WHEAT STORAGE COSTS IN NEW SOUTH WALES

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1. INTRODUCTION

In the last few years increasing interest has focused on the capacity, standard and efficiency of wheat storage facilities in N.S.W. While the emphasis has been principally directed to the demand for more storage capacity, attention also has been drawn to the capacity and efficiency of the handling equipment and also to the quality of the storage services.

Underlying the increased level of interest is the changing circumstances in which the industry now finds itself. Primarily has been the rapid upsurge in wheat production coming from both higher yields and an increased acreage. In excess of 100 million bushels were harvested in each of three successive harvests culminating with a record crop of 151·5 million bushels in 1964–65. Even higher levels of production appear likely in the future with the advent of new technology and

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improved farm practices and particularly if the current relative trend of wheat and wool prices continue. At the same time the advent of bigger and faster stripping machinery, bulk handling, and improvements in the means of road transport have reduced the harvesting period and so placed added pressure on storage facilities. Consumers of wheat are demanding more and better equipped storage facilities to permit the holding of larger reserves as a buffer or insurance against sudden fluctuations in the supply of, and demand for, wheat.

The function of storage is simply to transfer a commodity forward from one time period to another. In the case of wheat, permanent storage requires that the grain be protected against weather, vermin, and insect parasites such that quality and quantity of the stored wheat is maintained over time. Some wheat storage facilities which do not meet the definitional requirements of permanent storage for extended periods are referred to by other terms, such as temporary storage.

The objects of this paper are to enumerate the types and capacity of permanent wheat storage facilities in N.S.W., and second, to construct cost schedules for these facilities. Comparison of the relative costs of the different storage media aims to aid decisions on the type or types of wheat storage facilities to construct in the future when such decisions are to be made.

Before proceeding immediately to the objectives of the article I will consider the background of wheat storage in N.S.W. with the aim of clarifying the problem and also to classify the different permanent storage media. In section 3 the method of analysis, assumptions and data sources will be discussed. Cost schedules will be hypothesized in section 4. In section 5 estimates of the harvesting rate are given. Estimates of the available permanent storage capacity and of the cost schedules are given in sections 6 and 7, these are then collated and discussed in section 8.

2. Background to the Field of Enquiry

The Australian Wheat Board has delegated its authority over the receival, storage, and transport of wheat in N.S.W. to the New South Wales Grain Elevators Board (GEB) which acts as its agent. Wheat for sale does not become eligible for payment until it has been delivered to a GEB receival point.[1]

In order to meet world demand requirements it is essential that grain be given complete protection so that physical quality of the wheat is maintained from the time of delivery into storage to the time of delivery to the consumer if we are to avoid price discounts on our wheat.

Over 95 per cent of all wheat deliveries in N.S.W. are handled and stored in bulk. The change from bag to bulk storage is basically the substitution of capital for labour. Parish,[2] Candler,[3] and Donaldson

[1] Strictly this is not correct as by special arrangements some premium wheat is delivered direct to the mills. However, before payment is made for this wheat the transaction must be recorded by the GEB.

[2] R. M. Parish, "Bulk Handling of Wheat on the Farm", *Review*, Vol. 20 (1952).

[3] W. Candler, "A Study of the Economics of Bulk Handling of Wheat on Farms", *Review*, Vol. 27 (1959).

and Ryan[4] have demonstrated the relative advantage of bulk and semi-bulk handling over bags at the farm level. Lower handling costs, particularly at the terminals, and easier and more efficient control of vermin and insects are some of the most important reasons for the shift from bag to bulk storage by the GEB. For the rest of this article I will therefore proceed on the assumption that bulk wheat storage is more efficient in terms of resources used than is the storage of wheat in any other form.

Because we aim to minimize the total bundle of marketing costs it is necessary to consider the effect that location of storage units has on transport costs. Average and marginal wheat transport costs per ton mile are relatively greater for short hauls compared to longer hauls. Also, over long distances, rail transport is more efficient than road transport. The marginal road transport cost per ton mile falls from ten cents for five to ten miles to eight cents for more than ten miles. By comparison the marginal cost of rail transport per ton mile is four cents at ten miles, two cents at 200 miles (the average distance wheat in N.S.W. is transported) and one cent at 300 miles and beyond.[5] This structure of freight rates has established a definite transport pattern. Wheat is transported by road from each farm to the closest railway siding and thence by rail to the metropolitan areas of Sydney and Newcastle. This pattern has a restraining influence on the location of storage facilities such that they are situated either on the farm or along the railway network.

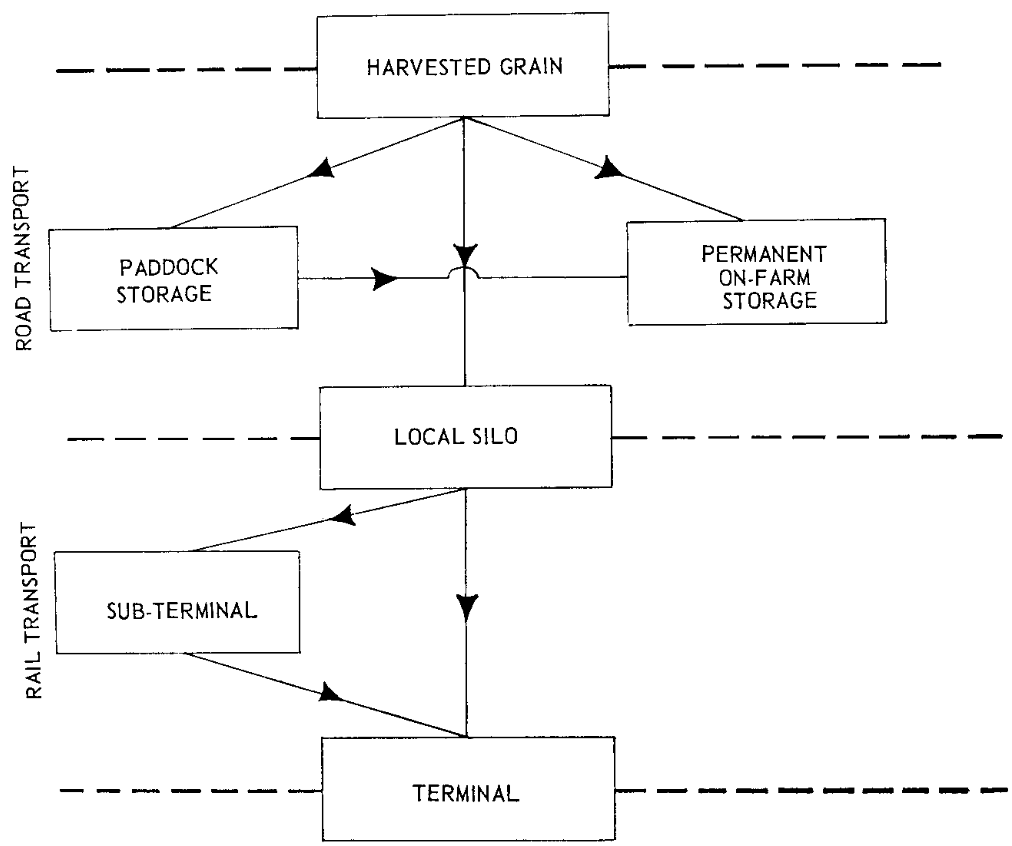

Figure 1. Classification of Permanent Storage Facilities and Wheat Transport Pattern in New South Wales

The problem may be further clarified by classifying the many storage structures. Characteristics by which storage structures might be classified include type of materials used in construction, storage capacity, method of ownership and control, location and so on. As a first basis for grouping, permanent storage units will be classified by their location. A diagrammatic representation is given in Figure 1. There are four locational classes—on-farm, local silo, sub-terminal, and terminal.

After grain is harvested it may be taken into local silo storage, or on-farm permanent storage, or temporarily held in paddock storage (which is not permanent storage) before being taken into permanent storage.

Local silos are found at rail sidings throughout the wheat belt. From the local silo wheat is transported by rail either directly to a terminal or firstly to a sub-terminal and at a later date to a terminal. For full utilization of their storage space both sub-terminals and terminals depend on shipments of wheat by rail from local silos. Compared to sub-terminals, terminals are situated at the points of consumption, i.e., at flour mills or at seaboard ports.

As similar type storage structures are found at local silo, sub-terminal and terminal locations their physical cost schedules will be identical. Thus, as a second line of classification, local silo, sub-terminal, and terminal storage will be grouped under commercial storage.

3. Methodology

A. Method of Analysis and Assumptions

Available permanent storage capacity in N.S.W. will be obtained from two sources; in the case of commercial storage from official sources, and; in the case of on-farm storage, available capacity will be estimated using information collected from a mail survey of N.S.W. wheat holdings.

Before securing data to construct cost schedules we must ask, what cost or costs do we desire to quantify, e.g., capital, annual, short run, long run, real or money cost? The primary aim of this paper is to compare the costs of constructing and operating different types of wheat storage media. Therefore, the appropriate costs are real long run annual costs, where the real cost of any storage unit is the opportunity cost to the wheat industry of employing resources in this unit rather than in another unit or elsewhere in the industry.

The real long run annual cost of a storage unit includes the physical cost of providing storage services, plus any additional costs which operation of the unit may cause other industry activities, less the value of any other services which the unit may provide without affecting the wheat storage activity. Physical costs will include overhead or fixed costs of depreciation, interest and insurance and operating or variable expenses of labour, repairs and maintenance, fuel and power and grain

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[4] G. F. Donaldson and J. G. Ryan, "Alternatives in Handling Grain at Harvest", *Agricultural Gazette of N.S.W.*, Vol. 75, Part 10 (October, 1964).

[5] These rail costs are only those met by the wheat grower and do not include a subsidy from the Treasury.

protectant chemicals. The adjustments which have to be made in order to go from physical costs to real costs will be hypothesized for each of the storage forms in section 3.

Initially costs are estimated for storage capacity rather than amount stored. This unrealistic assumption presumes that just enough grain is harvested each year to fill the storage unit once. The effect on real costs by relaxing this assumption will be discussed in relation to each storage form.

For the main part data used for costs schedules will be based on the most recent available data. Where possible, these estimates will be adjusted to reflect expected future trends.

B. Sources of Data

During August, 1965, 1,580 questionnaires were mailed to a sample of wheat farmers in N.S.W. Information sought included the farmer's wheat acreage, yield per harvested acre, harvesting and grain handling method and equipment, and the types and capacity of on-farm permanent and paddock storage.

A stratified random sample design was used. The method of stratification follows that used by Duloy and Watson in a wheat supply study.[6] In addition to their six regions (strata), a seventh stratum incorporating shires in the marginal western fringe was formed. The seven strata are enumerated by their member shires in Appendix A.

A list of eligible voters compiled by the A.W.B. for the election of N.S.W. farmer representatives in 1965 was used as the frame from which the sample was drawn. Non-respondents were sent reminder letters and new questionnaires twice at three-weekly intervals. All non-respondents in stratum I were personally interviewed to assess the extent, if any, of non-response bias. This analysis did not indicate any significant bias.[7]

The number of holdings sampled, the number who responded, and the number of replies used in the following analysis are shown in Table 1, together with the number of holdings growing 20 acres or more of wheat for grain.

Because the frame from which the sample was drawn contains a list of names of eligible persons rather than holdings it is not possible to definitely identify the population of holdings from which the sample was drawn. The number of holdings growing 20 acres or more of wheat for grain as defined by the Commonwealth Bureau of Census and Statistics (CBCS) would appear to be a feasible and reasonable approximation of the population. In Table 2 the mean harvested acreage per sample holding is compared with a crude estimate of the mean population acreage. Crude because it assumes that the remaining 1,502 wheat farmers who grow less than 20 acres of wheat in fact harvested zero acres. The difference between the sample and population mean acreages are positive

[6] See: J. H. Duloy and A. S. Watson, "Supply Relationships in the Australian Wheat Industry: How Stable is Stabilization," Paper presented to *Australian Agricultural Economics Society Annual Conference*, 1964 (Mimeographed).

[7] See: J. W. Freebairn, "Mail Surveys and Non-response Bias—Report on a N.S.W. Mail Survey," forthcoming.

for three and negative for the other four strata. With the exception of stratum I these differences are not significantly different from zero at the five per cent level using a *t* test.[8] Thus it will be assumed that the sample was drawn from the population of holdings growing 20 acres or more of wheat for grain.

TABLE 1

Number of Holdings Growing 20 Acres or More of Wheat for Grain, Number Sampled, Number Who Responded to Mail Survey and Number of Observations Used in Analysis by Strata and for New South Wales

Strata	I	II	III	IV	V	VI	VII	N.S.W.
Holdings growing greater than 20 acres of wheat for grain* ..	2,753	3,546	2,902	426	1,150	4,475	1,877	17,770‡
Number sampled	230	240	240	190	240	230	210	1,580
Number responding to survey ..	169	174	181	141	179	160	146	1,150
Number analysed†	201	151	168	115	166	138	136	1,075

* Source: Deputy Commonwealth Statistician, Sydney.

† Stratum I includes 38 observations collected from personal interviews of all non-respondents in that stratum.

‡ Includes 541 holdings in other shires.

TABLE 2

Comparison Between Sample and Population Estimates of Average Harvested Acreage per Holding

Strata	Mean Population Harvested Acreage	Sample Harvested Acreage		Difference
		Mean	Standard Deviation	
	Acres	Acres	Acres	Acres
I	240·2	282·6	209·1	−42·4
II	320·8	304·6	237·5	16·2*
III	434·4	489·5	451·6	−55·1*
IV	490·9	464·7	535·2	26·2*
V	211·2	199·1	148·0	12·1*
VI	285·6	308·1	225·1	−22·5*
VII	502·6	566·0	417·5	−63·4*

* Not significantly different from zero at the 5 per cent level.

Reliability of the sample as an unbiased estimator is shown in Appendix B where estimates of wheat yield per acre obtained from the survey are compared with those published by the CBCS. Differences between these two estimates do not differ significantly.

Data for estimating the cost schedules was obtained from makers of the common brand names of on-farm permanent storage, and from the GEB in the case of commercial storage.

[8] Although the distributions are positively skewed the *t* test, for these purposes, is valid. See: M. H. Quenoville, *Introductory Statistics.* (London: Butterworth-Springer Ltd., 1950) p. 173.

4. Theoretical Nature of Cost Schedules

For all types and forms of permanent storage one would expect a similar pattern of total, average, and marginal physical storage costs. As the size of a unit increases so will the total capital cost of the structure and of the handling equipment. However, capital costs will increase at a decreasing rate so that average and marginal capital costs will be a declining function of the size of the storage unit. This pattern can be attributed to the various internal economies of size, particularly technical economies. Moreover, because of their nature, the marginal effect of these economies would be expected to decline for storage units of very large capacities. The importance of diseconomies, on the hand, will be negligible because their effect can, in most cases, be nullified by duplication of storage units.

Since fixed costs are derived from capital costs, average fixed costs will fall with increasing size of the storage unit but probably at a declining rate. Average operating costs will be approximately constant for all sizes of the storage unit. If anything, they may be expected to fall with increasing size of the storage unit as it becomes possible to use more costly and technically efficient handling equipment.

Having postulated the pattern of physical costs we now want to consider what adjustments, if any, are needed to go from physical storage costs to real storage costs.

For all storage forms the efficiency of the farm stripping and transport activities may be affected by the receival rate, or handling capacity, of the permanent storage units. If the receival rate of permanent storage units is as fast as, or faster than the rate at which wheat can be stripped and transported, then operation of the storage units will not affect or hinder these farm activities. If, however, the receival rate is less than the rate of delivery, the level of efficiency of farm harvesting activities will be reduced because of these delays, and thus harvesting costs will be increased. Increased farm harvesting costs will accrue from grain quality and quantity losses while wheat is awaiting permanent storage and from forced idleness of men and machinery. These costs must be included in the real costs of these storage units.

An intuitive constraint on the construction of storage units is, therefore, that the unit be installed with handling equipment capable of receiving wheat into storage as fast as it is harvested. This does, however, assume that the cost of such equipment will be less than the additional costs imposed on the industry if less efficient equipment were installed.

Compared to the direct delivery of wheat from the header to a local silo, grain stored in on-farm permanent storage must be double handled. The cost of the extra handling must be included in real costs of on-farm permanent storage.

As well as providing wheat storage, on-farm permanent storage facilities may be used to store other farm commodities. The value of these services should be deducted from physical costs to obtain real costs. This would take the form of allocating fixed costs between wheat and other commodities. For any holding the marginal value of these services would be expected to decline with increasing quantities of permanent storage. There is a limit to the quantity of other commodities which require storage and certainly there would be a declining necessity to store these additional commodities. Again, the greater the quantity of on-farm permanent storage relative to commercial storage the longer, ceteris paribus, wheat would need to be held on the farm. This would result in less time available to store other products and for those commodities requiring continuous storage a decline in the quality of such services.

On-farm permanent storage may provide considerable utility to the farmer by permitting greater flexibility in the harvesting activity and by allowing his harvesting to proceed independently of other members of the industry. Direct benefits include minimizing costs incurred by delays in delivering grain to commercial storage and by reducing the strain on limited transport facilities. Less obvious benefits which may increase harvesting efficiency flow from giving the farmer greater control over the wheat harvesting operation, thus tending to facilitate more effective and rational managerial decisions. All these benefits seem analogous to Working's marginal convenience yield discussed in his theory of inverse carrying charges.[9] By the nature of these advantages one would expect this inverse carrying charge to approach zero for large quantities of storage.

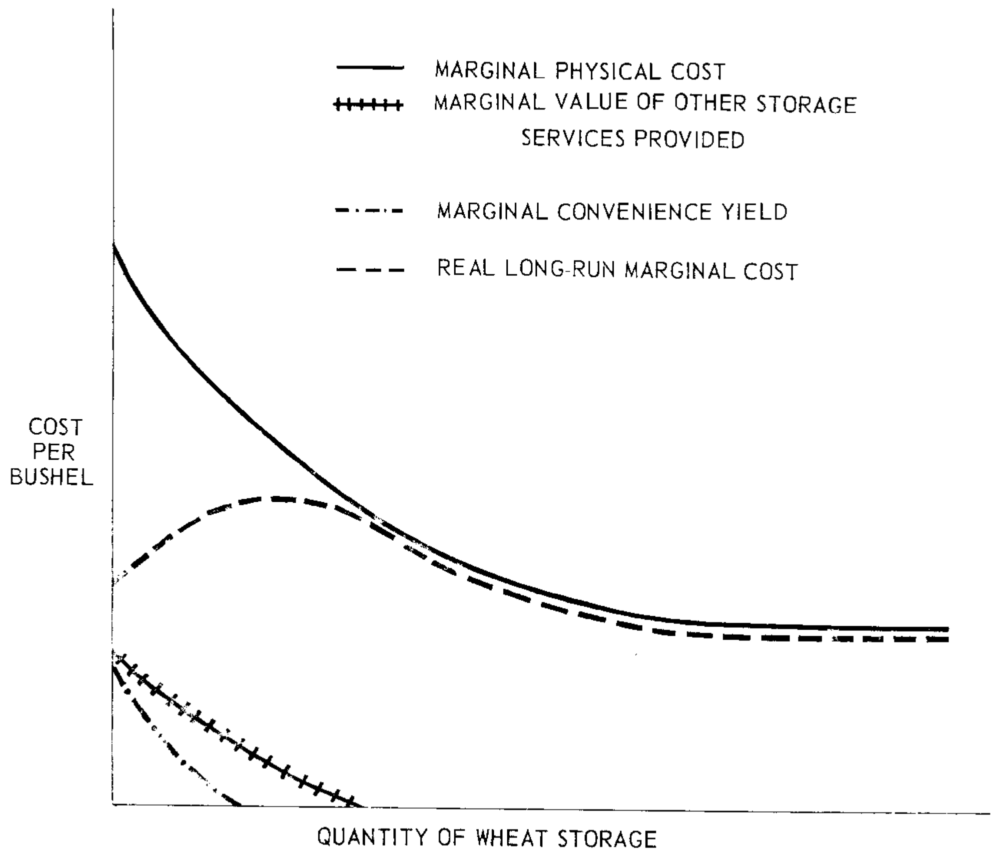

Figure 2. Real Long-Run Marginal Cost of On-Farm Permanent Storage

[9] Holbrook Working, "Theory of the Inverse Carrying Charge in Futures Markets," *Journal of Farm Economics*, Vol. XXX, No. 1 (February, 1948).

The aggregate effect of these considerations is summarized graphically in Figure 2 for marginal costs. Marginal real long run annual cost of on-farm permanent storage being marginal annual physical storage cost, plus the marginal cost of handling grain through a local silo, less both marginal convenience yield and the marginal value of other storage services provided.

In the case of local silo storage real long run costs will be the same as physical storage costs.

As a means of intra-seasonal storage sub-terminals and terminals depend entirely on supplies of wheat being transhipped by rail from local silos during a brief harvesting season. They therefore depend on the handling capacity of local silo equipment and on adequate rail facilities. The handling capacity of local silos must be increased so as to handle sufficient grain fast enough for the sub-terminal and terminal's requirements as well as for their own. These additional machinery costs are attributed to the real costs of sub-terminals and terminals and not those of local silos.

Available rail facilities are in general restricted to the minimum quantity of such facilities necessary to transport all wheat to the terminals before the next harvest. Up to the point where these facilities are fully employed sub-terminals and terminals do not add to the costs of wheat transport. A higher level of utilization of these storage forms will necessitate the purchase of additional wheat trucks, all of which will lie idle during the non-harvesting period of the year. The fixed costs of the additional rolling stock must be included in the real costs of sub-terminal and terminal storage.

To the physical costs of sub-terminals must be added a second handling charge, plus any additional freight which may be incurred by breaking the journey.

Note, that for all storage forms, real costs exclude the expenses of handling wheat through a terminal. The reasons for this omission are first that these costs are common to all storage forms, and second they vary depending on whether the wheat is to be used for local consumption or exported.

How does relaxing the static assumption of a known fixed quantity of grain to be stored from year to year, i.e., estimating costs for storage capacity rather than for amount stored, affect the relative advantages of the different storage forms? A priori one would expect that the quantity of grain to be stored at terminals, and to a lesser extent sub-terminals, which draw their supplies from a larger geographic area than other forms of storage would be relatively less variable from year-to-year than would be the case for local silo and on-farm permanent storages. If acceptable, this hypothesis means that real costs based on the more realistic premise of amount stored would look more favourably on terminals and to a lesser extent sub-terminals compared to local silo and on-farm permanent storages than do comparisons formed on the premise of storage capacity.

5. Harvesting Rate

When hypothesizing the nature of real costs it was assumed that the capacity of each storage unit's handling equipment would be such as to enable the unit's storage capacity to be fully utilized without causing delays in the harvesting operation. In this section the harvesting rate will be assessed in relation to the estimated stripping rate and the rate at which wheat can be transported from the header to permanent storage.

Estimates of the stripping rate are shown in Table 3, for different sets of circumstances, as the average (arithmetic mean) number of days required to strip each holding's wheat crop. All the estimates assume ideal harvesting weather permitting a full day's work, and include an allowance for mechanical breakdowns. Estimates are given for three crop yields, 15, 30 and 45 bushels per acre. Estimates are given for three crop conditions which are suggested as reflecting the most favourable conditions, the least favourable and the weighted average crop condition.

Table 3

Average Number of Days of Good Weather Required to Harvest Each Holding's Wheat Crop for Different Crop Conditions

Condition of Crop	Strata	Crop Yield: 15 Bushels per Acre	Crop Yield: 30 Bushels per Acre	Crop Yield: 45 Bushels per Acre
		Days	Days	Days
A. Crop in ideal standing condition	I	8·3	10·4	13·1
	II	7·4	9·3	12·0
	III	9·4	11·4	13·9
	IV	10·5	12·4	14·8
	V	7·0	8·7	10·6
	VI	9·0	11·1	13·7
	VII	11·2	14·8	18·4
B. Crop heavily lodged	I	12·2	15·4	19·6
	II	10·4	13·3	17·3
	III	13·9	17·0	20·9
	IV	13·4	16·0	19·2
	V	10·2	12·7	15·6
	VI	12·9	16·0	20·0
	VII	15·7	20·8	26·0
C. Crop in its most probable average condition	I	9·5	11·9	15·0
		(4·9)	(6·7)	(9·4)
	II	8·1	10·3	13·3
		(4·4)	(5·9)	(8·1)
	III	10·6	12·9	15·8
		(6·3)	(7·5)	(9·0)
	IV	10·9	12·9	15·5
		(6·6)	(8·0)	(10·1)
	V	8·0	9·9	12·1
		(5·0)	(5·2)	(7·4)
	VI	9·9	12·2	15·1
		(6·9)	(7·7)	(9·2)
	VII	12·1	16·0	20·0
		(6·7)	(10·5)	(13·7)

Section A of Table 3 gives estimates for a standing crop. Section B gives estimates for a badly lodged or down crop, caused by adverse weather, excessive soil fertility, or both. The probability of these conditions occurring are at least three years in ten in strata I, III, and VI which are the relatively higher yielding strata compared to less than two years in ten for strata IV and VII. Similarly, the extent to which lodging slows-down stripping is higher in the former strata. Section B is therefore likely to be applicable in those areas and in those years in which yields are high. In section C the number of days required to strip a holding's wheat crop in its most probable condition, Y, is assessed using the equation

$$Y = X_1 \left[1 - X_2 + \frac{X_2}{1 - X_3} \right]$$

Where X_1: number of stripping days required for a standing crop,

X_2: farmer's estimated probability of a badly lodged crop occurring, and

X_3: farmer's estimated proportional effect by which a lodged crop reduces the stripping rate. For individual holdings in particular years this estimate is probably unrealistic. However, it is suggested that the average for a number of holdings in any area is realistic. In any year we usually find a range of yields and crop conditions from holding to holding.

A slight but significant positive correlation was found between the number of stripping days and wheat acreage per holding. Differences between strata estimates are largely explained by this relation.

Estimates of the sample standard deviations are given in brackets for section C of Table 3. As the hypothesis of a normal distribution is statistically significant using chi-squared tests we can say that only half the farmers in any area will have completed stripping by the time the number of days in Table 3 have elapsed, and so on.

In practice the stripping period will be longer than suggested in Table 3. The incidence of unfavourable weather, particularly as it shortens the effective working day, and the fact that farmers in one area do not begin stripping simultaneously will extend the stripping period.

Survey data revealed that at least 95 per cent of holdings have sufficient trucks and labour to transport their wheat to the nearest local silo as fast as, or faster than, the rate at which it is stripped. Therefore the harvesting rate is determined almost entirely by the stripping rate.

6. On-farm Storage

A. Storage Capacity

Provision to hold wheat on every wheat holding serves an important and necessary function in the harvesting operation by providing a buffer between the stripping activity and other harvesting activities. By removing some of the direct and constant dependence of stripping or other activities and vice-versa, this buffer helps to foster greater overall harvesting efficiency.

The form in which this wheat is held on each holding is mainly determined by each farmer's grain handling method. For these purposes handling methods may be classified into four groups, complete bag handling, bag to bulk or semi-bulk, fully bulk with only paddock storage (B.H.), and fully bulk with some permanent storage (B.H.P.). In this section we are principally concerned with the last group of holdings because they alone have on-farm permanent storage.

In Table 4 the proportion of holdings using each of the four handling methods are shown. In terms of the quantity of wheat handled, B.H.P. and to a lesser extent B.H. is more important than this table might suggest because these two handling methods, particularly B.H.P., which require greater total capital outlays than do the other methods, are more commonly used on holdings with large wheat acreages than on those with small wheat acreages.

TABLE 4

Classification of Holdings by Grain Handling Method by Strata

Strata	Complete Bag Handling	Bag to Bulk	Bulk with Paddock Storage Only	Bulk with Permanent Storage
	Per cent	Per cent	Per cent	Per cent
I	11·8	13·3	53·5	21·4
II	4·3	10·0	58·6	27·1
III	9·5	13·7	29·8	47·0
IV	9·9	12·7	41·4	36·0
V	13·9	26·7	23·6	35·8
VI	7·8	23·5	35·9	32·8
VII	2·2	5·9	52·9	39·0

In Table 5 the pattern of on-farm permanent storage on survey holdings is shown, firstly as a frequency distribution of holdings classified by quantity of permanent storage, and secondly as the average (arithmetic mean) quantity of permanent storage per holding. The fact that the distribution is positively skewed means that it may be preferable to use the median or mode as a measure of the typical quantity of permanent storage per holding in preference to the mean.

A more useful measure of farm storage as a buffer is given in Table 6, where the quantities of paddock and permanent storage per harvested acre are shown. For comparative purposes data is also given for those holding's using B.H. Another advantage of this measure is that the distributions of storage per acre are normal and so avoids the problems encountered in describing skewed distributions.

TABLE 5

Classification of Survey Holdings with Some Permanent Storage by Quantity of Permanent Storage, and Average Quantity of Permanent Storage per Holding

Class Interval	I	II	III	IV	V	VI	VII	N.S.W.
	Per cent							
Bushels								
0– 1,500	2·5	16·2	2·5	7·1	10·0	11·6	5·7	8·4
1,501– 2,500	30·0	25·6	11·1	9·5	18·8	16·3	20·8	18·0
2,501– 3,500	17·5	28·7	11·1	11·9	19·3	16·3	21·0	17·5
3,501– 4,500	15·0	..	6·2	7·1	5·0	16·3	13·3	9·4
4,501– 5,500	5·0	5·4	7·4	4·8	13·3	9·3	4·8	7·3
5,501– 6,500	10·0	7·1	9·9	4·8	3·5	11·6	13·3	9·9
6,501– 9,500	2·5	11·5	6·1	9·5	13·3	7·0	13·3	9·0
9,501–13,500	7·5	2·7	22·1	14·3	10·2	2·3	5·7	10·0
13,501–20,500	10·0	..	16·3	21·4	5·2	7·0	1·9	7·3
Over 20,500	..	2·7	7·3	9·5	1·7	2·3	..	3·5
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Permanent storage per holding (bu.)								
Mean	4,913	4,171	9,721	11,940	6,015	5,443	4,691	6,291
S.D.	4,487	5,107	7,966	15,644	5,830	5,551	3,551	5,657

TABLE 6

Average Capacity of Bulk Wheat Storage per Harvested Acre for Survey Holdings Classified by Handling Method and Strata

Strata	Holdings Using B.H.	Holdings Using B.H.P.		
		Paddock Storage	Permanent Storage	Total Bulk Storage
	Bushels per Acre			
I	13·3 (7·7)	7·6	12·9	20·5 (9·0)
II	11·0 (6·2)	6·7	11·6	18·3 (8·7)
III	11·9 (7·7)	4·2	11·7	15·9 (7·8)
IV	9·5 (5·8)	3·3	15·2	18·5 (10·9)
V	12·0 (6·5)	5·1	15·0	20·1 (9·0)
VI	10·4 (5·3)	7·4	12·7	20·1 (7·4)
VII	9·5 (5·8)	5·3	7·9	18·2 (6·2)

Steel silos, grain sheds and bins beneath sheds, particularly weldmesh bins, are the most popular types of on-farm permanent storage. In terms of storage capacity grain sheds are the most important and provide 65 per cent of all on-farm permanent storage. Weldmesh bins beneath existing sheds are second and are followed by steel silos (Table 7).

TABLE 7

Relative Importance of Different Types of On-farm Permanent Storage by Strata and N.S.W.

Strata	Grain Sheds	Steel Silos	Bins Beneath Sheds	Total
	Per cent			
I	61·4	6·8	31·8	100·0
II	64·7	22·0	13·3	100·0
III	68·5	11·8	19·7	100·0
IV	82·0	7·3	10·7	100·0
V	65·8	13·6	20·6	100·0
VI	58·0	16·5	25·5	100·0
VII	57·4	24·1	18·5	100·0
N.S.W.	64·6	14·7	20·7	100·0

Estimates in Table 8 of number of holdings are calculated as the product of number of holdings in the population and the proportion of survey holdings with some permanent storage. Storage capacity is calculated as the product of number of holdings with some permanent storage and permanent storage capacity per sample holding with some permanent storage. Estimates are given at the mean and 95 per cent confidence limits.[10] Respective estimates of on-farm permanent storage capacity are 35·9 million bushels at the mean and 30·7 and 41·2 million bushels for the lower and upper confidence limits. Geographically, approximately 18 million bushels are in those areas serviced by the Newcastle terminal and the other 17 million bushels in the central and southern areas of N.S.W. serviced by the Sydney terminal.

TABLE 8

Estimated Number of Holdings with On-farm Permanent Wheat Storage and Estimated Total Capacity of On-farm Permanent Wheat Storage for Strata and N.S.W.

Strata	Number of Holdings	Capacity of Permanent Storage		
		Mean	95 per cent Confidence Intervals	
			Upper	Lower
	No.	'000 bushels		
I	578	2,839	3,182	2,496
II	957	3,991	4,752	3,231
III	1,364	13,259	14,997	11,672
IV	153	1,827	2,203	1,450
V	414	2,490	2,824	2,156
VI	1,477	8,039	9,370	6,709
VII	732	3,434	3,863	3,009
N.S.W.	5,675	35,879	41,191	30.723

B. Cost Schedules

Cost schedules will be estimated for steel silos, prefabricated grain sheds, and Weldmesh bins erected beneath existing sheds. As well as being the most common types of on-farm permanent storage they are readily available on the market.

Capital Costs

Capital costs of steel silo and grain shed structures include the cost of materials (valued f.o.r. Newcastle), erection costs at commercial rates, and concrete floors. In the case of weldmesh bins, capital costs include the mesh, air tube, emptying panel and flat iron on which the bin is erected. For the three types, grain-handling equipment is a 30-foot mobile auger, plus a sweep for grain sheds. A summary of capital costs for varying storage capacities is given in Table 9.

[10] Although the distribution of holdings by storage capacity per holding is non-normal the sample mean is normally distributed about the population mean and therefore these estimates will be unbiased and best. See: Quenoville, *op. cit.*, p. 173.

TABLE 9

Storage Capacity, Total and Average Capital Cost of Steel Silos, Grain Sheds and Weldmesh Bins Beneath Existing Sheds

Storage Capacity	Capital Costs		Total Capital Cost	Average Capital Cost per Bushel
	Structure	Equipment		
Bushels	$	$	$	Cents
		Steel Silos		
1,200	547	766	1,313	109·4
2,000	707	766	1,473	73·7
3,100	941	766	1,707	55·1
3,700	1,019	766	1,785	48·2
4,900	1,567	766	2,333	47·6
6,800	1,960	766	2,726	40·1
9,400	2,744	766	3,510	37·3
14,800	4,075	766	4,841	32·7
25,900	7,132	766	7,898	30·5
		Grain Sheds		
6,700	2,253	808	3,061	45·7
8,550	2,494	808	3,302	36·6
10,100	3,001	808	3,809	37·7
13,100	3,340	808	4,148	31·7
16,675	4,192	808	5,000	30·0
22,250	5,036	808	5,844	26·3
26,825	5,884	808	6,692	24·9
		Weldmesh Bins		
1,000	41	766	807	80·7
2,000	82	766	848	42·4
3,000	123	766	889	29·6
5,000	205	766	971	19·4
7,000	287	766	1,053	15·0
10,000	410	766	1,176	11·8
13,000	533	766	1,299	10·0
18,000	738	766	1,504	8·4
22,000	902	766	1,668	7·6
27,000	1,107	766	1,873	6·9

These capital costs may be considered as an absolute maximum. For any holding they may be considerably less for several reasons. Silos and grain sheds may be erected by using general farm labour, whose opportunity cost during slack periods may be less than commercial erection costs. The full capital cost of the auger has been attributed to these facilities, when, in practice it also may be used in the normal grain-handling activities. More likely, the mobile auger replaces a cheaper portable auger. These last two factors are more likely to be valid for small levels of storage capacity, where the high capital costs are largely due to equipment costs, than they are at higher levels.

Annual Physical Costs

Steel silo and grain shed structures are depreciated at three per cent per annum and weldmesh bins at ten per cent. Handling equipment is depreciated over ten years after allowing for a salvage value of 200 dollars for the auger. These rates have been chosen with respect to giving a reasonable life expectation to the asset and with respect to the asset's market value. Interest at 5·5 per cent per annum for the use of capital is charged against the average value of all capital employed. The final item in fixed costs is an insurance charge of 12·5 cents per 100 dollars on all capital.

Variable costs included in this analysis are:

(1) auger running costs at 25 cents per 100 bushels consisting of 20 cents for repairs and maintenance and five cents for fuel and oil;

(2) labour at $1.20 per hour for attendance of the auger and for 30 minutes required to erect each 1,000 bushel weldmesh bin. For the individual holding the opportunity cost of labour may, however, be less than, or greater than, this market cost;

(3) hessian lining of weldmesh bins at eight dollars per 1,000 bushel bin; and

(4) the cost of chemicals to protect grain against insect parasites—phostoxin tablets at $8.33 per 1,000 bushels. Provided this treatment is carried out and wheat is not put into storage at moisture levels above 12·5 per cent, grain losses are likely to be negligible as "biochemical deterioration is apparently not usually important under Australian conditions".[11]

A summary of the annual physical costs is shown in Table 10. More detailed schedules are given in Appendix C.

Over all ranges of storage space weldmesh bins beneath existing sheds are the cheapest type of on-farm permanent storage. In relative terms this advantage is greater at lower levels of storage capacity than at higher levels. For 2,000 bushels of storage capacity the average physical cost of weldmesh bins is 7·25 cents per bushel compared to 8·28 cents and 14·04 cents per bushel for steel silos and grain sheds respectively. At 27,000 bushels storage capacity the average physical costs per bushel for weldmesh bins, steel silos, and grain sheds are 3·21 cents, 3·71 cents, and 3·34 cents respectively. However, the quantity of weldmesh bin storage on any holding is limited by the availability of free shed space. Thus it may only be an appropriate alternative at low levels of storage capacity. Comparing steel silos and grain sheds, steel silos provide cheaper storage up to 10,000 bushels and then grain sheds.[12]

This pattern of storage costs approximately corresponds with the pattern of storage types found on survey holdings. Holdings with greater than 10,000 bushels of storage capacity had either grain sheds, weldmesh bins, or a combination of both. Holdings with less than 10,000 bushels of storage capacity mostly depended on weldmesh bins and steel silos, with only a few having grain sheds in this range.

[11] See, "Bulk Storage of Grain, A Summary of Factors Governing Control of Deterioration", *C.S.I.R.O. Division of Mechanical Engineering*, Report E.D. 8, May 1964, p. 39.

[12] A similar study by G. F. Donaldson and J. G. Ryan, "The Cost of Storing Grain on Farms", *N.S.W. Department of Agriculture, Division of Marketing and Agricultural Economics Bulletin* M 12, 1965, arrived at similar conclusions to this study. However the absolute storage costs figures are different because of the different assumptions made, particularly those with respect to interest and depreciation rates and insect control.

TABLE 10

Total and Average Annual Physical Storage Cost of Steel Silos Grain Sheds and Weldmesh Bins Beneath Existing Sheds

Storage Capacity	Annual costs		Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Fixed	Variable		
Bushels	$	$	$	Cents
		Steel Silos		
1,200	125·4	17·6	143·0	11·91
2,000	136·6	29·1	165·7	8·28
3,100	153·1	44·9	198·0	6·38
3,700	158·5	53·7	212·2	5·73
4,900	197·2	71·9	269·1	5·49
6,800	224·5	99·4	323·9	4·76
8,600	268·1	125·0	393·1	4·57
9,400	279·3	136·5	415·8	4·42
14,800	372·5	214·9	587·4	3·96
18,500	443·8	269·0	712·8	3·85
22,200	515·4	322·7	838·1	3·77
25,900	586·7	376·4	963·1	3·71
		Grain Sheds		
6,700	250·9	97·3	348·2	5·19
8,550	267·7	124·2	391·9	4·58
10,100	303·2	146·7	449·9	4·45
13,100	327·0	190·3	517·3	3·94
17,675	386·6	256·8	643·4	3·64
22,250	445·7	323·3	769·0	3·45
26,825	508·3	389·7	898·0	3·34
		Weldmesh Bins		
1,000	93·0	23·1	116·1	11·61
2,000	98·7	46·3	145·0	7·25
3,000	104·5	69·4	173·9	5·79
5,000	115·9	115·9	231·8	4·63
7,000	127·6	161·9	289·5	4·13
10,000	144·6	231·3	375·9	3·75
13,000	161·8	300·7	462·5	3·55
18,000	190·6	416·3	606·9	3·37
22,000	213·6	508·9	722·5	3·28
27,000	242·2	624·5	866·7	3·21

Fixed costs are the largest sector of annual physical costs, particularly at the lower levels of storage capacity. In the realistic situation where crop failures will occur from year to year, it is advantageous to have storage units with a low ratio of fixed to total costs. For all levels of storage capacity this ratio is the lowest for weldmesh bins. Comparing steel silos and grain sheds, the ratio is lowest for steel silos up to 10,000 bushels and then grain sheds.

From the analysis of annual physical costs weldmesh bins beneath existing sheds are the most efficient type of on-farm permanent storage. In the absence of available free shed space steel silos are more efficient for storage of up to 10,000 bushels and thence grain sheds.

Real Costs

To physical costs must be added the expenses of handling wheat through a local silo and the cost of chemicals to protect the wheat against insect parasites.

From physical costs must be deducted the value of any other storage services which on-farm permanent storage provides in addition to wheat storage. This requires estimation of (a) the extent to which these facilities are, or may be used to store other farm commodities, and (b) the value to place on these services. While the former can be approximately estimated, very little can be said objectively about the latter other than as discussed in the theory of these costs.

Survey holdings with on-farm permanent storage were asked if, and to what extent, they used their permanent storage facilities to store farm commodities in addition to wheat. These estimates are shown as percentages in Table 11. 68·7 per cent of farmers with some permanent storage said they did store other commodities and the quantity of storage space so used was estimated as 66·7 per cent of permanent storage space.

TABLE 11

Proportion of Survey Holdings with Some Permanent Storage Who Use These Facilities to Store Other Farm Products and the Quality of Storage Space So Used for Strata and N.S.W.

Strata	Per cent of Holdings which Store Other Products	Percentage of Storage Space Used to Store Other Products
I	67·5	69·3
II	50·0	54·3
III	72·2	73·5
IV	67·5	54·6
V	66·1	50·5
VI	64·3	56·2
VII	69·8	52·7
N.S.W.	68·7	66·7

Machinery, particularly wheat harvesting machinery, is the most important other commodity. Others include fertilizer, other farm equipment and summer growing grains, in that order of importance. Almost all shed space in which weldmesh bins were erected is used to store these other commodities when it is not being used for wheat storage. Also, grain sheds are ideally suited to storage of these other commodities.

Extrapolating from sample to population, approximately 24 million bushels of the current 35·9 million bushels of on-farm permanent storage is used for storage of other commodities as well as for wheat. However, we may disregard the value of other storage services provided by weldmesh bin storage because no cost for use of the shed is included in the physical costs of weldmesh bins. This accounts for approximately eight million bushels.

Results from the survey support the hypothesis advanced that the quantity of any additional permanent storage that will be used to store other products as well as wheat will decline. Only 15 per cent of farmers without permanent storage indicated their intention to use such facilities to store other commodities if they were to construct some permanent storage in the future.

On-farm permanent storage may facilitate managerial efficiency. To measure this increase for the aggregate of wheat holdings is beyond the present level of knowledge. If there is sufficient storage capacity it is doubtful if the marginal convenience yield would be significant for many farmers.

The principal factors which have fostered the construction of on-farm storage in recent years are concerned with losses incurred by farmers during delivery delays through damage of grain held in paddock storage and the costs of idle men and trucks held-up in queues. Such costs can be reduced by the construction of more permanent storage anywhere, and so they are irrelevant to assessing the real costs of on-farm permanent storage.

Overall it does not appear that real costs of on-farm permanent storage would be much less than physical costs except at low levels of storage capacity.

7. Commercial Storage

A. Storage Capacity

In Table 12 is shown the quantities of local silo, sub-terminal, and terminal storage capacity for the years 1957–58 to 1964–65 inclusive. Over this period the importance of mill-owned storage has declined both absolutely and relatively. All of the increased commercial storage capacity over this period has come from increased local silo storage capacity. During the same period sub-terminal storage capacity has remained constant, and terminal storage capacity has fallen. In 1964–65 there was 70·3 million bushels of local silo storage, 16·5 million bushels of sub-terminal storage, and 17·2 million bushels of terminal storage, a total of 140 million bushels of commercial storage.

Table 12

Capacity of Local Silo, Sub-terminal and Terminal Bulk Wheat Permanent Storage in N.S.W., Annual 1958-59 *to* 1964-65

Season	GEB Storage			Mill Storage Terminal
	Local Silo	Sub-terminal	Terminal	
	Thousand Bushels			
1957-58	41,250	16,500	12,200	6,484
1958-59	45,220	16,500	11,700	6,476
1959-60	45,240	16,500	11,700	6,436
1960-61	47,070	16,500	11,700	5,940
1961-62	51,286	16,500	11,700	5,771
1962-63	58,846	16,500	11,700	5,571
1963-64	65,527	16,500	11,700	5,571
1964-65	70,250	16,500	11,700	5,571

Source: *The Wheat Situation*, No. 25, Bureau of Agricultural Economics, Canberra. *Annual Reports of Grain Elevators Board*, 1958 to 1963.

B. Cost Schedules

Cost schedules will be estimated for silos, bulkheads, 'A' type depots and 'C' type depots. These have been the most important types of commercial storage built in recent years, and it is expected that, with modifications, these types will be used in future construction plans.

Silos consist of numerous vertical concrete bins. Bulkheads and depots on the other hand, are single cell, horizontal storage units. Bulkheads are entirely steel structures whereas depots have concrete walls and steel roofs. Both the 'C' type depot and the bulkhead are rectangular in shape, while the 'A' type depot is circular. All horizontal units have concrete floors and aeration equipment. For all types, wheat is handled by elevators and conveyor equipment.

Capital Costs

Capital costs are derived from the capital costs of storage units constructed for the GEB over the period 1959 to 1964 inclusive. Because of the effects of time of construction, location, different tendering arrangements and circumstances, and minor technical differences between storage units, these costs are not strictly comparable in their present form. All data was first converted into 1965 values using the Index of Minimum Weekly Wages paid for Building and Construction in N.S.W. as an inflator.[13] Regression lines were then fitted to the adjusted data.

Utilizing the hypothesis that capital costs are a function of the size of the storage unit, the equation form $Y = aX^be$ was used to estimate capital costs of silos and bulkheads (Y is total capital cost, X storage capacity, e the random error, and a and b the parameters). Reasons for selection of this equation form are threefold; if $0 < b < 1$, average and marginal capital costs will be a declining function of storage capacity but at a decreasing rate; it is inexpensive in degrees of freedom which are limited by six observations; and it gave as good as, or a better fit, R^2, than did other equation forms. Least squares methods were used to estimate the parameters. The estimated functions for silos and bulkheads are given in the footnotes of Table 13.[14]

Capital cost schedules for silos, bulkheads, and wheat depots are shown in Table 13. In terms of the demand for capital resources, bulkheads are the most efficient type of commercial storage for all levels of storage capacity.

Annual Physical Cost

Silo and depot structures are depreciated at one per cent per annum and bulkhead structures at three per cent. Equipment is depreciated over a twenty-year period. Interest at 5·5 per cent per annum for the use of capital is charged against the average value of all capital employed. It is argued that 5·5 per cent is the opportunity cost of employing capital in storage facilities in the sense that this is the rate the GEB would have to offer to raise capital from the public. This is the rate at which

[13] Source: *Labour Reports*, 1958 *to* 1965, Commonwealth Bureau of Census and Statistics, Canberra.

[14] In the case of depots data was comparable except for the time element and so no functions were fitted.

similarly constituted authorities, e.g., Sydney Water Board and Sydney County Council, raise finance from the public;[15] 12·5 cents per 100 dollars is charged for insurance of all capital assets.

TABLE 13

Storage Capacity, Handling Rate of Equipment, Total and Average Capital Cost of Silos, Steel Bulkheads and Wheat Depots

Storage Capacity	Handling Rate of Equipment	Capital Cost: Structure	Capital Cost: Equipment	Total Capital Cost	Average Capital Cost per Bushel
'000 bu.	Tons/hr	$	$	$	Cents
			Silos*		
200	150	118,000	51,000	169,000	84·5
300	150	161,200	69,300	230,500	76·8
400	150	201,100	86,200	287,300	71·8
500	150	238,560	102,240	340,800	68·2
600	150	274,400	117,600	392,000	65·3
700	150	304,400	136,800	441,200	63·0
			Bulkheads†		
100	60	25,500	14,600	40,100	40·1
200	90	47,300	28,200	75,500	37·8
300	150	63,440	41,360	104,800	34·9
400	150	82,700	52,300	135,000	33·8
500	150	103,000	61,000	164,200	32·8
			'A' Type Depot		
400	150	148,500	86,900	235,400	58·8
700	200	189,200	121,680	310,880	44·4
1,000	200	247,800	164,200	412,000	41·2
			'C' Type Depot		
1,500	250	387,100	252,900	640,000	42·7

* Total capital cost derived from

$Y = 14{\cdot}68X^{0{\cdot}7657}$ $\quad R^2 = 0{\cdot}74$

(0·1724)

Y: Total capital cost; X: Storage capacity.

† Total capital cost derived from

$Y = 1{\cdot}64X^{0{\cdot}8776}$ $\quad R^2 = 0{\cdot}89$

(0·1031)

Y: Total capital cost; X: Storage capacity.

Variable or operating costs included in the schedules are:

(1) repairs and maintenance of capital assets;

(2) fuel, power, grease, etc., to run the handling equipment at two cents per 100 bushels;

(3) labour to operate handling equipment, to attend weighbridge, and for checking grain at $3.05 per hour. This is done by a three-man team. Overtime pay and time lost through mechanical breakdowns and waiting is not considered; and

(4) costs of protecting grain against insect parasites.

[15] For 10 to 15 years loans which are guaranteed by the N.S.W. Government.

All grain is initially sprayed with malathion protectant costing 0·14 cents per bushel. In silos subsequent treatment involves turning the wheat and administering phostoxin tablets. This involves chemical costs of 0·06 cents per bushel, labour, and machinery operating costs. In horizontal storage subsequent protection is obtained by cooling the grain through aeration. Cost of power to operate aeration equipment is approximately one dollar per 2,500 bushels per annum. As with on-farm permanent storage grain losses are assumed to be negligible.

A summary of annual physical costs is shown in Table 14. More detailed schedules are given in Appendix D.

TABLE 14

Total and Average Annual Physical Storage Cost of Silos, Bulkheads and Wheat Depots

Storage Capacity	Annual Costs		Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Fixed	Variable		
'000 bushels	$	$	$	Cents
		Silos		
200	8,589	1,841	10,430	5·22
300	11,704	2,484	14,188	4·73
400	14,581	3,167	17,748	4·44
500	17,296	3,850	21,146	4·23
600	19,894	4,548	24,442	4·07
700	22,569	5,246	27,815	3·97
		Bulkheads		
100	2,648	1,030	3,678	3·68
200	4,842	1,372	6,214	3·11
300	6,994	1,593	8,587	2·86
400	8,978	1,950	10,928	2·73
500	10,871	2,317	13,188	2·64
		'A' Type Depot		
400	12,598	1,898	14,496	3·62
700	16,914	2,816	19,730	2·82
1,000	22,533	3,784	26,317	2·63
		'C' Type Depot		
1,500	34,916	5,168	40,084	2·67

For all levels of storage capacity the horizontal types of storage offer the cheapest commercial storage. Up to a million bushels, bulkhead storage is the cheapest of those considered. The average annual physical storage cost of bulkhead storage being 3·68 cents per bushel for a 100,000 bushel unit, declining to 2·64 cents per bushel for a 520,000 bushel unit which is the largest bulkhead constructed in N.S.W. For a million bushels of storage capacity the 'A' type depot is marginally cheaper at 2.63 cents per bushel than is bulkhead storage. The 1·5 million bushel 'C' type depot is slightly dearer again at 2·67 cents per bushel.

Fixed costs absorb 80 per cent or more of total costs for all storage units considered except for the 100,000 bushel bulkhead. The ratio of fixed to total costs is approximately the same at comparable levels of storage capacity for bulkheads and silos and slightly higher in the case of depots, particularly the 'C' type depot.

How does segregation of wheat affect physical costs? In the case of silos which have numerous bins there are no problems. In bulkheads and 'C' type depots wheat may be segregated by making separate piles of grain at no extra cost. Given the existing requirements for segregation, such segregation is adequate for the handling and storage of wheat in N.S.W.[16] There can be no segregation in 'A' type depots without the erection of partitions which will increase physical costs.

Taking annual physical costs, bulkheads are the most efficient type of commercial storage for storage of up to one million bushels. Compared to the 'A' type depot which is marginally cheaper for the storage of a million bushels or more bulkheads have other advantages which favour the latter. First the ratio of fixed to total physical costs is lower for bulkheads, second, 'A' type depots are unsuited to the segregation of wheat, and third, the time required to fill an 'A' type depot, 134 hours, is in excess of the harvesting period under most circumstances; the period of time required to fill a bulkhead, 89 hours, is within this restriction.

Real Costs

To the physical costs of sub-terminals is added a rail stop-over charge of 2·5 cents per bushel, which is an additional freight charge imposed on wheat stored at sub-terminals only. Also, the real costs of a sub-terminal will include an additional handling charge of 0·19 cents per bushel.

The additional fixed costs of maintaining machinery with a handling capacity in excess of the local silo storage unit's requirements, so that sufficient wheat can be handled for the local silo, sub-terminal and terminals' storage requirements, must be included in the real costs of sub-terminal and terminal storage. Because of the many variables operating in this situation, and because of the absence of any applicable data, these costs cannot be estimated with any accuracy.

The high capital cost of additional rolling stock, plus the limitations of available locomotive power and line space, suggest that the quantity of terminal storage at least, and probably the quantity of sub-terminal storage, which, because of the shorter haulage can obtain a higher level of utilization of rail trucks, will be limited to the quantity of wheat which can be shifted during the harvesting period by the existing quantity of rolling stock.[17] The relevant problem here is really how to use our existing rail facilities most efficiently.

In the more realistic situation, in which the assumption of a fixed known quantity of wheat to be stored from year to year is relaxed, it was argued that the real costs of terminal and sub-terminals may be less than

[16] Personal communication with member of GEB.

[17] To date no definite cost of wheat waggons has been publicly stated. *The Australian Financial Review*, October 6, 1965, reported a cost of approximately $14,000 for the 56-ton aluminium wheat hoppers.

those of local silo and on-farm storage units. This hypothesis rests on the premise that relative production variability declines as the geographic area increases.

To test this hypothesis let us simplify the problem by assuming that production variability is a direct function of yield per acre. At one extreme if yield in one area moves inversely to yield in another the hypothesis is unequivocally true. If, on the other hand, they move together the hypothesis is false.

If we look at a matrix of correlation co-efficients of yields per acre between different shires for the period 1930–31 to 1961–62 we find that neither of the extremes is realistic. All the co-efficients were positive and ranged from 0·07 to 0·94 suggesting that yields move together but not perfectly.[18] Another matrix showing the probabilities of above median yields in one shire co-inciding with below median yields in another and vice versa was computed. Expressed as an percentage, these probabilities ranged from zero to 35, those for adjoining shires being less than 12. A more exacting test in which only the first and fourth quartiles were matched reduces the respective percentages to zero, to 11, and three. If sub-terminals are dependent on wheat grown in adjoining shires the validity of the hypothesis is doubtful, and its implication negligible. In the case of terminals the hypothesis demands greater respect.

Real costs of local silo storage units remain the same as physical costs. Those of sub-terminals include 2·69 cents per bushel for additional freight and handling expenses, plus additional machinery fixed costs in addition to physical costs. Real costs of terminals include physical costs, plus additional machinery fixed costs, less a slight advantage for comparisons based on amount stored rather than storage capacity. These remarks assume that the quantity of sub-terminal and terminal storage capacity for intra-seasonal storage is limited by available rail transport facilities. This latter qualification is invalid for inter-seasonal storage comparisons.

8. Discussion and Conclusions

Estimates of the average real long run annual costs are collated and compared. The aim of this discussion is primarily to aid decisions on the type or types of wheat storage facilities to construct in the future.

The validity of the ensuing discussion is limited by the many inherent problems encountered in this type of project. Some sectors of real costs, because of the unavailability of data, have not been quantified. Again, those costs which have been estimated, have been estimated only after making many assumptions, some of which are largely subjective. Perhaps the greatest limitation lies in anticipating the future by making projections largely based on past experience.

Before proceeding to the cost analysis it may be worthwhile to summarize the estimates of permanent bulk wheat storage capacity. For the 1964–65 harvesting season there was approximately 140 million bushels of permanent bulk wheat storage space in N.S.W., consisting of 35·9 million bushels of on-farm permanent storage, 70·3 million bushels of local silo storage, 16·5 million bushels of sub-terminal storage and 17·3 million bushels of terminal storage.

[18] See Duloy and Watson, *op cit*, Appendix I (c).

TABLE 15

*Average Real Long Run Annual Costs per Bushel of On-farm, Local Silo, Sub-terminal and Terminal Permanent Bulk Wheat Storage**

Storage Capacity	On-farm			Local Silo	Sub-terminal		Terminal	
	Weldmesh Bins	Silos, Grain Sheds						
		Measured Cost	Other Factors		Measured Cost	Other Factors	Measured Cost	Other Factors
'000 Bushels	Cents	Cents		Cents	Cents		Cents	
1	11·89	12·18	Less average value of other services used and convenience value.			Plus average cost of use of rail trucks and increased machine holding costs.		Plus average cost of use of rail trucks and increased machine holding costs, less advantage of stable grain supply.
2	7·53	8·56						
3	6·07	6·66						
5	4·94	5·77						
10	4·03	4·70						
20	3·65	3·73						
100				3·68	6·37		3·68	
200				3·11	5·80		3·11	
300				2·86	5·55		2·86	
500				2·64	5·33		2·64	
1,000				2·64	5·33		2·64	
5,000				2·64	5·33		2·64	

* Theoretically the cost of handling grain through the terminal should be added to all costs to obtain real costs.

In Table 15, estimates of the average real long run annual costs for the four storage forms are shown. Costs shown under each storage form are those of the cheapest type of storage unit feasible. Under on-farm permanent storage, estimates are given for both weldmesh bins beneath existing sheds and steel silos and grain sheds because of the relative advantages of each under different circumstances. Real costs of local silo, sub-terminal, and terminal storage are based on the physical costs of steel bulkheads.

Essential to the comparison of real costs is an assessment of the quantities of wheat to be stored at each location, particularly as this determines the extent to which advantage is taken of the cost economies of size. The definitional nature of sub-terminal and terminal storage guarantees that the advantages of size will be fully exploited. Throughout N.S.W. the capacity of local silo storage at rail sidings ranges from 30,000 bushels through to 2·25 million bushels. In recent years construction of units of less than 300,000 bushels has been the exception. Referring back to Table 5 the mean quantity of on-farm permanent storage per holding is 6,291 bushels, median 4,189 bushels, and only 2,451 bushels at the mode. Only 20 per cent of holdings have in excess of 10,000 bushels. These statistics may be even lower in reference to construction of additional on-farm permanent storage as holdings with relatively small wheat acreages undertake construction of permanent storage.

Principle reason for the relative inefficiency of sub-terminal storage compared to local silo and terminal storage is the extra freight cost of 2·5 cents per bushel and to a lesser extent a second handling charge of 0·19 cents per bushel.

In reference to the value of services provided by on-farm permanent storage in addition to those of wheat storage it was suggested that they would be negligible for any additional on-farm permanent storage. Also, the quantity of additional on-farm permanent storage which might be provided by weldmesh bins beneath existing sheds, which is the cheapest type of on-farm permanent storage, is not likely to be substantial. Thus, except for those holdings which can service relatively large quantities of on-farm permanent storage, this form of storage does not seem to provide an economic alternative to, say, more local silo storage.

The greater convenience and ease of operation of local silo storage compared to terminal storage makes it the cheapest form of storage if the advantages of size can be fully utilized, i.e., for storage of at least half a million bushels. For those areas which cannot service a structure of such capacity, surplus grain should be moved into terminal storage, rail transport facilities permitting.

Appendix A

List of Shires in Survey by Strata

Strata I—South Western Slopes

Shires of Boorowa, Burrangong, Demondrille, Gundagai, Holbrook, Hume, Illabo, Jindalee, Kyeamba, Mitchell, Narraburra, Tumbarumba, Tumut and Weddin.

Strata II—Riverina

Shires of Berrigan, Canargo, Coolamon, Corowa, Culcairn, Jerilderie, Leeton, Murray, Urana, Wakool, Windouran, Narrandera, Wade, Lockhart and Balranald.

Strata III—Shires in Northern N.S.W. with large acreage increases in recent years.

Shires of Liverpool Plains, Nundle, Tamarang, Yallaroi, Ashford, Boolooroo, Boomi, Coonabarabran and Namoi.

Strata IV—A "new" area separated from III because of greater yield variability

Shires of Bogan, Warren, Walgett, Coonamble and Cobar.

Strata V—Old established wheat growing areas in Northern N.S.W.

Shires of Barraba, Bingara, Cockburn, Macintyre, Manilla, Murrurundi and Peel.

Strata VI—"Central" N.S.W.

Shires of Gilgandra, Boree, Goobang, Jemalong, Coolah, Molong, Talbragar, Timbebrongie, Wellington, Cudgegong, Lyndhurst, Merriwa and Waugoola.

Strata VII—Marginal Western fringe in established growing areas.

Shires of Bland, Lachlan, Carrathool, Waradgery, Murrumbidgee.

Appendix B

Comparison Between Sample and Statistician's Yield Estimates 1964–65

Strata	Official Estimated Yield*	Sample Yield		Difference
		Mean	Standard Deviation	
	Bus/acre	Bus/acre	Bus/acre	Bus/acre
I	25·8	26·8	8·7	−1·0†
II	24·2	25·5	8·2	−1·3†
III	29·3	30·0	9·5	−0·7†
IV	24·2	24·8	8·8	−0·6†
V	26·3	26·8	8·9	−0·5†
VI	26·4	26·9	7·0	−0·5†
VII	25·6	24·8	6·2	0·8†

* Source: New South Wales Statistical Register.

† Not significantly different from zero at the 5 per cent level.

APPENDIX C (A)

Annual Physical Cost of Steel Silos

Storage Capacity	Fixed Costs				Operating Costs			Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Depreciation		Interest	Insurance	Auger Running Costs	Labour	Chemicals for Grain Treatment		
	Structure	Equipment							
Bushels	$	$	$	$	$	$	$	$	Cents
1,200	16.4	56.6	36.0	16.4	6.0	1.6	10.0	143.0	11·91
2,000	21.2	56.6	40.4	18.4	10.0	2.4	16.7	165.7	8·28
3,100	28.2	56.6	47.0	21.3	15.5	3.6	25.8	198.0	6·38
3,700	30.6	56.6	49.0	22.3	18.5	4.4	30.8	212.2	5·73
4,900	47.4	56.6	64.0	29.2	24.5	6.6	40.8	269.1	5·49
6,800	58.8	56.6	75.0	34.1	34.8	8.0	56.6	323.9	4·76
8,600	77.6	56.6	92.0	41.9	43.0	10.4	71.6	393.1	4·57
9,400	82.4	56.6	96.4	43.9	47.0	11.2	78.3	415.8	4·42
14,800	122.4	56.6	133.0	60.5	74.0	17.6	123.3	587.4	3·96
18,500	153.0	56.6	161.0	73.2	92.5	22.4	154.1	712.8	3·85
20,500	174.2	56.6	187.0	85.0	102.5	24.6	170.8	800.7	3·90
22,200	183.6	56.6	189.2	86.0	111.0	26.8	184.9	838.1	3·77
25,900	214.2	56.6	217.2	98.7	129.5	31.1	215.8	963.1	3·71

APPENDIX C (B)

Annual Physical Cost of Steel Grain Sheds

Storage Capacity	Fixed Costs				Operating Costs			Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Depreciation		Interest	Insurance	Auger Running Costs	Labour	Chemicals for Grain Treatment		
	Structure	Equipment							
Bushels	$	$	$	$	$	$	$	$	Cents
6,700	67.6	60.8	84.2	38.3	33.5	8.0	55.8	348.2	5·19
8,550	74.8	60.8	90.8	41.3	42.7	10.3	71.2	391.9	4·58
10,100	90.0	60.8	104.8	47.6	50.5	12.1	84.1	449.9	4·45
13,100	100.2	60.8	114.1	51.9	65.5	15.7	109.1	517.3	3·94
17,675	125.8	60.8	137.5	62.5	88.4	21.2	147.2	643.4	3·64
22,250	151.1	60.8	160.7	73.1	111.3	26.7	185.3	769.0	3·45
26,825	179.8	60.8	184.0	83.7	134.1	32.2	223.4	898.0	3·34

APPENDIX C (c)

Annual Physical Cost of Weldmesh Bins Under Cover of Existing Sheds

Storage Capacity	Fixed Costs				Operating Costs				Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Depreciation		Interest	Insurance	Auger Running Costs	Hessian	Labour	Chemicals for Grain Treatment		
	Structure	Equipment								
Bushels	$	$	$	$	$	$	$	$	$	Cents
1,000	4.1	56.6	22.2	10.1	5.0	8.0	1.8	8.3	116.1	11·61
2,000	8.2	56.6	23.3	10.6	10.0	16.0	3.6	16.7	145.0	7·25
3,000	12.3	56.6	24.5	11.1	15.0	24.0	5.4	25.0	173.9	5·79
5,000	20.5	56.6	26.7	12.1	25.0	40.0	9.2	41.7	231.8	4·63
7,000	28.8	56.6	29.0	13.2	35.0	56.0	12.6	58.3	289.5	4·13
10,000	41.0	56.6	32.3	14.7	50.0	80.0	18.0	83.3	375.9	3·75
13,000	53.3	56.6	35.7	16.2	65.0	104.0	23.4	108.3	462.5	3·55
18,000	73.8	56.6	41.4	18.8	90.0	144.0	32.4	149.9	606.9	3·37
20,000	82.0	56.6	43.6	19.8	100.0	160.0	36.0	166.6	664.6	3·32
22,000	90.2	56.6	45.9	20.9	110.0	176.0	39.6	183.3	722.5	3·28
27,000	110.7	56.6	51.5	23.4	135.0	216.0	48.6	224.9	866.7	3·21

APPENDIX D (A)

Annual Physical Cost of Concrete Silos

Storage Capacity	Fixed costs				Operating costs				Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Depreciation		Interest	Insurance	Repairs and Maintenance	Labour	Fuel, Power Oil, etc.	Chemicals for Grain Treatment		
	Structure	Equipment								
'000 Bushels	$	$	$	$	$	$	$	$	$	Cents
200	1,180	2,550	4,648	211	460	461	120	800	10,430	5·22
300	1,612	3,465	6,339	288	480	624	180	1,200	14,188	4·73
400	2,011	4,310	7,901	359	495	832	240	1,600	17,748	4·44
500	2,386	5,112	9,372	426	510	1,040	300	2,000	21,146	4·23
600	2,744	5,880	10,780	490	540	1,248	360	2,400	24,442	4·07
700	3,044	6,840	12,133	552	570	1,456	420	2,800	27,815	3·97

APPENDIX D (B)

Annual Physical Cost of Steel Bulkheads

Storage Capacity	Fixed Costs				Operating Costs				Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Depreciation		Interest	Insurance	Repairs and Maintenance	Labour	Fuel, Power Oil, etc.	Chemicals for Grain Treatment		
	Structure	Equipment								
'000 Bushels	$	$	$	$	$	$	$	$	$	Cents
100	765	730	1,103	50	540	270	80	140	3,678	3·68
200	1,419	1,310	2,021	92	570	362	160	280	6,214	3·11
300	1,903	2,078	2,882	131	605	328	240	420	8,587	2·86
400	2,481	2,615	3,713	169	640	430	320	560	10,928	2·73
500	3,090	3,060	4,516	205	680	537	400	700	13,188	2·64

APPENDIX D (c)

Annual Physical Cost of Bulk Wheat Depots

Storage Capacity	Fixed Costs				Operating Costs				Total Annual Physical Cost	Average Annual Physical Cost per Bushel
	Depreciation		Interest	Insurance	Repairs and Maintenance	Labour	Fuel, Power Oil, etc.	Chemicals for Grain Treatment		
	Structure	Equipment								
'000 Bushels	$	$	$	$	$	$	$	$	$	Cents
				'A' Type						
400	1,485	4,345	6,474	294	600	418	320	560	14,496	3·62
700	1,892	6,084	8,549	389	700	576	560	980	19,730	2·82
1,000	2,478	8,210	11,330	515	800	784	800	1,400	26,317	2·63
				'C' Type						
1,500	3,871	12,645	17,600	800	900	968	1,200	2,100	40,084	2·67