breeders.

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(2) A transfer of benefits is involved between sellers and purchasers of feed. In the short term probably only the purchasers would be in a drought-affected area.

A comparison can be made between feeding sheep NDR grain and allowing the risk of mortality. As has been shown there are a number of factors involved so that depending for instance on the length of time feeding was required, the cost of feeding could be cheaper or dearer than letting sheep die. For short periods of feeding allowing sheep to die may be cheaper because of low initial mortality rates; over a longer period of feeding it could be cheaper to feed sheep; over long periods of feeding (of over a year) it would again have been cheaper to allow deaths to occur. The decision as to whether to feed or allow sheep to die would depend on the decision makers' personal probability distribution of the length of feeding needed. The value of a sheep was taken to be a replacement cost of $10.

A point which bears mention here is that the replacement cost of $10 used when drought feeding costs are being compared with letting sheep die is itself likely to depend on some sheep having been kept alive by drought strategies. The $10 is consistent with observed recent post-drought prices ruling after a drought in which sheep saving drought strategies had been freely applied. Failure to apply these strategies, among which the feeding of sheep was prominent, would have resulted in much larger losses of breeders with slower post-drought recovery and higher post-drought prices.

From the foregoing discussion it seems likely that there would be a widespread use of NDR grain on individual farms applied where it was thought this would be advantageous.

An advantage of the NDR is that the cost of the feed and transport would not be incurred unless an individual grazier made such a purchase of grain, which it is assumed he would not do unless he thought the benefits to him would exceed the cost. The other components of cost, storage and opportunity costs, are incurred before purchase by individual graziers, but are much smaller.

Another component of costs not measured in the simulations would be administrative costs. Administration would consist of declaring drought areas, administering the holding of grain in designated locations, and supplying grain to drought areas on demand. Administration costs would probably be fairly fixed in total amount, so that costs per unit of grain would decrease with the number of bushels handled through the scheme.

5.2 Finance.

The financial arrangements which would be necessary in such a scheme have not been examined in depth. There are two stages envisaged in the change of ownership of NDR grain. Firstly, when the grain in official silos becomes part of the NDR and secondly when it is transported to individual farms.

The financing of the first change of ownership would probably be related to financing arrangements associated with non-NDR grain held in silos. A point here is that those NDR policies which require less holding of grain between years could perhaps be more readily financed. The transfer of the grain from the NDR to the farm also involves the question of payment based on costs associated with the grain obtained. Graziers obtaining grain through the scheme would be expected to pay costs which fully recover the costs of operating the scheme. These include the cost of the grain itself, transportation costs, including interstate transport if incurred, to a centre in the drought shire, costs of storing the grain including variable costs as outlined by Freebairn [21] and interest on capital tied up in the grain. The cost to the grazier could be put at a fixed level through the drought. This would give the grazier the advantage of prior knowledge of drought prices, as suggested by Morley and Ward. [46] A wide range of grain costs was considered in the simulations.

Regarding payment to grain growers for grain put into an NDR it is assumed that these growers would obtain a first advance on this as on other grain accepted into official grain storage. A possibility is that the balance of payment above the first advance could be made to growers when the grain is designated as being part of the NDR. The NDR authority could pay the full cost of the grain when this is acquired by the NDR, with this outlay plus interest thereon to be recouped at a later date when the grain is purchased by graziers in a drought.

Obviously in order to purchase the grain from grain growers the authority would need working capital. This could perhaps be obtained from graziers as an interest earning revolving fund. Alternatively interest bearing loans could perhaps be obtained from the Central Bank. The simulations have assumed that grain is held in the NDR on a revolving basis with an upper limit to the length of time held. This could be a relevant factor in decisions regarding the mechanics of a revolving fund or the term of a loan.

5.3 Operational Control

Operational control of the NDR simulation model of Chapter 3 would include the following:

(1) Declaration of "droughts" for NDR purposes, that is declaration that NDR grain is guaranteed to be available.

(2) Obtaining up-to-date estimates each year of NAS(I) and MNAS.

(3) Controlling inputs of grain into the NDR during the normal grain intake period. The intake formula of the simulation model was

Grain intake in year I = D * NAS(I) + E * MNAS.

(4) Selecting values of D and E which for the level of expected demand for NDR grain per adult sheep in the drought area give desired levels of costs, grain intake, storage, etc. In initial implementation there would be no records of demand per sheep for an NDR as such, although recent purchases of grain in droughts would be a guide.

(5) Meet orders for NDR grain either from within-State grain stocks or imports from other States.

(6) Keep records of quantities of grain sold to declared drought areas. These can be related to the number of adult sheep in the declared area to obtain data on demand per sheep.

(7) Keep records of the different components of costs.

(8) Keep records of storage required and storage available.

(9) Adjust the levels of D and E if a difference in estimated demand is indicated by (6).

(10) Make payment to an Authority representing grain growers for grain taken into the NDR, and collect payment from graziers for grain supplied during drought. Keep the appropriate records.

5.4 General

The National Drought Reserve scheme studied here seems to be operable and likely to give average costs of grain which could allow opportunities for feeding to be carried out by the individual grazier with costs less than benefits.

The NDR purports to give a guaranteed supply of grain to meet drought demand, held as far as possible in rationalized locations. Although attention has been given to cost minimization of a particular type of NDR policy, clearly this is not the only type of NDR policy. Alternative designs could quite well exist which could prove more suitable. Attention might be given to the use of short-term forecasting. Distinction can be made here between what Brown [32] calls "predictions" and what he calls "forecasts". "Predictions" take account of any relevant knowledge, for example of current pasture conditions, and on-farm fodder reserves, whereas "forecasts" would be based on statistics of past drought demand levels. A forecasting technique which could be relevant here is the "exponentially weighted moving average". [33, 34] On the other hand it could prove to be advantageous in practice to develop an NDR system which incorporates short-term predictions. These were not included in the simulations, which concentrated on exploring the performance of systems with a fairly wide range of combinations of demand levels and grain input levels.

Inclusion of short-term predictions in a simulation of this type could take the form of assuming a distribution of errors in forecasting demand for grain per sheep in a drought and considering this when selecting grain input policies.

In times of excess grain supply the NDR scheme would tend to dispense with deliberately holding grain between years. Costs of storage allocated to the scheme could be reduced or eliminated, where this grain would have been held in any case other than as a drought reserve.[3] The function of the scheme would then be largely confined to holding grain in the appropriate localities, meeting orders, keeping records of costs and demand levels, and providing information for extension work. Benefits of a rationalized control of a plentiful grain supply could take the form of reduction in transportation costs by holding the grain near current droughts or by encouraging growers to replace other drought feeds where these are dearer than grain.

Regarding various possibilities of improving the design of NDR systems, this would seem to be a desirable part of implementation of such a scheme. The basic aim of the research here was to try and find whether an NDR scheme was economically feasible. This is shown to be so if only one system is shown to be economically feasible.

Resources permitting, further research could be directed towards NDR systems based on Australia as a whole rather than on individual States. Detailed study could be made of the opportunity

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(3) A factor which may cause grain to be held between grain intakes is the capacity of railway rolling stock needed to move grain to the terminals at the coast.

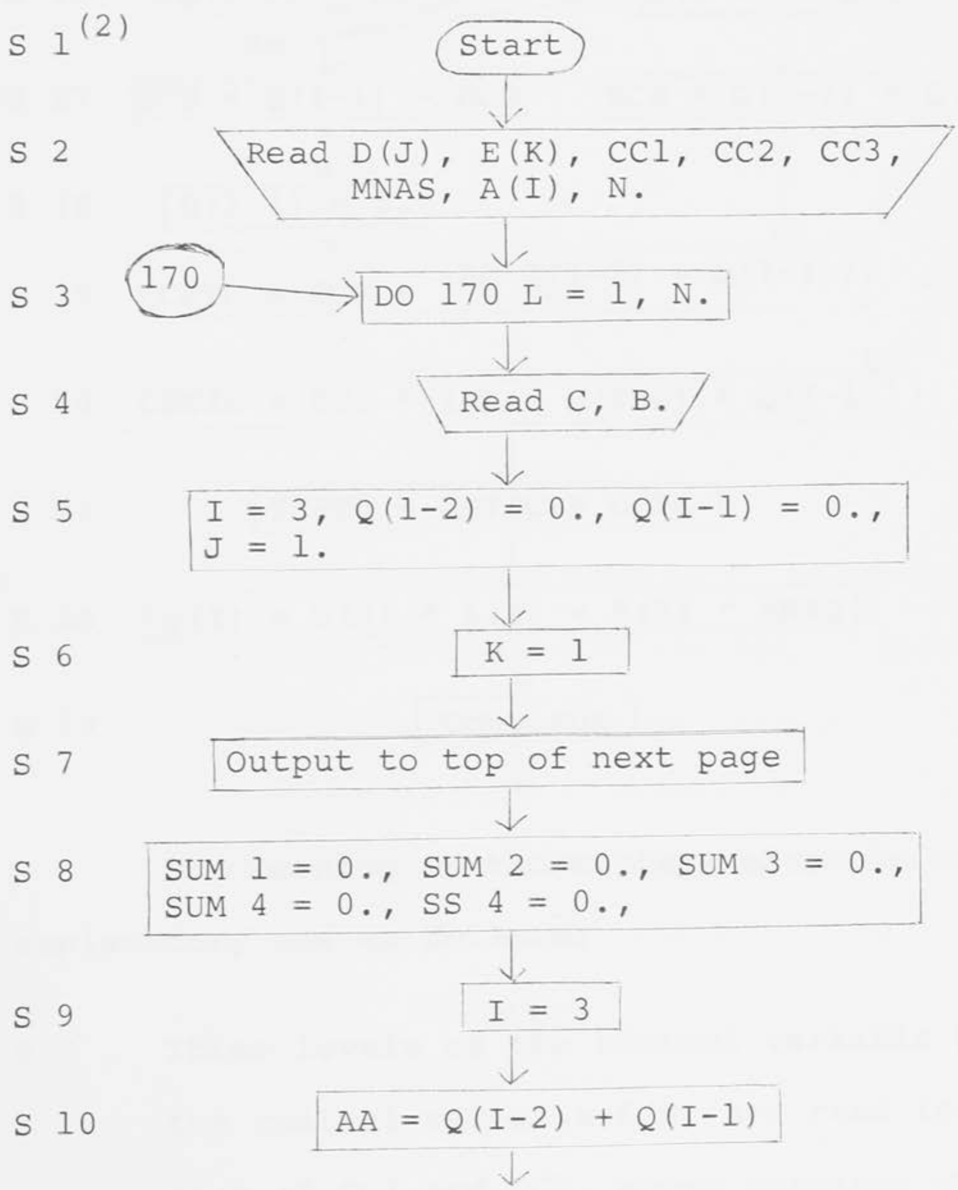
cost of removing grain from the normal marketing flow. If an NDR scheme were implemented the information acquired regarding the probability distribution of demand per sheep for NDR grain could lead to further refinement in the inventory policies used. A synthesis could also be sought with individual farms as the building blocks to build up a picture of the impact of an NDR, given the existence of alternative drought strategies. Such a study if feasible could measure the aggregate net benefit including consideration of the effect of any resultant increase in wool industry production on net returns, given the elasticity of demand.

However it seems clear that it would be possible to implement a scheme which would meet constraints of grain supply and grain storage, which would allow interstate imports, be operational, and supply grain to graziers in droughts at a cost which would allow individual net benefits. With first decile drought declaration, the costs of holding the grain are not large, so that provided administration costs per bushel are not large, the main component of cost occurs when a grazier decides to purchase grain, presumably to achieve an individual net benefit.

Appendix I.

Flow Diagram A1 describes a portion[1] of the "basic" simulation model - NDR based on wheat; drought years from September to September; two grain input control variables D and E; a 3-pool model. A discussion of the flow diagram follows.

Flow Diagram A1



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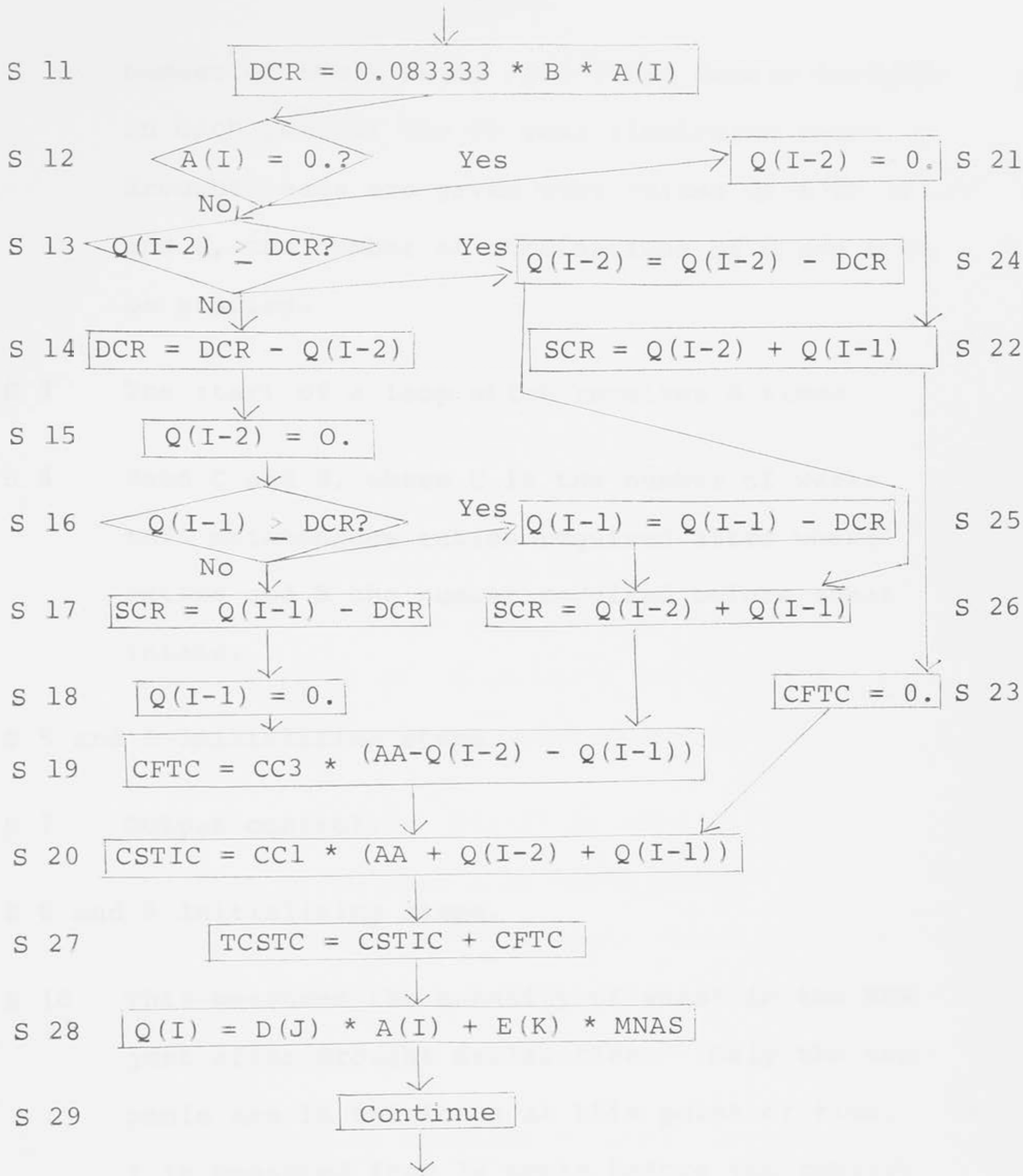
(1) The full programme is not covered by this flow diagram as this would be repetitive. Computer instruction for the period December to September are very similar to those for the period September to December to which this flow diagram refers.

(2) S 1, S 2, ... are abbreviations of Step 1, Step 2, ...



The meaning of those steps which do not seem self-explanatory are as follows:

S 2 Three levels of the control variable D(J) and of the control variable E(K) are read in; one value each of CC1 and CC3, whose meanings will be explained in the discussion regarding S 19 and S 20; a value of MNAS, the "maximum" number of adult sheep; A(I), with I varying from 3 to 32, where A(I) is the number of adult sheep in a first decile drought in each year of the 30 year simulation (non-drought years are given zero values of A(I)); and N, the number of combinations of C and B to be studied.

S 3 The start of a loop which revolves N times.

S 4 Read C and B, where C is the number of weeks full maintenance ration required after wheat intake and B the number required before wheat intake.

S 5 and 6 Initializing steps.

S 7 Output control.

S 8 and 9 Initializing steps.

S 10 This measures the quantity of wheat in the NDR just after drought declaration. Only the two pools are in existence at this point of time. Year I is measured from 12 weeks before the central point of time of wheat intake to 40 weeks after wheat intake. S 10 represents the start of a new year. The Q(I-1) in the equation was Q(I) at the end of the previous year, the Q(I-2) in this equation was previously Q(I-1), and what was Q(I-2) has now been eliminated.

S 11 The number of bushels of NDR grain demanded for drought feeding over the 12 weeks before grain intake is calculated as the product of the number of bushels required per sheep per week for a maintenance ration, the number of weeks ration demanded per adult sheep and the number of adult sheep in the area.

S 12 The test is made as to whether the number of sheep in declared droughts is zero in year I. If year I is not a drought year, the program moves through steps S 21, S 22, S 23 and S 20. If year I is a drought year, this program moves to S 13.

S 21 The grain in pool Q(I-2) is sold at the beginning of year I, if year I is not a drought year. With the 3-pool system, this grain would have been sold at the end of year I in any case, so keeping it during year I would serve no useful purpose.

S 22 The surplus or shortage of wheat in year I is calculated. Here there is a surplus equal to Q(I-1) as Q(I-2) has been put equal to zero.

S 23 The cost of feed and transport to drought areas over the 12 weeks before grain intake is put equal to zero.

S 20 The cost of storage and interest is calculated. CC1 is put into the computer as data input and is equal to (12 * (C1 * C3 + C2) * 0.5), where 12 is the number of weeks over which the cost is calculated, C1 is the cost per bushel of wheat, C3 is the opportunity cost allowed as a percentage per dollar-week of capital tied up in the grain, and C2 is the storage cost per bushel-week. The expression {(AA + Q(I-2) + Q(I-1)) * 0.5} is the average number of bushels in stock, AA being the number of bushels at the beginning of the 12 weeks' period and Q(I-2) + Q(I-1) the clearing stock.

S 13 If year I is a drought year, a test is made to see whether the wheat in pool Q(I-2) is sufficient to meet demand. If so, the program moves through steps 24, 26 and 19.

S 24 The quantity of wheat in pool Q(I-2) is reduced by the demand on NDR.

S 26 Surplus for year I equals Q(I-2) + Q(I-1).

S 19 The cost of feed and transport is calculated. The expression AA - Q(I-2) - Q(I-1) is the difference between opening stock and closing stock which difference is caused by transporting grain to drought areas. CC3 is the cost of wheat plus transport per bushel of wheat sent to drought areas.

S 14 If Q(I-2) is not sufficient to meet the demand, the program proceeds through steps 14 and 15 where the remaining level of demand is calculated and Q(I-2) put equal to zero.

S 16 The remaining demand is matched against the remaining pool Q(I-1). If there is not sufficient wheat, S 17 will calculate the level of stockout, and in step 18, Q(I-1), which in physical terms cannot be negative, is put equal to zero. The other path, through steps 25, 26 and 19 does not introduce any new procedure or concept.

S 27 The total cost for the 12 weeks' period before grain intake is calculated.

S 28 The level of grain input in year I is equal to the number of sheep (if any) in declared droughts in year I multiplied by the level of D(J) currently being examined plus the "maximum" number of adult sheep multiplied by the level of E(K) currently being examined.

In this abbreviated flow diagram only one loop is explicitly referred to, the one commencing at step 3. In the actual program there are three further loops, developed to study different levels of J, K and I. The four loops allow a number (N_1) of demand combinations to be associated with a number (N_2) of the control variable combinations giving a total of $N_1 * N_2$ combinations each over a simulated 30 years. It was found that with N_1 equal to nine (three levels of C the demand per sheep over the 40 weeks after grain intake, combined with three levels of B, the demand per sheep over the 12 weeks before grain intake) and N_2 equal to nine (three levels of grain input control D(J) with three levels of grain input control E(K)) a simulation of 30 years for a State, e.g. New South Wales, carried out on an IBM 360 computer, took about three minutes computer time. This made this program operationally attractive as a means of studying the effects in different States of different combinations of NDR grain input policies and demand levels. All programs were written in FORTRAN.

Appendix II

Some variations of the "basic" simulation model given in Appendix I.

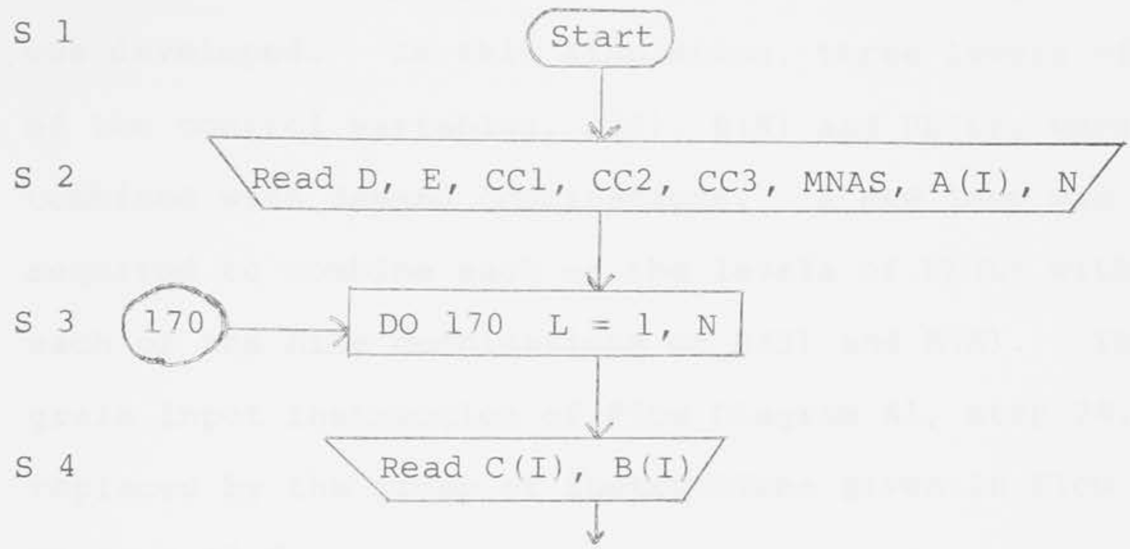
A slight variation of the program discussed in Appendix I allows the performance of different input policies to be examined when demand per sheep is no longer treated empirically as a constant through all droughts in a given 30 year run. The variation in the program allows an arbitrary number of 30 year simulations to be carried out in the one computer run, variation in a 30 year simulation in demand per sheep, but with only one combination of the grain input parameters, D and E, in the two control variable case.

In the empirical work on the NDR, the characteristic of different combinations of demand and grain input policies have been studied initially using a constant level of demand per sheep through a 30 year simulation. The results obtained using a constant level of demand per sheep were tested with demands per sheep varying stochastically during a 30 year simulation around the constant level as expected value.

Flow Diagram A2.1 indicates some of the modifications which were necessary in the "basic" program to fit the new requirements.

Flow Diagram A2.1

(Relates to a portion of the Flow Diagram A.1)

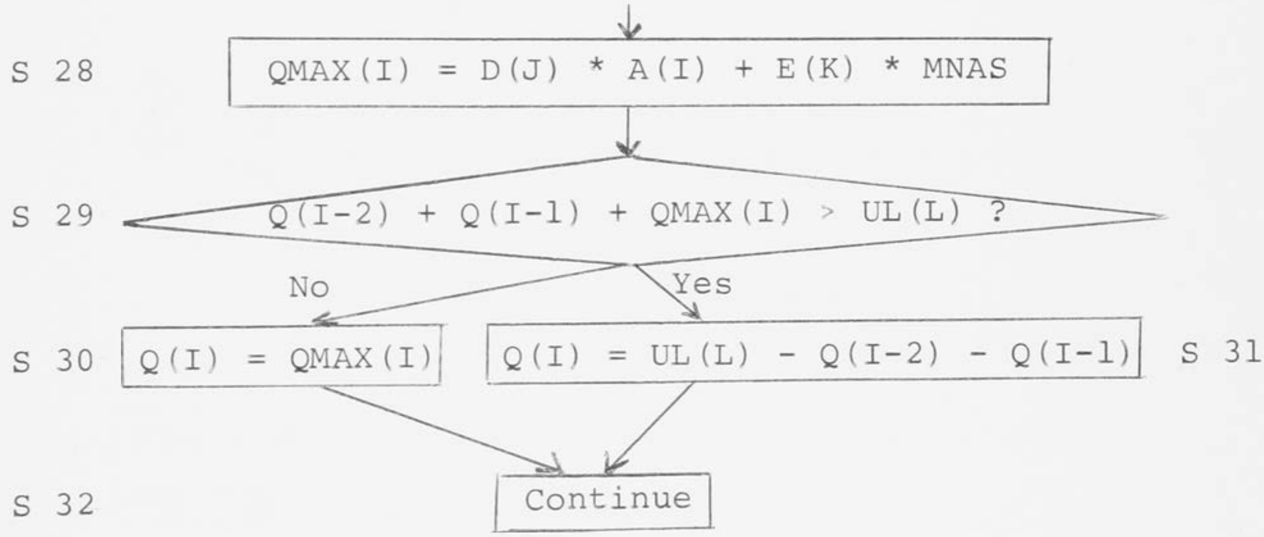


A comparison of steps 1 to 4 of Flow Diagram A2.1 with steps 1 to 4 of Flow Diagram A1 indicates the following differences. In step 2, instead of reading in the three levels of D(J) and E(K), the computer reads in only one value of both D and E.

The calculation of demand for the 12 weeks before wheat intake (see S11 of Flow Diagram A1) is now changed to DCR = 0.083333 * B(I) * A(I), to reflect the fact that demand per sheep, B(I), now changes between years. (A similar change takes place in the 40 weeks after grain intake.) The level of grain input in any year (see S 28 of Flow Diagram A1) is changed to Q(I) = D * A(I) + E * MNAS, as consistent with the fact that only one grain input policy, D, E, is now being considered in the one computer run.

In order to examine, for the three pool case, the performance with three control variables, another variation of the program discussed in Flow Diagram Al was developed. In this simulation, three levels of each of the control variables, D(J), E(K) and UL(L), were combined with demand combinations. A new loop was required to combine each of the levels of UL(L) with each of the nine combinations of D(J) and E(K). The grain input instruction of Flow Diagram Al, step 28, was replaced by the group of instructions given in Flow Diagram A2.2.

Flow Diagram A2.2



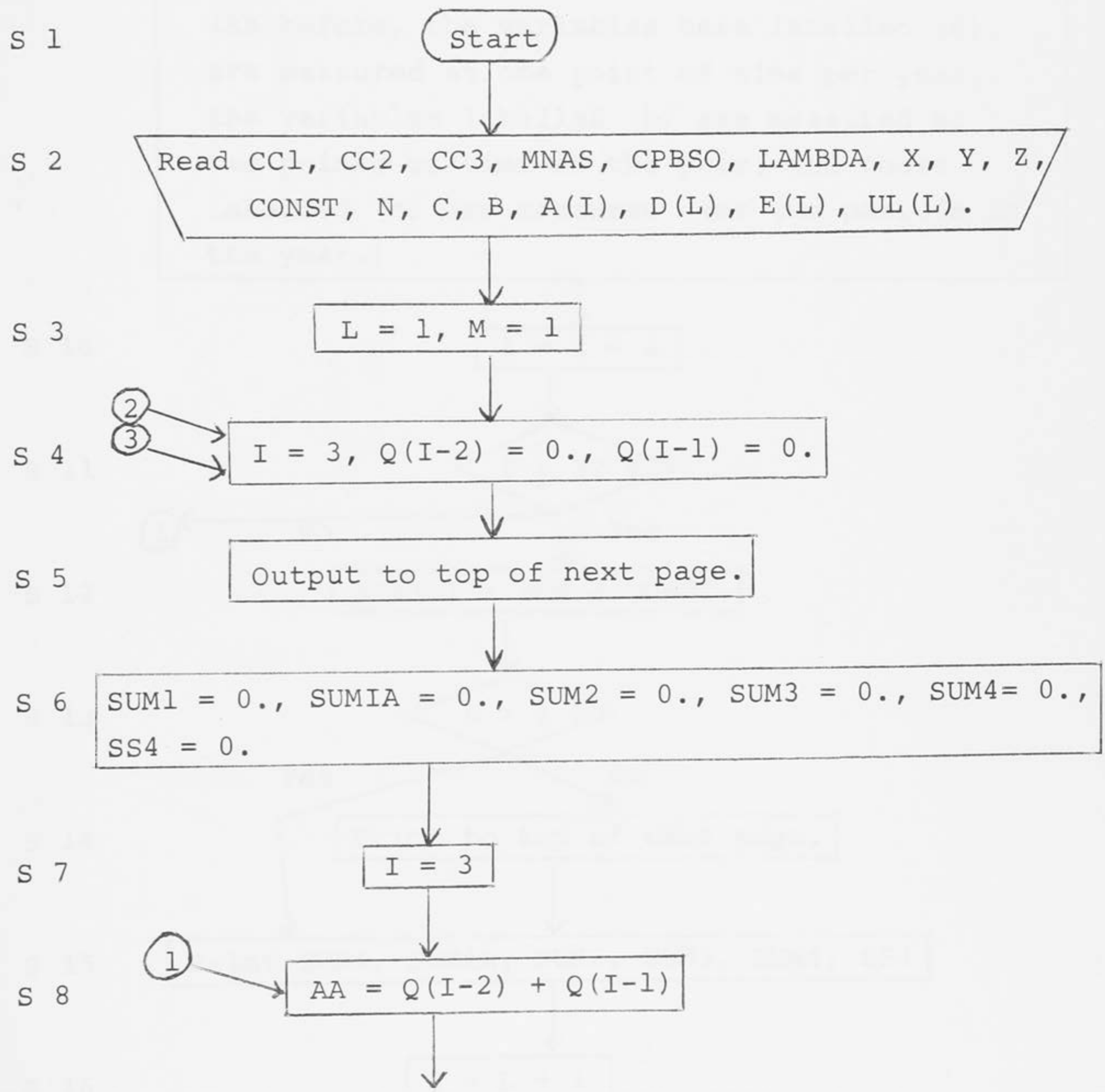
In these steps the maximum quantity of wheat which would go into NDR in year I if the upper limit is not effective, is calculated. Then this quantity is added to the quantity of wheat already in the NDR in previous pools to determine whether the upper limit is exceeded. If the limit is not exceeded the input in year I equals the maximum quantity, if it is exceeded, the input in year I is put at the amount which will put the total quantity in NDR at the upper limit.

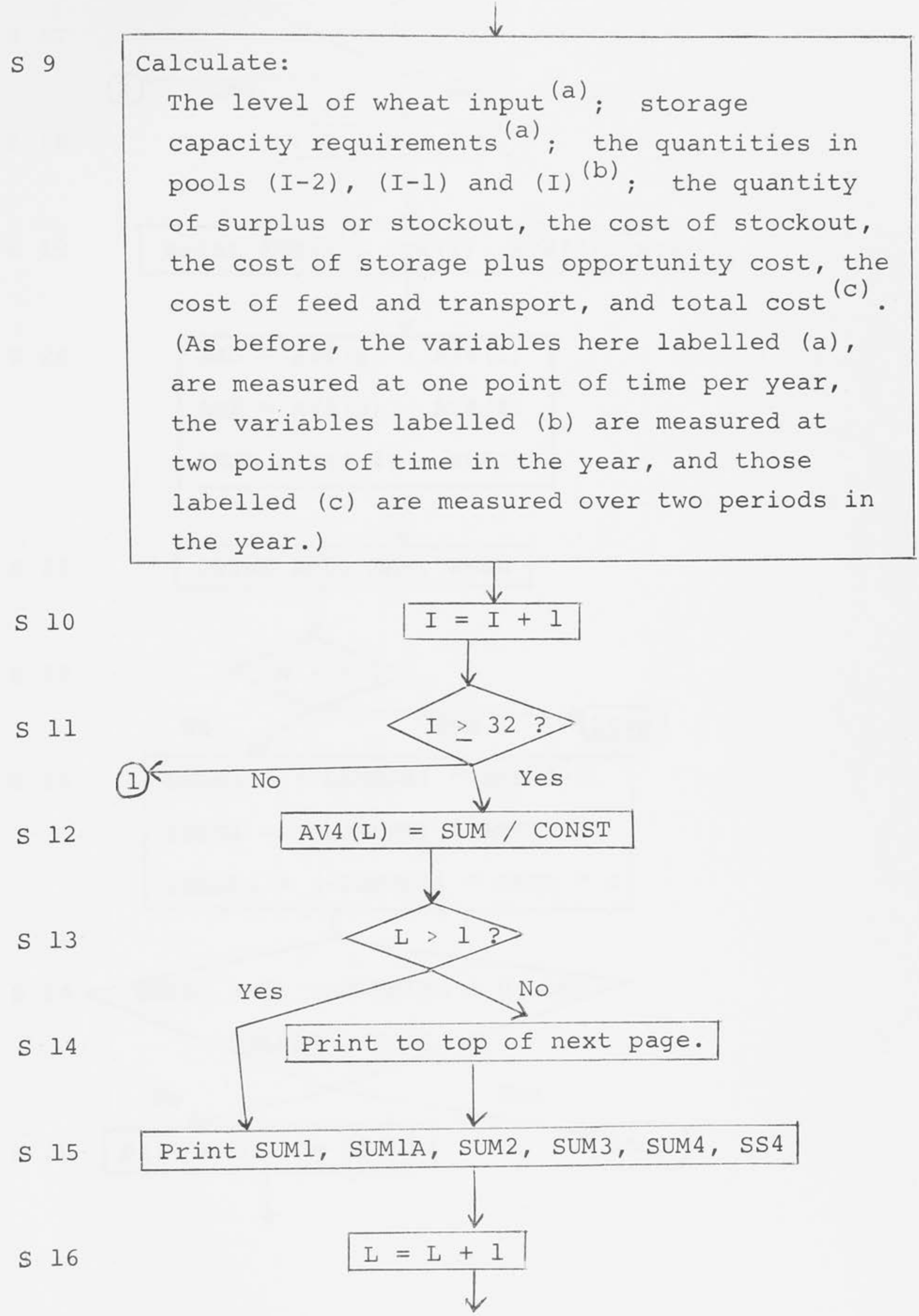
Programs for a "2-pool" system can be derived fairly easily from the corresponding "3-pool" system by eliminating Q(I-2) from the program, and carrying out any associated modifications.

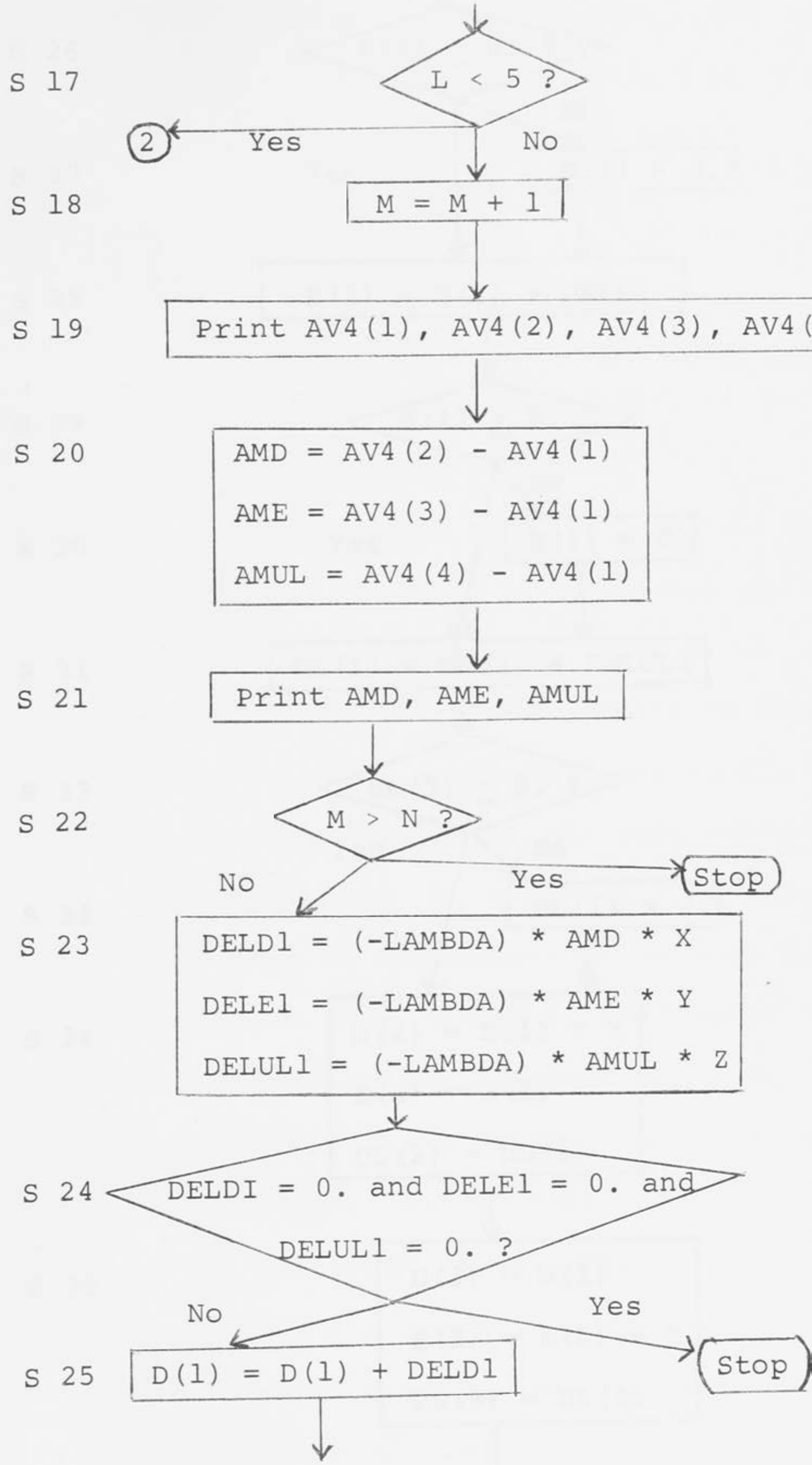
Appendix III

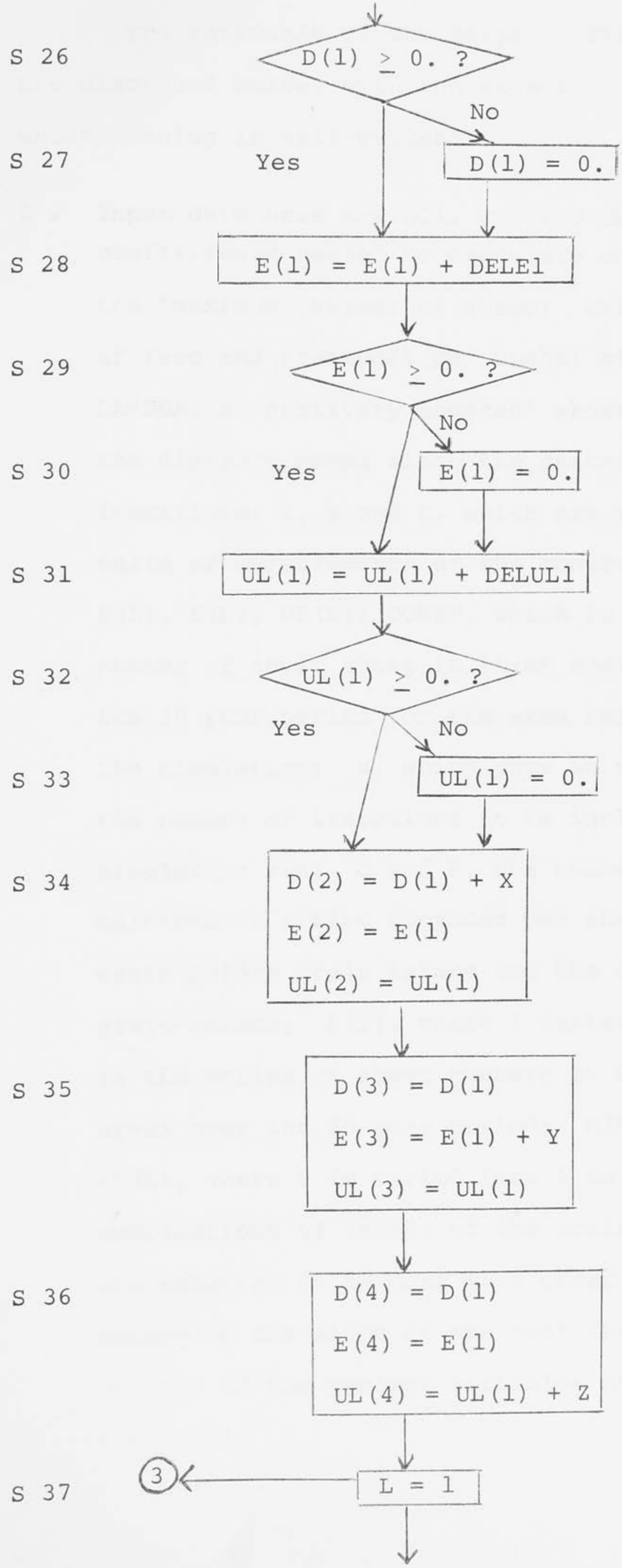
The following condensed flow diagram and accompanying discussion corresponds to the "steepest descent" program drawn up to search for the minimum cost NDR policy.

Flow Diagram A3.1




S 9
Calculate:
The level of wheat input(a); storage capacity requirements(a); the quantities in pools (I-2), (I-1) and (I)(b); the quantity of surplus or stockout, the cost of stockout, the cost of storage plus opportunity cost, the cost of feed and transport, and total cost(c). (As before, the variables here labelled (a), are measured at one point of time per year, the variables labelled (b) are measured at two points of time in the year, and those labelled (c) are measured over two periods in the year.)
S 10
I = I + 1
S 11
I ≥ 32 ?
1
No
Yes
S 12
AV4(L) = SUM / CONST
S 13
L > 1 ?
Yes
No
S 14
Print to top of next page.
S 15
Print SUM1, SUM1A, SUM2, SUM3, SUM4, SS4
S 16
L = L + 1


S 17
L < 5 ?
2
Yes
No
S 18
M = M + 1
S 19
Print AV4(1), AV4(2), AV4(3), AV4(4)
S 20
AMD = AV4(2) - AV4(1)
AME = AV4(3) - AV4(1)
AMUL = AV4(4) - AV4(1)
S 21
Print AMD, AME, AMUL
S 22
M > N ?
No
Yes
Stop
S 23
DELD1 = (-LAMBDA) * AMD * X
DELE1 = (-LAMBDA) * AME * Y
DELUL1 = (-LAMBDA) * AMUL * Z
S 24
DELDI = 0. and DELE1 = 0. and
DELUL1 = 0. ?
No
Yes
Stop
S 25
D(1) = D(1) + DELD1



S 26
D(1) ≥ 0. ?
No
S 27
Yes
D(1) = 0.
S 28
E(1) = E(1) + DELE1
S 29
E(1) ≥ 0. ?
No
S 30
Yes
E(1) = 0.
S 31
UL(1) = UL(1) + DELUL1
S 32
UL(1) ≥ 0. ?
Yes
No
S 33
UL(1) = 0.
S 34
D(2) = D(1) + X
E(2) = E(1)
UL(2) = UL(1)
S 35
D(3) = D(1)
E(3) = E(1) + Y
UL(3) = UL(1)
S 36
D(4) = D(1)
E(4) = E(1)
UL(4) = UL(1) + Z
S 37
3
L = 1

The rationale of the steps of Flow Diagram A3.1 are discussed below, with the exception of a few steps whose meaning is self-evident:

S 2 Input data here are CC1, CC2 and CC3, which are coefficients needed to calculate costs; MNAS, the "maximum" number of sheep; CPBSO, the cost of feed and transport per bushel of stockout; LAMBDA, an arbitrary constant whose size determines the distance moved along the descent path between iterations; X, Y and Z, which are the selected units of measurements of the control variables, D(L), E(L), UL(L); CONST, which is the total number of adult sheep in first decile areas during the 30 year period for the area being studied in the simulation; N, which puts an upper limit on the number of iterations to be included in the one simulation run; C and B, the number of weeks' maintenance ration demanded per sheep for the 12 weeks before grain intake and the 40 weeks after grain intake; A(I), where I varies from 3 to 32, is the series of sheep numbers in drought affected areas over the 30 year period; D(L), E(L) and UL(L), where L is varied from 1 to 4, which four combinations of levels of the control variables are selected to be near each other and used to determine the slope of the cost function with respect to each of the control variables at D(1), E(1), and UL(1).

S 3, 4, 6, 7. Initializing instructions.

S 8 Calculate the quantity in NDR at the beginning of the 12 weeks period before grain intake.

S 10, 11 The "year-increment" in S 10 and the test in S 11 cause the calculation of S 8 and S 9 to be repeated for each of the 30 years for levels of D(L), E(L) and UL(L) currently being considered.

S 12 Calculate the average cost over the 30 years for the current combination D(L), E(L) and UL(L).

S 13, 14, 15 Output control.

S 16, 17 A test causing all four neighbouring combinations of D(L), E(L) and UL(L), to be processed from step 4 to step 18.

S 18 Increment the iteration counter. Each iteration involves the calculation of the average cost over 30 years for a group of four neighbouring combinations of the control variables.

S 19 Print the average cost for each of the four combinations, or "points".

S 20 The estimated change in average cost per unit change in D, or slope with respect to D, is AV4(2) - AV4(1). The point (D(2), E(2), UL(2)) was derived from (D(1), E(1), UL(1)) by putting D(2) = D(1) + X, where X is a one unit change in D(L), and putting E(2) = E(1), and UL(2) = UL(1). The change in average cost measured by AV4(2) - AV4(1) is ascribed to one unit change in D(L).

The technique is repeated to measure the slope with respect to E and with respect to UL.

S 21 Print the size of the three slopes as at point (D(1), E(1), UL(1)).

S 22 Test whether N + 1 iterations have been completed. If so, stop.

S 23 In accordance with the technique of "steepest ascent" (here descent), the program selects a new point (D(1), E(1), UL(1)) a certain distance along this path. DELD1, DELE1 and DELUL1 are the changes to be made in the previous values of D(1), E(1) and UL(1). The change made in each of the three control variables is in accordance with the size of the slope associated with each; that is in accordance with AMD, AME and AMUL. The efficacy of the technique in selecting the steepest descent path depends on the choice of the units X, Y and Z. See Wilde [20 P.117].

S 24 A test is made to see whether all three slopes have zero value, in which case the iterations are stopped. For the given level of accuracy of the computations, an "optimum" has been found if the cost function is unimodel, or at least a local optimum if it is not.

S 25, 26, 27 A new value of D(l) is estimated on the descent path and put equal to zero if the estimated value is negative.

S 28, 29, 30, 31, 32, 33 New values (greater than or equal to zero) are estimated from E(l) and UL(l).

S 34, 35, 36 A set of points (D(2), E(2), UL(2)), (D(3), E(3), UL(3)) and (D(4), E(4), UL(4)) are calculated from (D (l), E(l), UL(l)), by perturbations of the control variables.

S 37 L is made equal to 1, and the instructions return to step 4 for the start of the next iteration.

Appendix IV

Flow Diagram of the Flock Recovery Computer Program.

The program allows a simulation of post-drought recovery of a flock of breeding ewes. The flock is assumed to have a given post-drought structure with sheep in each of the groups: 5½ year old ewes, 4½ year old ewes, 3½ year old ewes, 2½ year old ewes, 1½ year old ewes and 6 months old lambs of both sexes. Lambing rates and survival rates from one age group to the next are assigned. Various culling levels of ewe hoggets are assigned. Given values of the other parameters the culling levels selected will determine post-drought growth, if any, of the flock. The simulation gives annual flock structure in the post-drought recovery and annual values of wool sales and of sales of cast-for-age ewes, culled ewe hoggets and of wether hoggets which are assumed to be sold.

Here the computer program is much smaller than that written for the NDR models and the flow diagram is given for the computer program as a whole. The flow diagram is followed by an explanation of the steps contained in it.

The meanings of symbols used in the computer program (which was written in Fortran) were as follows:

CR(I) = proportions of sheep retained (applies to EH), CR(1), ... , CR(I).

B(J) = lambing rates, B(1), ... , B(J).

E5 = the number of 5½ year old ewes.

E4 = the number of 4½ year old ewes.

E3 = the number of 3½ year old ewes.

E2 = the number of 2½ year old ewes.

EH = the number of 1½ year old ewes.

AL = the number of lambs of both sexes (aged 6 months).

SE5 = the number of ewes sold as cast-for-age.

SEH = the number of ewe hoggets sold.

SWH = the number of wether hoggets sold.

SUME = E5 + E4 + E3 + E2 +EH.

OWL = total wool clip in the year.

OS = total number of sheep sold in the year.

TRW = total receipts for wool.

TRS = total receipts for sheep.

PW = the price of wool.

PS = the price of culled sheep.

S1 = the survival rate from 6 months to 18 months.

S2 = the annual survival rate of ewes.

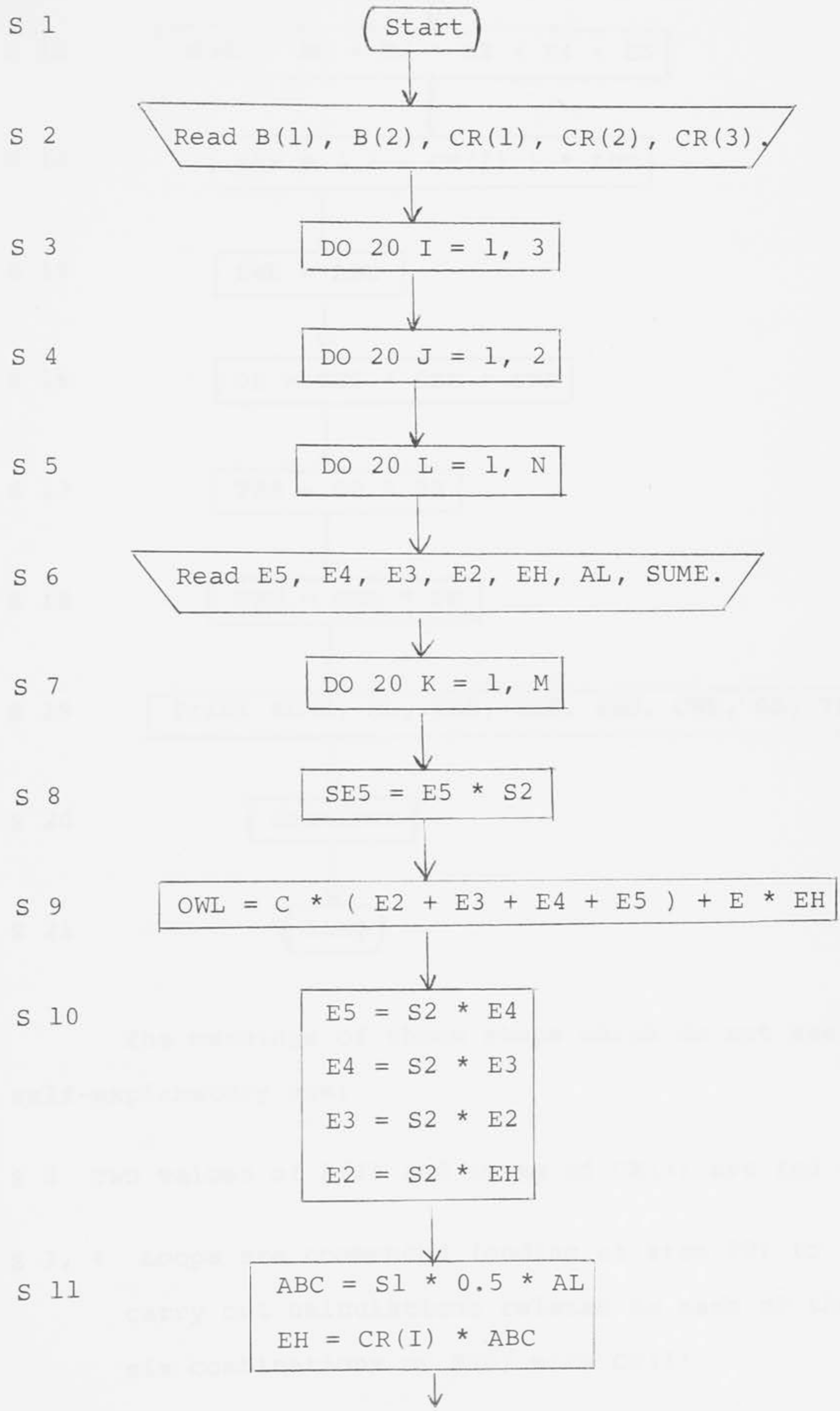
C = the number of pounds of wool per ewe.

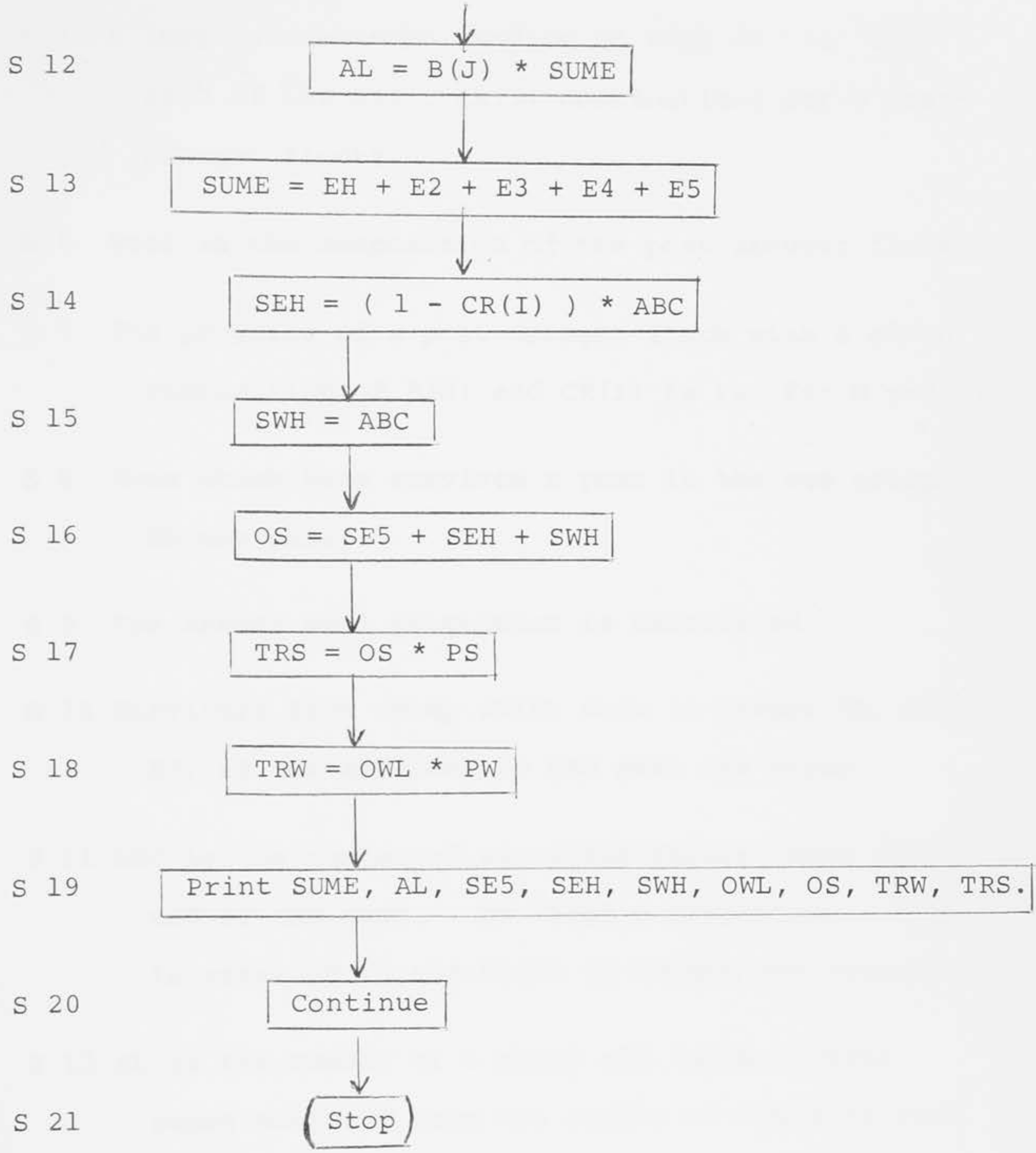
E = the number of pounds of wool per ewe hogget.

M = the number of "years" allowed in the simulation run.

N = the number of post-drought flocks considered in the simulation run.

Flow Diagram A4





The meanings of those steps which do not seem self-explanatory are:

S 2 Two values of B(J) and three of CR(I) are fed in.

S 3, 4 Loops are commenced (ending at step 20) to carry out calculations related to each of the six combinations of B(J) with CR(I).

S 5 A loop is commenced, ending at step 20, to "run" each of the B(J), CR(I) combinations for N post-drought flocks.

S 6 Read in the composition of the post-drought flock.

S 7 The progress of a post-drought flock with a given combination of B(J) and CR(I) is run for M years.

S 8 Ewes which have survived a year in the age group E5 are sold.

S 9 The annual wool production is calculated.

S 10 Survivors from sheep which were in groups EH, E2, E3, E4 are advanced to the next age group.

S 11 ABC is the number of surviving female lambs at the end of the year. Of these a proportion, CR(I), is retained in the flock to become ewe hoggets.

S 12 AL is the number of 6 month old lambs of both sexes obtained from the number of breeding ewes in the flock at the beginning of the year.

S 13 The number of breeding ewes is calculated to go into the beginning of the next year.

S 14 Culled ewe hoggets are sold.

S 15 Wether hoggets are sold.

S 16, 17, 18 The annual number of sheep sold and gross returns from sheep and wool are calculated.

S 19 Print results.

Appendix V

The graphs of Figures 4.7 and 4.8 relating average percentage mortality per week to the average number of food-units per week are free-hand curves based on a number of points identified from experiments. Experimental results examined were confined to dry merino sheep, either ewes or wethers of 2 to 3 years of age. Initial bodyweights in the experiments are taken to be reasonably homogeneous which seems to be substantiated by the relationship found in Figure 4.7 between the number of food-units per week and mortality rates.

Experimental background to Figure 4.7

Experiment A: References are the C.S.I.R.O. Leaflet Series No. 23, 1958, P.6, [17] and the Australian Journal of Agricultural Research, Volume 8, 1957, pp. 75-82 [24]. The type of feed used here was wheaten chaff with oats for a week, then just oats. Three levels of feed were given over 181 days: 41 sheep were given two food-units per week, 9 of which died or 0.85 per cent of the original number per week; 43 sheep were given 3 food units per week, 2 of which died or 0.18% per week; 43 sheep were given 4 food-units per week, none died. These were three year old dry Merino ewes with a mean bodyweight at the start of feeding of approximately 75 lb. This experiment was based on oats. The economic analysis of the results using wheat, assumes that any extra management input needed was forthcoming.

Experiment B: References are the C.S.I.R.O. Leaflet Series No. 23, 1958, p.10 (graph)[17], and The Journal of the Australian Institute of Agricultural Science, December 1955, p.224, Table IV. [35] In this experiment 2 tooth Merino ewes were fed different types of feed. Mortality was observed. Feeds considered included,

(i) wheaten chaff - oaten straw mixture containing 3.5% crude protein fed ad lib., and

(ii) this mixture plus 3.1 ozs. of wheat per day. The experiment was carried out over 167 days.

The number of food-units consumed per week by sheep receiving mixture (i) was estimated at 1.26 and mortality rate at 2.6% per week.

The number of food-units consumed per week by sheep receiving mixture (ii) was estimated at 2.28 and the mortality rate at 1.15% per week.

Experiment C: Reference "Australian Journal of Experimental Agriculture and Animal Husbandry", Volume 7, June, 1967, pp, 206-212 [36]. See (36 P.207 Table 1).

Sheep used in this experiment were "a uniform line of Merino wether, 30 months old and well fleshed but not fat". Various types of roughages were fed with or without a wheat supplement of 85 grams per sheep per day. After a transitional period, sheep were introduced to a feeding regime which was continued for 25 weeks.

From the various feeding regimes, estimates were made of the number of food units consumed per week and the associated mortality rates. From these a further 7 points were plotted in Figure 4.7.

Relevant details are tabulated below:

Groups and roughage diet	Crude protein content of roughage	Estimated daily roughage intake	Daily intake of wheat	No. of food-units per week	Mortality per week as a % of initial numbers
	%	grams/sheep	grams/sheep		
1. Chaffed wheaten straw	2.7	220	Nil	0.51	4.00
2. ditto	2.7	260	85	1.56	1.25
3. ditto	2.7	220	85	1.47	1.00
4. Chaffed wheaten straw - lucerne chaff (84%: 16%)	5.2	405	Nil	1.20	2.25
5. ditto	5.2	475	85	2.37	1.00
6. ditto	5.2	450	85	2.29	0.25
7. Chaffed wheaten straw - lucerne chaff (67.5%: 32.5%)	7.6	835	Nil	3.00	0.00

Appendix VI

Transportation Costs.

(i) Intrastate

The general approach used in calculating intrastate transportation costs is as follows:

1. For each year from 1936 to 1965, list the shires which have had 1st decile rainfall according to the Gibbs and Maher decile maps [14].
2. List the proportion of the area of each shire having first decile rainfall for each year.
3. For each shire and each year, multiply the proportion of area affected by drought (first decile rainfall) by the number of adult sheep in the shire as at 31st March, 1964. (It is assumed here that sheep populations within a shire are evenly distributed throughout the shire.) This multiple is therefore the number of sheep, based on 1964 sheep numbers, which would have been involved in the drought in the shire concerned.
4. For each year, calculate the total number of sheep involved in a drought in the State, i.e., total the numbers of sheep involved in droughts in all shires for each year. (For each year I, this total equals NAS(I); and MNAS = $\text{Max.}_{I}\ \{\text{NAS(I)}\}$.)

5. Choose a representation of droughts on the basis of size and location (size being entirely dependent on the number of adult sheep involved; and position of the droughts in relation to the wheat zone).
6. For each shire containing wheat silos, choose a town close to the geographical centre of the shire. This town, which will be referred to as a "silo shire centre", must have silos and must be next to a railway line.
7. For each shire with sheep populations, choose a town close to the geographical centre of the shire and, if possible, next to a railway line. If no railway line is near the centre, then choose a centre which is accessible by road from the nearest railway line. This town will be referred to as the "drought shire centre". In a silo shire, the silo shire centre and the drought shire centre is one and the same.
8. For each drought:

   (a) Calculate the cost per ton at wagon load rates of transporting wheat to a drought shire centre from its closest silo shire centre. If road transport is also involved, choose the lowest-cost route.

   (b) Calculate the cost of transporting 1 week's maintenance ration, at 5 lb. of wheat per week, to the drought shire centre from its closest silo shire centre, i.e., Transport cost in year I to shire =

(No. of sheep in drought in shire, in year I) * $\frac{5}{2,240}$ * (transport cost of wheat per ton.)

If the drought shire has a silo centre, then the transport cost from centre to centre is zero.

(c) Do this for all shires involved in the drought and total costs for the whole State for that drought.

9. Calculate the weighted average transport cost per ton over the chosen droughts and bring to the nearest 50 cents. (By rounding off in this way, the costs for New South Wales, Victoria and South Australia were increased while the cost for Western Australia was decreased. However, since the cost for Western Australia was small, it was decided to round off at the nearest upper 50 cents.)

Comments.

The approach outlined above was not followed meticulously because of the differences between shires and the differences between States. Some of the differences and the ad hoc decisions made are mentioned in the ensuing discussion.

Difficulties in obtaining a high degree of accuracy were encountered. Some of these difficulties were: <u>enlarging the Gibbs and Maher decile map to a scale similar to that of maps containing outlines of shire boundries;</u>

after observing the area of a shire involved in a drought, the proportion affected by drought had to be estimated visually; determining a geographical centre; varying area sizes of the shires made consistency difficult.

In order to overcome some of these difficulties, some drought shires were grouped together and given a common centre, especially if the area and non-drought sheep numbers of the shires were small.

Some silo shires were alloted more than one centre because more than one branch railway line ran through these shires and were supply lines to different non-silo areas. These centres were therefore not geographical centres. The assumption that sheep were evenly distributed throughout a shire had to be relaxed in some cases in order to gain some reality; instead the centre of the shire concerned was more of a transportation centre (e.g. the geographical centre in some shires in Western Australia were situated well away from civilization).

It was observed that the position of the wheat belt in relation to the pastoral zone was important. For instance, in Western Australia, the Agricultural Divisions are almost entirely a wheat/sheep zone; although some of the transport costs outside this zone were high, the sheep numbers were not (only about 20% of the total sheep population considered were outside this zone); this resulted in a low cost for Western Australia. In Queensland, costs were in general high because of the comparatively small wheat and sorghum zones and of the large pastoral zones.

The most important silo centres are those on the edge of the wheat belt. It has been assumed that there is sufficient storage capacity in such silo shires to withstand any demands. If only these shires were used for NDR storage, then transport costs of NDR grain to centres inside the wheat belt would have to be considered.

The transport costs considered are only those from shire centre to shire centre. Costs to the farm gate have not been considered; however, a costing to shire centres would tend to over-estimate costs to the farm gate in some instances and under-estimate them in others. Other costs such as special wagon costs, loading and unloading costs have not been taken into account because their effect is negligible. All freight rates used in the calculations date from 1965 on.

The following details for the individual States were relevant in considering transportation costs:

New South Wales

The south western corner of New South Wales was excluded from calculations for that State and included in those for Victoria - the reason being that the railway system in the area is a part of the Victorian railway system and is not connected to that of New South Wales. This area consists of the Shires of Balranald, Wentworth, Conargo, Murray, Windowan, Wakoal and the Municipality of Deniliquin (municipalities have been incorporated in the shires next to them). The Metropolitan and Cumberland Divisions were also excluded because of the small number of sheep in these areas.

Rail rates were obtained from Department of Railways, New South Wales, Circular No. 210, "Increases in Merchandise and Livestock Rates on and from 1st October, 1966", and road rates from The Master Carriers' Association of N.S.W.

Four droughts were chosen for the calculation of a transportation cost for New South Wales. The tabulation is:

Drought Year	Size and location of drought	Average cost per ton of transporting wheat
		$
1940	large and widespread	3.19
1945	small and in the wheat/ sheep zone	0.21
1960	small and in the high rainfall zone	5.81
1965	medium and widespread	3.98

The weighted average transportation cost (after rounding-off) was $3.50 per ton which was used in the NDR simulations.

Victoria

The south western corner of New South Wales was included in the calculations of transportation costs for Victoria (see above). The Metropolitin area in Victoria was excluded.

Rail rates were obtained from the Victorian Railways publication "Extract from Goods Rates Book No. 27 - Rates for the Carriage of Goods - effective from 14th August, 1966". Road rates were obtained by phone from the Bureau of Agricultural Economics, Canberra.

Four droughts were chosen for the calculation of a transportation cost for Victoria. The tabulation is:

Drought year	Size and location of drought	Average cost per ton of transporting wheat
		$
1937	small and greater part in the pastoral and high rainfall zones	4.15
1940	large and widespread	1.75
1944	medium and widespread	1.83
1959	small and in the wheat/ sheep and pastoral zones	2.12

The weighted average transportation cost (after rounding-off) was $2.00 per ton which was used in the NDR simulations.

South Australia

The Bureau of Census and Statistics quotes 1964 sheep numbers for "statistical counties" and not for shires as in the other States. The unit area for calculating costs was therefore the "county" and not the "shire".

It had been assumed, in calculating costs, that the sheep populations in the Unincorporated Areas (consisting of the greater part of South Australia north of the latitude at Port Augusta) were evenly distributed along the railway lines. However, the Year Book for South Australia states that all sheep flocks in South Australia are in the southern sector of these Areas. Costs have therefore been slightly overestimated.

Rail rates were obtained from the South Australian Railways publication, "Goods and Livestock Rates Book - 1st August, 1966". An estimate of 3 cents per ton mile both ways for road rates was obtained from the "Eyre Peninsula Road Transport Association". Since no shipping rates were on hand, the transport cost from Port Giles to Kangaroo Island was taken as $10 per ton of wheat.

Four droughts were chosen for the calculation of a transportation cost for South Australia. The tabulation is:

Drought year	Size and location of drought	Average cost per ton of transporting wheat
		$
1940	medium and widespread	0.92
1943	small and the greater part in the pastoral zone	3.55
1950	small and in the wheat/ sheep and pastoral zones	1.12
1959	large and widespread	1.56

The weighted average transportation cost (after rounding-off) was $1.50 per ton which was used in the NDR simulations.

Western Australia

Whereas the transportation costs used for the pilot study were calculated by use of the linear programming transportation model (see section 3.1.2), the cost used for the NDR simulations was calculated on the basis of the approach described in this Appendix. The area considered was extended from that in the pilot study to include all of Western Australia except for the Pilbara and Kimberley Divisions (that is about 3% of the Western Australian sheep population were excluded).

Rail rates were obtained from the Western Australian Railways "Goods Rates Book - 1st October, 1965". Road rates were obtained by phone from the Bureau of Agricultural Economics.

Three droughts were considered for the calculation of a transportation cost for Western Australia. The tabulation is:

Drought year	Size and location of drought	Average cost per ton of transporting wheat
		$
1940	large and widespread	0.48
1950	small and mainly in pastoral zone	4.44
1954	small and mainly in the wheat/sheep zone	0.10

The weighted average transport cost was $0.60 per ton; this was rounded off at $1.00 per ton which was the cost used in the NDR simulations.

<u>Queensland</u>

The approach used for calculating costs for Queensland was slightly different to that used for the other States. Because of the huge area involved, the location of the grain producing areas in relation to the pastoral areas, and the railway system, Queensland was considered as two sectors, North and South, and costs were calculated for these sectors separately. In addition, costs were calculated for each drought and these costs were fed into the NDR simulations on a year by year basis, because the range of costs for individual droughts was fairly large. Costs were calculated for wheat only; costs for the transportation of sorghum have been equated with those for wheat.

North Queensland consisted of the Far West, North West, Central West and Rockhampton Divisions. Only the Shires of Banana, Fitzroy and Livingstone were considered in the Rockhampton Division.

South Queensland consisted of the Downs, South West, Roma, Moreton, Maryborough and Rockhampton Divisions. In the moreton Division only the Shires of Beaudesert and Moreton were considered, in the Maryborough Division only the Shires of Kingaroy and Wondai and in the Rockhampton Division only the Shire of Taroom. All areas excluded from both North and South Queensland had too few sheep or no sheep at all.

Rail rates were obtained from the Queensland Government Railways publication "General Scales of Rates for Goods Traffic, Wool and Livestock Traffic - effective from 1st November, 1968". Due to the difficulty experienced in obtaining a schedule of road rates, an estimate of 3 cents per ton mile both ways was used.

Transportation costs calculated for Queensland were:

Drought year	North Queensland Cost per ton of transporting wheat $	Drought year	South Queensland Cost per ton of transporting wheat $
1938	18.76	1937	11.58
1946	7.70	1938	13.31
1948	11.43	1940	11.40
1951	0.80	1944	1.13
1952	17.02	1946	5.58
1957	0.89	1951	3.21
1959	18.76	1957	1.89
1961	18.50	1959	13.58
1963	26.96	1960	0.69
1965	13.62	1965	11.15

(ii) Interstate

Interstate transport costs were calculated for New South Wales, Victoria and South Australia in the following way:

For a given State:

1. Calculate the cost of transporting wheat from the centre of each of the other two States to the centre of the given State.

2. Assume equal quantities of grain are imported from the two States; thus the cost of importing grain is the average of the costs calculated in 1.

Costs between State centres are only approximate. They are:
\$15 per ton between Victoria and N.S.W. centres;
\$19 per ton between South Austn. and N.S.W. centres; and
\$11 per ton between South Austn. and Victorian centres.

Cost of importing grain for:
New South Wales is \$17 per ton or \$0.45 per bushel;
Victoria is \$13 per ton or \$0.35 per bushel; and
South Australia is \$15 per ton or \$0.40 per bushel.

The cost of importing grain into Western Australia was estimated from the centre of the South Australian wheat zone to the centre of the Western Australian Agricultural Divisions (which contained approximately 80% of the sheep population considered) by rail and ship.

The rail costs in South Australia and Western Australia were $2 and $5 per ton respectively. After discussions by phone with the Australian Wheat Board and the Department of Shipping and Transport, it was decided to use a shipping cost of $16 per ton. (This is a hypothetical estimate based on observed freight rates and shipping procedures between other Australian ports). A preliminary examination of railway freight rates between the two States suggested that they would be substantially higher than the combined shipping and rail rates. The total interstate freight cost is therefore $23 per ton or approximately $0.60 per bushel - the figure used in the NDR analysis.

For details of the Queensland importing cost see section 3.2.9

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