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ATTAINING THE LONG RUN
MINIMUM COST REORGANIZATION
OF THE MICHIGAN FERTILIZER INDUSTRY

By

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ABSTRACT

ATTAINING THE LONG RUN MINIMUM COST REORGANIZATION OF THE MICHIGAN FERTILIZER INDUSTRY

By

George R. Perkins

For three consecutive years in the late 1960's the returns to total assets in the fertilizer industry were below 2.0 per cent. These low returns were largely the result of excess production and marketing capacity that have created chaos in the marketing place. Over four billion dollars were invested in the fertilizer industry in the decade of the 1960's. The fertilizer industry in Michigan is not currently using many of the technological advances that have been available for several years.

A comprehensive computerized linear programming model of the Michigan fertilizer industry was developed to determine and analyze the long run minimum cost reorganization of the Michigan fertilizer industry. The model was sufficiently flexible so that a variety of problems could be studied by appropriate specification of constraints, parameters or activities. In this study the model was used to evaluate the impact of changing wage rates and changing capital returns on the long-run optimum organization of the industry. The transition process from the current organization to the long-run minimum cost organization was also studied.

The long-run minimum cost industry organization results in production and use of three products, each of which is high in nutrient content: anhydrous ammonia, monoammonium phosphate and granular potas-

sium chloride. Using the minimum cost industry organization, these three products could be delivered and applied on the farm for about 32.4 per cent less cost than was actually paid by Michigan farmers in 1970. This cost reduction is based upon supplying the same levels of N, P_2O_5, and K_2O that were used by Michigan farmers in 1970.

Changes in the wage rate from $3.00 to $6.50 per man hour resulted in only minor changes in the long run minimum cost industry organization. The effect of such changes in the wage rate are felt primarily by the dry blended fertilizer producers. Throughout the range of wage rates examined, there was no change in the mix of fertilizer materials produced; however, there were minor changes in how these materials were processed and handled.

The return on capital invested in manufacturing, processing, and storage facilities was varied from -2.0 per cent to 20.0 per cent to determine the impact on the long-run minimum cost industry organization. The impact of such variation was surprisingly small; dry blended fertilizer producers are affected to the greatest extent, while there is no change in the mix of fertilizer materials produced.

A six-year transition from the current industry organization to the long-run minimum cost organization was analyzed to determine which products and processes should be discarded in favor of new investment to supply the 1970 levels of N, P_2O_5, and K_2O to Michigan. During the transition, about 47.5 million dollars of new investment would be required, while the total cost savings would amount to nearly 139.4 million dollars, as compared to maintaining the 1970 industry organization and its associated total cost throughout the transition.

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CHAPTER I

INTRODUCTION

The Problem Setting

In 1970, the estimated manufacturing capability of commercial fertilizer companies in North America was 61 per cent greater than estimated domestic use. At the same time, gross production capacity was more than double domestic use.[1] This disparity between production capability and consumption is part of a continuing trend of the recent years. In 1965, for example, estimated fertilizer production capability in North America was 16.21 million tons[2] of plant nutrients. By 1970, this figure had grown to an estimated 27.45 million tons.[3] This represents an annual compound growth rate of 11.1 per cent. Meanwhile, domestic use in North America increased from 11.59 million tons in 1965 to an estimated 17.06 million tons in 1970 representing an annual compound growth rate of 8.1 per cent (Harre, *et al.*, p. 23). Thus, the growth in fertilizer production capability has been over 37 per cent greater than that of use in recent years.

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[1]Gross production capacity is equal to estimated fertilizer production capability plus the total production for all other industrial uses. For example, besides the use of phosphates for fertilizer, they have been commonly used in detergents.

[2]Throughout this study, "tons" will be used to mean "short tons."

[3]See Table I-1.

Table I-1. North American production capability compared with use and Michigan use 1965 and 1970

	Nitrogen	Phosphate	Potassium	Total
PRODUCTION CAPABILITY				
North America (million tons)				
1965	5.82	4.98	5.41	16.21
1970	10.89	7.46	9.18	27.45
Annual Growth	13.18%	8.42%	11.16%	11.10%
USE				
North America (million tons)				
1965	4.83	3.79	2.97	11.59
1970	7.84	5.05	4.18	17.06
Annual Growth	10.17%	5.90%	7.07%	8.10%
Michigan (tons)				
1965	92,243	120,649	112,604	325,496
1970	141,932	140,650	155,441	438,023
Annual Growth	9.00%	3.12%	6.65%	6.12%
PRODUCTION CAPABILITY AS PER CENT OF USE				
North America				
1965	120	131	182	140
1970	138	148	220	161

Sources: Compiled from Harre, et al., Estimated World Fertilizer Production Capacity as Related to Future Needs 1970 to 1975, p. 23, Table A-3; and Michigan Department of Agriculture, "Tonnage of Fertilizer Sold in Michigan from January 1 Through December 31, 1970."

The situation in Michigan was quite similar during this period. Total nutrient use grew from 325,496 tons in 1965 (Hargett, p. 56) to 438,023 tons in 1970 (Michigan Department of Agriculture). On an annual basis, this growth corresponds to a rate of 6.12 per cent.

The Tennessee Valley Authority (TVA) estimates that fertilizer use in North America will grow at slightly less than a 5.2 per cent annual rate between 1970 and 1980. They have estimated 1980 use to be 28.27 million tons of plant nutrients (Harre, et al., p. 23). Given the industry's production capability in 1970 and assuming neither new investment nor loss from depreciation, fertilizer use growing at 5.18 per cent annually would finally equal current existing production capability sometime just prior to 1980. Figure I-1 graphically depicts this relationship.

While total productive capability in North America was growing 11.1 per cent compounded annually, nitrogen production capability increased 13.18 per cent annually, during the five year period from 1965 to 1970. In 1965, estimated nitrogen fertilizer production capability was 5.82 million tons yearly; by 1970, this figure had nearly doubled to 10.81 million tons. Use of nitrogen during the same period increased at a rate of 10.17 per cent annually (Harre, et al., p. 23). Although the growth rate of nitrogen utilization was the fastest of the three basic nutrients (nitrogen, phosphate, and potassium), it was still less than the overall growth of productive capability. During the same period, nitrogen use in Michigan grew at a 9.0 per cent annual rate. Nitrogen usage by Michigan farmers was 92,243 tons in 1965 (Hargett, p. 56). By 1970, nitrogen use had grown to 141,932 tons (Michigan Department of Agriculture).

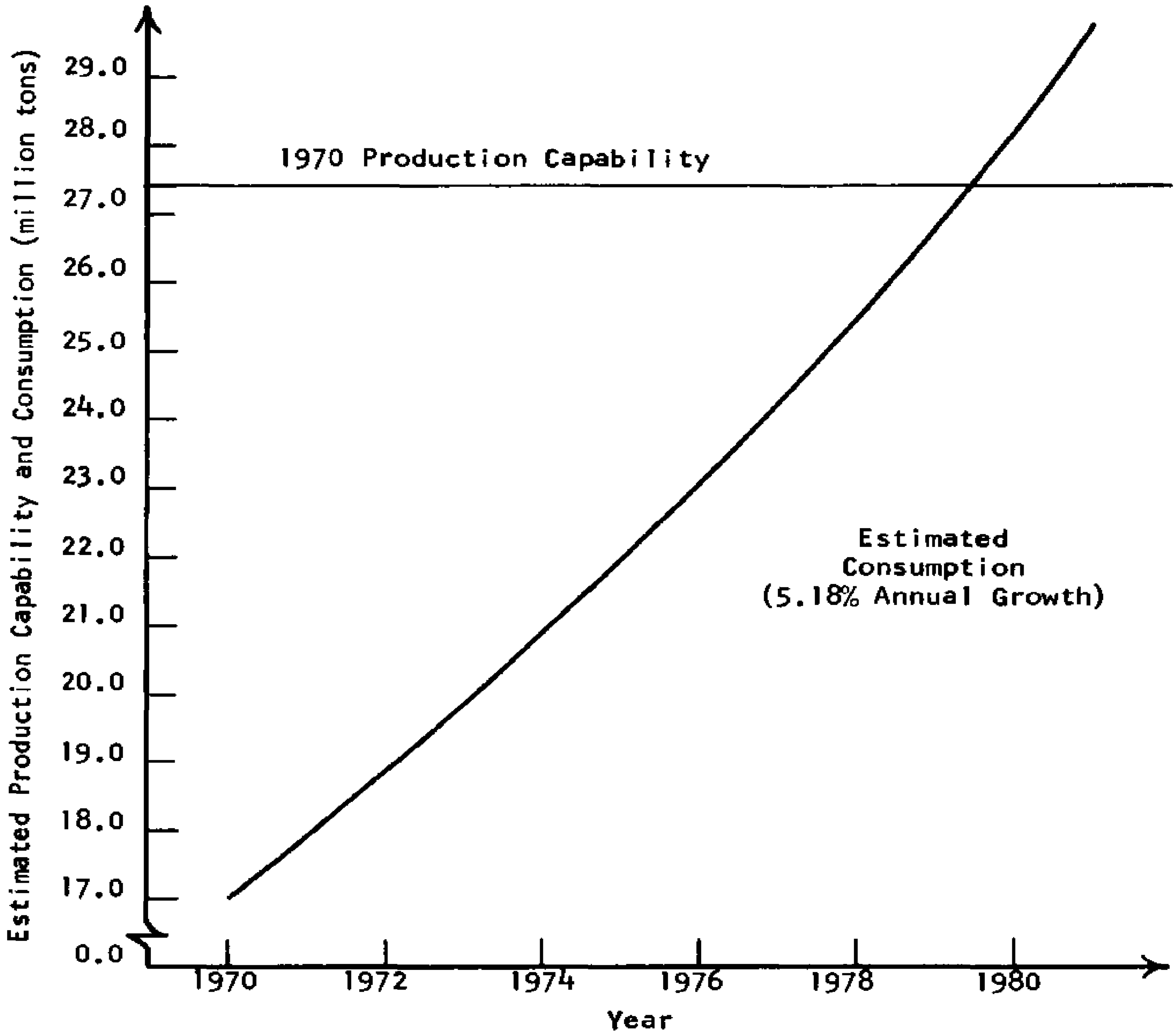

Figure 1-1. 1970 Production Capability Compared With Estimated Fertilizer Use Growth In North America.

Nitrogen use in Michigan increased considerably faster than either phosphate or potassium, yet its growth was somewhat less than the 10.17 per cent annual growth of nitrogen use in North America.

Phosphate use in North America, with an annual growth rate of 5.9 per cent over the same five year period, had the slowest annual increase on a percentage basis; purchases of 5.05 million tons in North America during 1970 were only one-third more than the 3.79 million tons purchased in 1965. At the same time, productive capability for P_2O_5 increased nearly 50 per cent from 4.98 million tons in 1965 to 7.46 million tons in 1970 (Harre, et al., p. 23). Similar to usage, phosphate productive capability had the lowest annual percentage increase; the annual increase was 8.42 per cent during the five year period. In this same period, phosphate purchases in Michigan grew 3.12 per cent annually. Comparable to the North American trend, phosphate usage in Michigan had the lowest growth rate of the three basic nutrients during the pentade.

Potash (potassium), produced largely in Canada, had an annual growth rate of 11.16 per cent in production capacity during the period from 1965 to 1970. At the beginning of the five year period, estimated production capability of K_2O was 5.41 million tons in North America. By 1970, production capability was 9.18 million tons. Farm usage of K_2O in North America grew at 7.07 per cent annually during this period.[4] An interesting fact about the potash industry

[4]During 1970, Canada produced 3,497,901 tons of potash and exported 679,128 tons (Oil, Paint, and Drug Reporter, March 29, 1971) from North America. In 1968 (latest available figures), the U.S. production of potassium was 1,575,834 tons (Harre, 1970), most of

is the disparity between production capability and usage. At the beginning of the five year period, production capability was 182 per cent of usage. By 1970, this figure was 220 per cent.[5] Meanwhile, potassium usage in Michigan grew 6.65 per cent annually, from 112,604 tons in 1965 to 155,441 tons in 1970. Figures 1-2 through 1-4 depict the North American situation.[6]

Growth in productive capability of the magnitude experienced in the fertilizer industry requires high levels of investment. It has been estimated that during the decade of the 60's, there was 4 billion dollars invested in the fertilizer industry. About half of this investment was for new production capability, while the remaining 2 billion dollars went for marketing and distribution facilities. Turberville, speaking to the Fertilizer Production and Marketing Conference in 1969, succinctly phrased the plight of the industry: "Excess production capacity and excess marketing capacity operating

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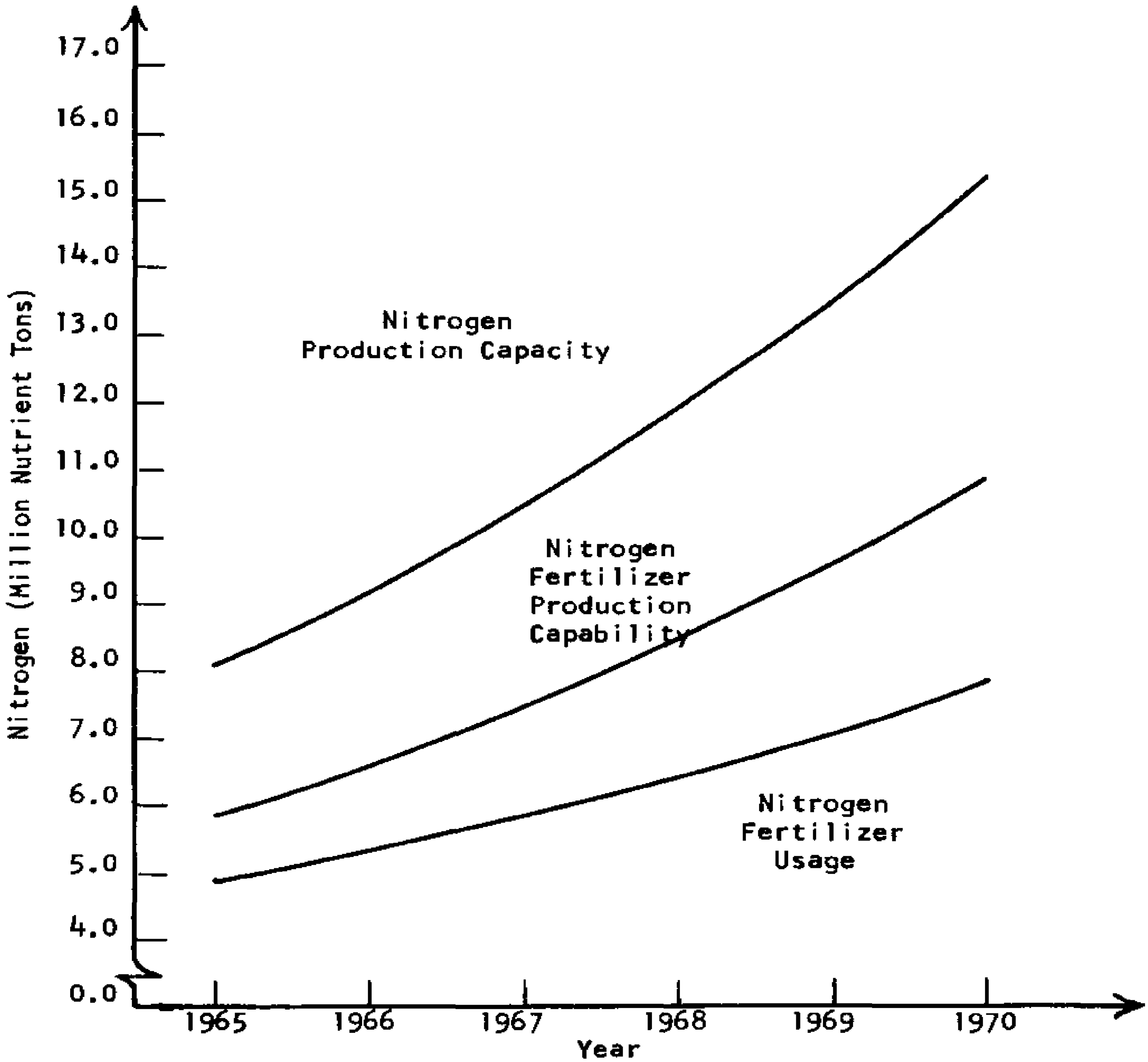
which was used within the U.S. This makes a total of 5,073,735 tons produced with about 4,394,607 remaining in North America. The implication is that production capability was utilized to only 55 per cent while 86.6 per cent of the total production remained within North America. Furthermore, only 95.1 per cent of total production was used; the remaining was probably stockpiled.

[5]The similar figures for nitrogen and phosphorous at the beginning of the period are 120 per cent and 131 per cent, respectively. The period ending figures are 138 per cent and 148 per cent, respectively.

[6]Figures 1-2 through 1-4 also include the growth of total productive capacity, which is distinguished from fertilizer production capability. The difference between the two is the total production capability for all other uses of the product in question. So, production capacity is the gross production capacity for all purposes; whereas, fertilizer production capability is that production designated for fertilizer purposes.



Figare I-2. Nitrogen: Production Capacity, Fertilizer Production Capability and Usage (North America).

Source: Harre, <u>et al</u>., p. 23.

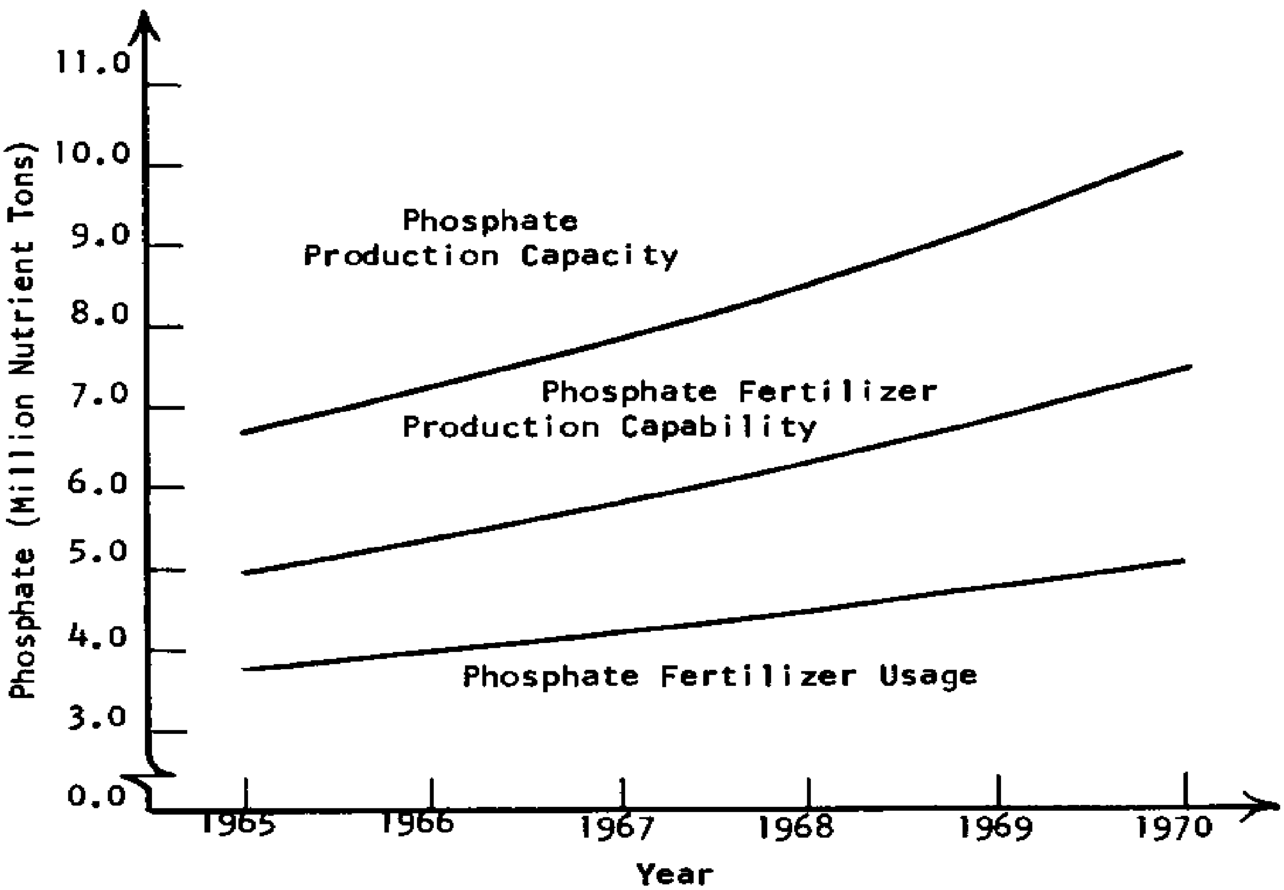


Figure I-3. Phosphate: Production Capacity, Fertilizer Production Capability and Usage (North America).

Source: Harre, <u>et al</u>., p. 23.

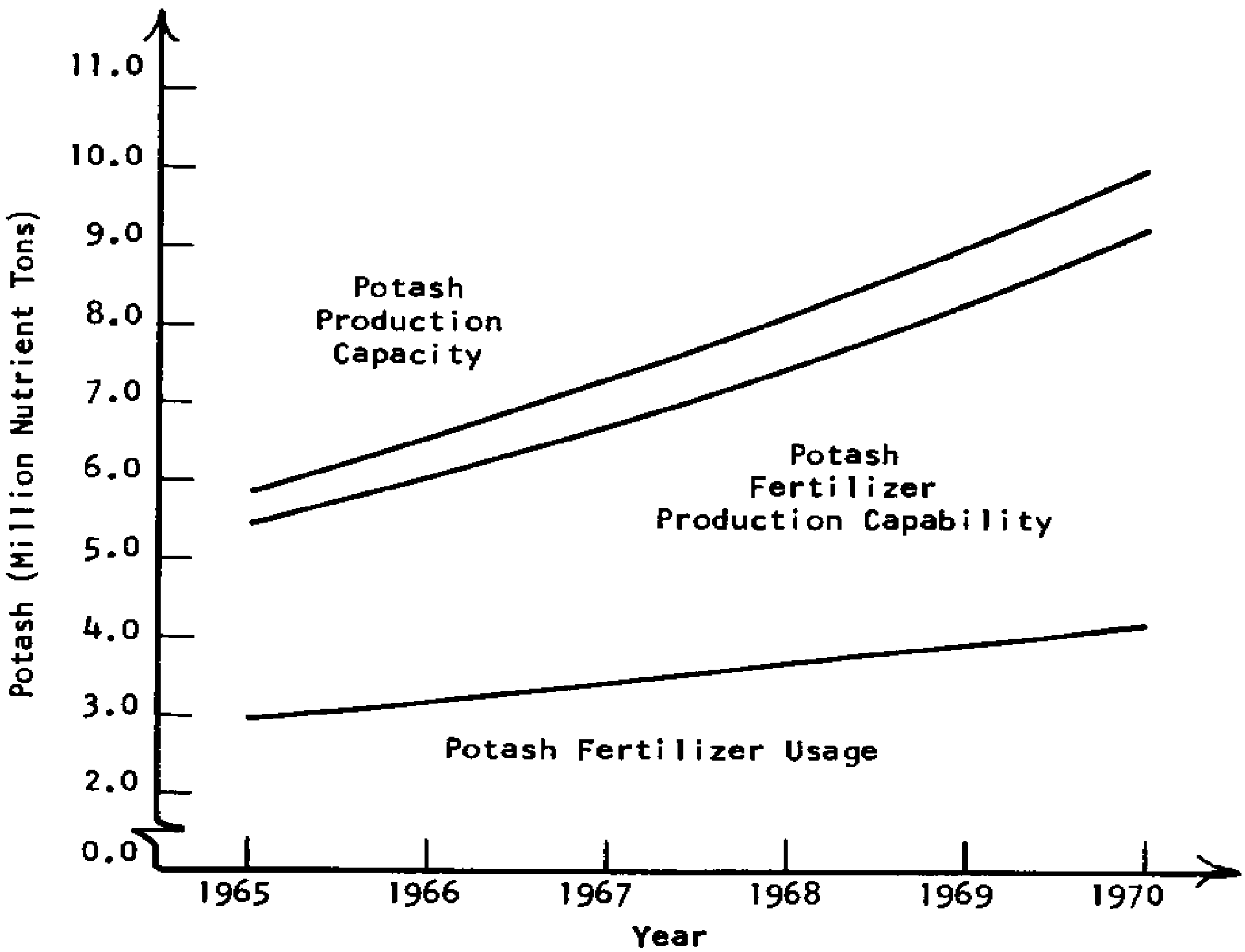


Figure I-4. Potash: Production Capacity, Fertilizer Production Capability and Usage (North America).

Source: Harre, et al., p. 23.

without management constraint have created chaos in the market place and have made us a sick and unprofitable industry," (Turberville, 1969).

In 1970, the level of investment utilized to produce and market the fertilizer nutrients used in Michigan exceeded 75.4 million dollars. On the other hand, had the industry been more efficiently organized, the level of investment could have been about 37.6 million dollars.[7] This is a reduction of over 50 per cent. If the industry were earning only 5 per cent on their investment, the reduction in cost[8] brought about by the lower investment would be 1.89 million dollars. This is equivalent to $4.31 per nutrient ton of consumption in Michigan. Clearly, overinvestment is evident in the fertilizer industry. Furthermore, changes in the level of investment have significant implications on the cost of supplying fertilizer to the Michigan farmers.

For three consecutive years in the late 60's, the returns to total assets in the fertilizer industry were below 2 per cent. In 1965, the industry in the United States had total assets of 1,156 million dollars and net income after taxes of 9.154 million dollars. This corresponds to a 0.792 per cent return on investment, if total

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[7]See Appendix A, Table A-32, 1970 Actual and Optimum, respectively.

[8]Return on investment is generally not considered to be a cost. However, if management prices his firm's product such that it reflects a positive return on investment, the difference in price from that corresponding to a zero return on investment is a cost incurred by the purchaser of the product. Thus, return on investment can be thought of as a cost to the purchaser.

assets are considered as investment. Meanwhile, all manufacturing industries combined had a 6.13 per cent return on investment (assets) (Internal Revenue Service, 1965). In 1966, the fertilizer industry had substantial gains in both total assets and net income after taxes. Assets were up 21 per cent to 1,402 million dollars, while income increased 147 per cent to 22.603 million dollars. These changes brought about a 1.612 per cent return on investment (assets), while all manufacturers obtained a 6.26 per cent return (Internal Revenue Service, 1966). The figures for 1967 are quite discouraging to investors. Net income after taxes for all fertilizer companies slumped to 5.123 million dollars, while total assets increased to 1,476 million dollars. Although total assets were above the 1965 level, the decrease in net income caused the return on investment to drop to 0.347 per cent. That same year, all manufacturers combined, while receiving the lowest return (5.11 per cent) of the three years, attained nearly a 15 fold advantage over the fertilizer industry on a basis of returns on investment. Table I-2 gives a summary of the above discussion and presents an interesting comparison with prime commercial paper. Prime commercial paper has been a more profitable investment, on the average, than the fertilizer industry. Furthermore, prime commercial paper would generally be associated with a much lower risk. Clearly, the fertilizer industry has been receiving very low returns on investment. One can appreciate Turberville's statement, cited earlier, calling the fertilizer industry "sick and unprofitable."[9]

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[9]Unfortunately, more recent data on investment returns in the industry are unavailable. Sources in the industry claim that 1968 and 1969 were the worst investment years for fertilizer companies.

Table I-2. Comparison of selected returns on investment 1965-7 (per cent, annual)

Year	Fertilizer Industry[a]	All Manufacturing[a]	Prime Commercial Paper[b]
1965	0.792	6.131	4.38
1966	1.612	6.259	5.55
1967	0.347	5.110	5.10

Sources: Internal Revenue Service, 1965; 1966; 1967; and U.S. Government, February, 1971.

[a]After taxes.

[b]Before taxes.

In 1970, over 645 thousand man-hours of labor were expended in the fertilizer industry to meet Michigan's consumption.[10] Workers in the manufacturing industries averaged $3.36 per hour in the same year. Five years earlier, the average hourly wage rate was $2.61 for this group.[11] The $0.75 increase in the rate represents a jump of nearly 30 per cent. In addition, this $0.75 increase would, assuming constant technology, indicate an increase of over 480 thousand dollars in the cost of fertilizer going to Michigan farmers in 1970. Even under optimal conditions, where labor utilization drops to less than 400 thousand man-hours,[12] the $0.75 change in the wage rate amounts

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[10]See Appendix A, Table A-32.

[11]"Employment and Earnings," U.S. Department of Labor, Bureau of Labor Statistics, Vol. 17, No. 11, May 1971, Table C-1, p. 89.

[12]See Appendix A, Table A-32.

to nearly 300 thousand dollars. Cost changes of these magnitudes imply a need to analyze the various production and processing technologies to determine if shifts in the labor input would be economically desirable.

Although the returns on investment have been very poor in the recent past, the situation with respect to labor is quite different. In 1965, the value added per man-hour expended in manufacturing fertilizer in the U.S. was $11.75; for mixing fertilizer only, the figure was $10.28. These compare quite favorably with the $8.54 added per man-hour in 1965 in all manufacturing in the U.S. and the $10.33 added per man-hour in all manufacturing in Michigan during 1967 (Table I-3).

Table I-3. Value added per man-hour for selected industries 1965-67

	1965	1966	1967
Fertilizer manufacturing	$11.75	$12.43	$13.49
Fertilizer, mixing only	10.28	11.07	10.97
All manufacturing, U.S.	8.54	8.93	9.41
All manufacturing, Michigan	NA[a]	NA	10.33

Source: Census of Manufacturers, 1967.

[a]Not available.

In 1966, the value added per man-hour in the manufacturing of fertilizers rose by nearly 6 per cent to $12.43. The figure for mixing fertilizer rose more than 7 per cent to $11.07, while all manufacturing in the U.S. increased only 4.5 per cent to $8.93. The corresponding figures for Michigan are unavailable for 1965 and 1966.

In 1967, the value added per man-hour in manufacturing fertilizers increased over 8.5 per cent. At the same time, mixing fertilizer decreased to $10.97 per man-hour. All manufacturing continued to increase at nearly a constant rate to a three year high of $9.41. Labor, although not used extensively in the fertilizer industry, has certainly produced respectable value added data, especially during the same period in which returns on investment have been dismally low. It appears as though the fertilizer industry is efficiently utilizing labor, but investment decisions have not proved to be very profitable.

Before delineating the objectives of this study, the perspective and background of it needs to be outlined.

The Background

This study is part of a larger study of the fertilizer industry in Michigan. A building-block approach was used to create a systems model of the fertilizer industry with particular emphasis on its activities in Michigan.

The model contains about 30 different "blocks," each of which represents a specific fertilizer product or processing segment of the industry. The entire model is formulated in a linear programming framework. Each of the "blocks" is a collection of activities (columns in a matrix) that are pertinent to the particular product or process represented by the "block." Manufacturing, retailing, storage, transportation, and distribution are among the activities contained within a typical "block."

The "blocks" are all tied together with the appropriate constraints (rows in the matrix) representing technical relationships and controls. For example, each ton of a particular fertilizer applied on the farm must activate the appropriate activities to insure that the fertilizer was manufactured, stored, transported, marketed, etc. In addition, the necessary inputs (such as labor, capital, and raw materials) need to be activated; all of this is done by the controls or rows in the matrix.

The "demand" for fertilizer is represented by three separate rows, one for each of the three basic nutrients. The model is constrained by these three rows to "supply" their respective levels of nutrients to Michigan farms. Moreover, the model is required to minimize the total cost of "supplying" the fertilizer, subject to all the imposed constraints. With the appropriate controls, it becomes possible to simulate the fertilizer industry in Michigan.

Included in this simulation model are regional production facilities for the manufacture of nitrogen, phosphate, and potassium products. For instance, the manufacture of anhydrous ammonia along with the production of major forms of nitrogenous fertilizers at the Gulf Coast are included in the model.

Phosphate materials are simulated as originating in Florida and potassium products in Saskatechewan, Canada. The product output of these facilities is assumed to flow into the distribution system for the United States in general, as well as for Michigan.

In addition to the three regional locations, granulation facilities and the manufacture of nitrogen and phosphate fertilizers as well as terminaling operations are simulated in the Midwest. The

Midwest facilities are included as a means of simulating activities that serve the Midwest in general and are important to the distribution of fertilizers in Michigan.

Central Michigan facilities are also included in order to reflect conditions of large-scale operations performed in proximity to final use. Facilities in various outstate locations are all the smaller-scale mixing facilities and retailing functions that typically serve the farmer directly. In total, the model contains 2,654 activities (columns) and 771 constraints (rows).

An example will help to give a better understanding of the modeling technique employed. A centrally-located bulk blender in Michigan can receive its input materials from a terminal in Michigan, directly from Michigan manufacturers, from a Midwest terminal or manufacturers, or from manufacturers located in the three regions of basic production. Between the Michigan bulk blender and his potential input suppliers are all of the possible transportation modes that are potentially appropriate for the particular product in question. From the bulk blender, the product can be transported in bulk or bags to either a satellite warehouse or directly to the farm via any of the potential transportation modes. The model not only includes the organization of the fertilizer industry as it exists today, but also numerous alternative arrangements of facilities and technical processes that could be economically desirable.

It can be seen that the model contains many alternatives and could be quite flexible. Within the framework of the model, many problems can be analyzed. For example, the impacts of shifts in the nutrient ratio of fertilizer use and the consequences of using sub-optimal products can be determined; alternatively, the consequences and implications of sulfur oxide emissions that are converted to various fertilizer materials can also be analyzed.[13]

With a general understanding of the content and structure of the analytical model, let's examine the objectives of this study.

Objectives

The objective of this study is to determine and analyze an optimum (from the standpoint of minimum total cost) transition path from the current industry organization to a long run optimum (minimum total cost) industry organization. Particular attention will be given to shifts in the organization, the least cost product mix, the cost of supplying the three basic nutrients, and the distribution of fertilizer to the Michigan farmer. More specific objectives include:

1. Determine the sensitivity of the long and short run optimal organizations of the industry to changes, especially increases, in the wage rate.
2. Ascertain to what extent changes in the rate of return on invested capital have on the short and long run optimum industry organizations.
3. Analyze the transition with respect to the amount of new investment required each year and the potential reduction

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[13]These two problem areas are being analyzed by Dennis R. Henderson and David M. Bell, respectively. Their findings and the findings of this study will be combined in a report that discusses the industry in greater detail.

in the total cost of supplying Michigan farmers with the levels of N, P_2O_5, and K_2O used in 1970.

Review of Literature

The literature of capital budgeting contains considerable discussion of different types of rates of return and their usefulness in making capital investment decisions. A survey by Miller indicates widespread use of rates of return in evaluating prospective investments (Miller, 1960). The same survey also indicates that "sophisticated" measures of return, such as discounted cash flow rate of return and net present value, are not as widely used as "unsophisticated" measures of return, such as payout period and simple rate of return. Sophisticated is a term applied here to those measures of return that take into account the time value of money. With these measures, cash flows that occur early in the life of an investment are weighted more heavily than those that occur later in its life. This weighting procedure is used to reflect the possibilities of reinvesting early cash flows for additional cash flows before the later ones are realized. Dean has focused attention on the sophisticated measures of return as a means for improving capital investment decisions (Dean, 1954).

In an industry that has experienced considerable change in technology, such as the fertilizer industry, these sophisticated measures might be very appropriate. Heavy weights could be placed on the most immediate years such that investments that returned their value as quick as possible might be selected. On the other hand, if a projection of future industry organization can be utilized, investments with slower pay-back might be preferred if they were a part of the future industry organization, and the quick pay back investments were not part of the long run optimal industry organization. For a short lived investment, the difference between simple and time adjusted rates of return may be of little importance, since the rates would be nearly equal. Only when the life of the asset is quite long is there an appreciable difference between the two methods. The time adjusted process would be very appropriate for such investments as inter-state pipeline facilities, which have an expected life of 20 years or more. On the other hand, the two methods would yield approximately the same results when applied to, say, a bulk fertilizer spreader which has an expected life of perhaps 5 years.

Regardless of whether time adjusted or simple rate of return is used to evaluate an investment, most assets with any appreciable expected life may become "fixed." A "fixed asset" is one for which there is a divergence of acquisition and salvage values (prices) and more importantly, the value of the asset in its current use is between its acquisition and salvage values. That is, the marginal value product of the asset in its current use is less than it would cost to purchase more of the asset and, at the same time, greater than the amount for which the asset could be sold. Thus, the most profitable amount of the asset to use, if it is to be used at all, is the amount currently on hand. This arises from the fact that the marginal cost of obtaining more of the asset (acquisition price) is greater than the marginal value product of the asset. Simultaneously, the marginal value (revenue) of selling one unit of the asset (salvage price) is less than the marginal value of the asset in its current use.

Edwards has delineated a set of rules for optimal adjustments under conditions of fixed assets when credit facilities are limited (Edwards, 1958). He used on-farm opportunity costs, relative to off-farm opportunities for acquisition and salvage factors, to determine the best combination of fixed factors. Smith used a linear programming framework with divergent acquisition costs and salvage values to demonstrate that cognizance of these two values in the factor market can have a substantial effect on the organization of activities and the flow of profits (Smith, 1955).

In Chapter IV of this study, zero salvage values will be assumed for existing facilities, during the transition from the current industry organization to a long run optimal organization. During this transition, new facilities will be "purchased" at their acquisition costs and existing facilities will be utilized only if their total variable costs are less than the total cost of new facilities.

The Research Approach

Three basic solutions were obtained with the model under varying assumptions. These solutions are summarized in Appendix A. Common to all three solutions is the assumption concerning the levels of N, P_2O_5, and K_2O to supply to the Michigan farms. These "demand" constraints represent the actual use of nutrients in Michigan during 1970 and were 141,932, 140,650 and 155,441 tons of N, P_2O_5, and K_2O, respectively.

The first solution, "1970 Actual," was made while constraining the model to duplicate, as close as possible, the actual production, processing, and use of fertilizer that transpired to service Michigan farmers' demand in 1970. While these restrictions became very confining, the model was still free to choose the least cost transportation modes from those that exist. This solution is a benchmark in that it represents the activities involved and costs incurred in the fertilizer industry during 1970 while meeting Michigan's demands for plant nutrients.

Very rigid controls (constraints) were employed to insure that the 1970 Actual solution would simulate the current fertilizer industry in Michigan as accurately as possible, given the framework of the model. Nearly all products and processes in the model were scheduled to operate at prescribed levels. The only optimizing that was allowed involved the transportation activities; insufficient data precluded the specification of levels of operation for transportation activities.

From an organizational standpoint, the 1970 Actual solution is characterized by the production and processing of numerous products, some of which are very low in nutritive content. The low nutritive content of these products implies that additional tons of inert material (usually either limestone filler or water in the cases of dry and liquid mixed fertilizers) would have to be processed and transported relative to substitute products of higher nutritive content. For example, the use of aqueous ammonia as a source of direct application nitrogen instead of anhydrous ammonia would result in 2.91 tons of additional material handling for each ton of nitrogen. This occurs because aqueous ammonia contains only 24.2 per cent N; whereas, anhydrous ammonia contains 82.2 per cent N. In 1970, for example, 3,897 tons of aqueous ammonia were used for direct application, which resulted in over 11,000 additional tons of material handling, compared to NH_3.

This additional product handling is very costly and may or may not be partially offset by the low nutritive product selling at a lower cost. It depends to a large extent on what the cost per unit of nutrient is and on what the handling and transportation costs are. From an agronomic standpoint, there is virtually no difference among fertilizers of comparable nutritive content, assuming the nutrients are readily available to the plant.

Table A-32 of Appendix A lists the average analysis and total material tonnage of the three solutions. It can be inferred from that table and Table A-1 of the same appendix that the low analysis product used in the 1970 Actual solution were economically inferior to the high analysis products used in the other two solutions. Note, in particular, that the 1970 Actual solution was the only one in which limestone filler was used in dry mixed products (Appendix A, Table A-32).

From the standpoint of representing the true industry organization, the 1970 Actual is quite good; on the basis of production of specific products by particular technologies, the model very closely represents the true industry. There are, however, some points on which 1970 Actual (or the model) does not accurately represent the real industry.

The most notable of these points is that of representing individual firms. Like nearly all simulation models, the fertilizer industry model lacks realism due to the necessary aggregation of individual firms into a single or small number of "typical" firms. Closely related to the aggregation problem, is the inability of the model to represent real cost curves. In any simulation model that involves aggregation of economic units, the cost curve of the aggregate only approximates the effect of the aggregated units cost curves. Unless the aggregate cost curve is linear, linear programming techniques allow only an approximation of the aggregate cost curve; more specifically, linear programming assumes a constant marginal cost for each activity, thereby implying a linear total cost curve. Consequently, the total cost of 1970 Actual is an approximation of the total expenditures by farmers. Moreover, 1970 Actual has a 7.5 per cent return on invested capital built into it; whereas, firms in the industry probably did not obtain a return that high.

Despite the preceeding short-comings and limitations of the model, 1970 Actual is a very close approximation of the industry as it existed in 1970. Industry participants validated every cost schedule prior to its inclusion in the model and endless hours were spent checking the accuracy of the model and the included data. In addition, numerous validation trials were made to eliminate logic errors.

The second solution, "Constrained Optimum," is the result of relaxing some of the constraints imposed during the 1970 Actual solution. Constrained Optimum is to be looked upon as a short-run optimal industry organization. That is, the fertilizer industry could shift to this organization today without incurring any new investment. In other words, this solution is the answer to the question: "Given current facilities, how should the industry be organized (what products, how and where processed and stored, how transported, etc.) to minimize the cost of supplying Michigan with its 1970 levels of consumption of N, P_2O_5, and K_2O?" This solution will be analyzed in the next chapter.

The "Optimum" solution is, in essence, the Constrained Optimum problem, except that the qualifying restriction of existing facilities was removed. Optimum can, then, be regarded as the long-run optimal organization of the industry, since the model is allowed to select those activities that minimize cost regardless of whether or not the facilities exist. This solution is perhaps best interpreted as how the industry would be organized if minimum cost were the objective and all facilities had to be purchased.

Utilizing these three solutions as a background, this study will investigate the sensitivity or stability of the latter two solutions with respect to the wage rate and return on investment. Then, a transition from Constrained Optimum will be made to Optimum under various assumptions.

Labor was delineated in the model for most of the activities. Those activities, for which labor cost at $4.00 per man-hour was less than 10 per cent of the total variable cost of that activity, have had the labor cost lumped in with the other costs rather than specifying it as a specific input. That is, for such activities, the labor cost is assumed to be unimportant and is included in the cost of the activity rather than specifying a labor coefficient and forcing the activity to "purchase" labor at the specified cost. This implies that such an activity's total cost does <u>not</u> vary as the wage rate changes. Different wage rates will be specified and their corresponding impact upon the Constrained Optimum and Optimum industry organizations will be analyzed. Of particular interest will be increases in the wage rate, owing to the recent trend of wages.

Since return on investment has been extremely low in recent years, it is desirable to examine the short and long run optimum industry organizations to determine to what extent various rates of return change the optimum organization of the industry. The underlying economic theory involved here is that of opportunity cost. Theoretically, the firm can (should) invest its available money such that it will receive the highest return. If investment external to the firm yields greater return than internal investment, then the former, rather than the latter, should be undertaken.

Ideally, management would like to receive a very high return on invested funds--somewhere around 15 to 20 per cent would be quite attractive. To investigate the effects of various rates of return on investment, a range from -2 to 20 per cent will be used to reflect management's willingness to accept minor losses and obtain handsome returns. This will be accomplished by maintaining all other constraints and varying the rate of return on invested capital over the prescribed range, utilizing both the Constrained Optimum and Optimum solutions as points of departure.

Since there is a substantial difference in the total cost among the three organizational solutions derived by the model (Appendix A), the transition path from the 1970 Actual to the Optimum is well worth delineating. Feasible assumptions will be made concerning depreciation, return on new investment, capital rationing and other crucial factors. These assumptions will be expounded upon later.

Organization of the Study

Chapter II will be concerned with the impact of various rates of return on investment on the Constrained Optimum industry organization. In addition, that organization will be analyzed to determine if changes in the wage rate affect the optimum mix of products, facilities, transportation, etc.

Chapter III will be devoted to analyzing the stability of the long run Optimum organization when it is subjected to changes in the rate of return on investment and in the wage rate. Chapter IV will trace an optimal path of transformation of the current industry organization to the long run optimal. Finally, Chapter V will summarize the entire study and draw conclusions from the analyses.

CHAPTER II

THE IMPACT OF WAGE RATES AND RATES OF RETURN ON INVESTMENT ON THE OPTIMUM SHORT RUN INDUSTRY ORGANIZATION

This chapter will examine the sensitivity of the Constrained Optimum organization of the fertilizer industry to changes in the wage rate and the rate of return on investment capital.[1] The impact of alternative wage rates on that organization is examined first. The analysis then turns to the implications of alternative interest rates.

The Impact of Alternative Wage Rates

Labor is an important input in the production of fertilizer. Some products require a higher labor input in their production than do other products. In addition, certain products can be manufactured by alternative processes, each of which uses a different level of labor per ton of product. Consequently, variations in the wage rate could cause a shift from one process to another or from one product to another when minimizing the total cost of supplying the desired levels of nutrients.

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[1]Changes in these variables were not analyzed under the constraints of the 1970 Actual organization, owing to its suboptimal nature. However, comparisons are made with the levels of utilization of the various factors in that organization.

In order to discover such shifts in the Constrained Optimum organization, where only existing facilities can be used, the wage rate was varied from \$3.00 to \$6.50 per man-hour, inclusive. This range was identified as the most likely to be realized in the near future, although the recent trend in wages suggests that the middle and upper portions of this range will be the most probable.

Utilizing the flexibility of Control Data Corporation's linear programming routine, "Optima," the wage rate was changed in \$0.25 increments. Each resulting wage rate was then used to determine the consequent minimum cost industry organization.

Given the alternative technologies included in the model that were available for selection in the short run (viz., those technologies currently feasible and being used in existing facilities), there is no combination of technologies that would be more economically desirable (in terms of minimizing total cost) than those utilized in the Constrained Optimum organization, provided the wage rate is in the previously mentioned range.[2] Consequently, the same products, processes, modes of transportation, etc. specified in the Constrained Optimum are those comprising the most efficient organization for each wage rate examined.[3] This industry arrangement is stable despite the fact that the total cost increased more than 1.5

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[2]The wage rate assumed in the Constrained Optimum organization was \$4.00 per man-hour.

[3]Since Appendix A outlines in detail the components of the Constrained Optimum organization, refer to it for the optimal organization of the industry for any wage rate in the range investigated.

million dollars and the wage bill as a percentage of the total cost increased more than 110 percent over the range of wages examined (Table II-1).

The aforementioned "Optima" routine calculates "shadow-prices" for each constraint (Optima, p. 33). Since the N, P_2O_5, and K_2O "demands" were modeled as constraints, each has a shadow-price computed and printed, corresponding to each wage level. These shadow-prices are essentially "incremental costs" since each represents the amount by which the total cost would change, over the narrow range of the solution at hand, if the corresponding constraint were changed by one unit (tons of plant nutrient) and all other constraints are held constant (Optima, p. 33). They should <u>not</u> be considered equivalent to either "marginal" or "average" cost as the latter are defined in economic theory.

Table II-1 presents some interesting data concerning the effect of increasing wages on the incremental cost of nitrogen, phosphate, and potassium. The cost of P_2O_5 was affected the most by changes in the wage rate. An increase of \$0.25 per man-hour caused an incremental cost of \$0.3647 per ton of P_2O_5. The same wage shift caused an increase of \$0.2580 per ton of K_2O and only \$0.0530 increase in the cost per ton of nitrogen. Although the production of P_2O_5 is the most sensitive to labor costs, the alternative processes that can be used to produce it were not sufficiently affected by the changing wage rate to cause change in the Constrained Optimum organization.

Two possible reasons can be given as to why no change in the

Table II-1. The impact of wages in the short run

Wage Rate (Dollars/man-hour)	Total Cost (Dollars)	Man-Hours Labor	Cost[a] N	Cost[a] P_2O_5	Cost[a] K_2O	Cost/ Nutrient Ton[b]	Wage Bill (Dollars)	Wage as % of Tot. Cost
3.00	52,103,065	452,182	108.12	152.77	101.33	118.90	1,356,546	2.60
3.25	52,216,111	452,182	108.18	153.13	101.59	119.16	1,469,592	2.81
3.50	52,329,156	452,182	108.23	153.50	101.84	119.42	1,582,637	3.02
3.75	52,442,202	452,182	108.28	153.86	102.10	119.67	1,695,683	3.23
4.00	52,555,247	452,182	108.33	154.23	102.36	119.93	1,808,728	3.44
4.25	52,668,293	452,182	108.39	154.59	102.62	120.19	1,921,774	3.65
4.50	52,781,338	452,182	108.44	154.96	102.88	120.45	2,034,819	3.86
4.75	52,894,384	452,182	108.49	155.32	103.13	120.70	2,147,865	4.06
5.00	53,007,429	452,182	108.55	155.69	103.39	120.96	2,260,910	4.27
5.25	53,120,475	452,182	108.60	156.05	103.65	121.22	2,373,956	4.47
5.50	53,233,520	452,182	108.65	156.42	103.91	121.48	2,487,001	4.67
5.75	53,346,566	452,182	108.71	156.78	104.17	121.74	2,600,047	4.87
6.00	53,459,611	452,182	108.76	157.14	104.42	121.99	2,713,092	5.08

Table II-1. (cont'd.)

Wage Rate (Dollars/man-hour)	Total Cost (Dollars)	Man-Hours Labor	Cost[a] N	Cost[a] P_2O_5	Cost[a] K_2O	Cost/ Nutrient Ton[b]	Wage Bill (Dollars)	Wage as % of Tot. Cost
6.25	53,572,657	452,182	108.81	157.51	104.68	122.25	2,826,138	5.28
6.50	53,685,702	452,182	108.86	157.87	104.94	122.51	2,939,183	5.47
Change in nutrient cost/$0.25 change in wage rate			0.0530	0.3647	0.2580			

[a]Incremental cost per nutrient ton (dollars).

[b]Total cost divided by total nutrient tonnage (438,023 tons).

optimal short run industry organization was experienced during parameterization of the wage rate. First, those technologies that do not appear in the Constrained Optimum organization may have cost components other than labor that make them sub-optimal. That is, the overall relative inefficiency of the excluded technologies more than outweighs any relative advantage in labor utilization they may hold over the technologies included in the Constrained Optimum organization. Secondly, those technologies in the Constrained Optimum organization may have an absolute advantage over the excluded technologies in terms of labor usage. If this is true, then increasing the wage rate makes those included technologies even more desirable from a minimum cost standpoint. On the other hand, lowering the wage rate would, at some wage level, swing the absolute advantage in favor of the excluded technologies. However, at the minimum wage rate investigated, \$3.00, this phenomenon did not occur.

Thus, over the range of wages examined, it is not possible to discern any advantage or disadvantage, in terms of labor utilization, that the technologies included in the Constrained Optimum may have relative to the alternatives. It can only be concluded that, if a relative disadvantage does exist, it is not sufficient enough to induce a change in the short run optimal industry organization.

It should be noted that the linear nature of the linear programming model embodies constant coefficients. This implies that, regardless of the level of utilization of a particular technology, the same amount of labor will be required for each nutrient ton of product, given a particular technology.[4] Thus, the relative advantage a particular technology may hold over others is a function of factor costs (wage rate, input costs, etc.) and the constant coefficients and is not, therefore, a function of the level of utilization of that technology. This implies that the model cannot represent a change in the amount of labor used per nutrient ton without changing technologies. Therefore, the real world case of reduced labor usage, resulting from higher wages, with continued use of the same capital equipment cannot be simulated within the model. Changes in the utilization of labor per nutrient ton can occur in the model only by changing the technology employed. The analysis will now turn to the effect of changes in the rate of return on investment on the Constrained Optimum industry organization.

Return on Investment in the Short Run

Although new investment was not allowed in the short run, return on investment capital[5] was varied to reflect changes in total cost

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[4]The problem of indivisibilities is not serious in this study. It is assumed that those activities (production, processing, etc.) that are represented in the model as being located outside Michigan (i.e., in the Midwest, Gulf Coast, Florida, or Saskatchewan), operate at their most efficient rates. Any product of such operations that does not flow to Michigan is assumed to be consumed in the remainder of the U.S. Those activities located in Michigan are, for the most part, of relatively small capacity. Consequently, a large number of them are generally needed to meet the desired level of total product. Thus, they are assumed to operate relatively close to their most efficient level, any variation in total volume being spread among the appropriate number of facilities to maintain this relationship.

[5]Not all activities had investment capital delineated in the model. It was not specified for transportation activities, except

that would be imposed if entrepreneurs tried to realize a return on their investment equal to the opportunity cost of their invested capital. That is, if the interest rate on long term investment-type loans is, say, 10.0 percent and entrepreneurs feel they should be receiving this same rate on their investment in capital, then they would charge 10.0 percent of their invested capital as an operating cost and price the product such that returns are equated to costs. The cost of fertilizer to the farmer would reflect this charge since the entrepreneur has passed on the interest cost in the form of higher prices.

Return on investment is typically used as a measure of profit by which two or more investment schemes may be compared. In addition, it is a useful guide as to how well an individual investment is succeeding. Theoretically, a firm should invest its funds in those activities that return the highest return on investment, given that profit maximization is its goal. Consequently, a firm would like to receive a return on its investment that is comparable to that which it could receive if the funds had been invested in alternative projects either external or internal to the firm.

As mentioned earlier, these returns on investment in the fertilizer industry, if positive, in some sense imply additional costs that must be paid by the farmer.[6] The extent of these costs and the changes

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for pipe-line facilities. However, all manufacturing, processing and storage facilities had investment capital broken out as a separate cost item.

[6]This discussion precludes the problem of low returns causing

in the industry organization resulting from different rates of return on investment are discussed in the following pages for the short run situation as implied by the Constrained Optimum organization and its constraints.

Using the parameterization controls embodied in "Optima," the rate of return will be changed over a prescribed range. Changes in the optimal industry organization will be analyzed and the corresponding rate of return noted.

The range of rates selected for analysis runs from -2.0 per cent which reflects a minor loss on investment, to 20.0 per cent, representing more than 10 times the return currently being experienced in the industry. This upper limit on the range will enable us to ascertain the associated costs to farmers if fertilizer companies were to earn returns comparable to the most profitable corporations.[7]

The rate of return was set at 20.0 per cent and incremented downward in steps of 2.0 percentage points. In the range of rates from 6.0 to 4.0 per cent, it was discovered that numerous changes in the optimal industry organization were being made; consequently, incrementation in steps of 0.1 percentage points was subsequently made in this range to detail the analysis.

At the highest rate of return examined, 20.0 per cent, the

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firms to drop out of the industry and thereby possibly causing higher prices owing to decreased supply.

[7]In 1965, for example, ten of the largest 500 firms earned over 25 per cent, after taxes, on their investment (Economic Concentration, Part 5A, p. 2185).

product mix was unchanged from that of Constrained Optimum (compare Appendix Tables A-1 and B-1). However, the types of facilities used to produce that product mix were somewhat different. When return on investment is at 20.0 per cent, diammonium phosphate is produced via the TVA process in Florida and in the Midwest (Appendix B, Table B-11). This process is used until the return on investment is lowered to 14.0 per cent, at which rate the slurry ammoniation process replaces it. The latter process is less labor and more capital intensive relative to the TVA process (Henderson, et al.). Consequently, return on investment greater than 14.0 per cent causes the investment cost to outweigh the labor savings, thereby giving the TVA process a lower total cost.

Lowering the return on investment to 12.0 per cent resulted in utilization of anhydrous ammonia retailers, which had not been utilized at higher rates of return. The NH_3 retailer replaces direct shipment of NH_3 from the Gulf Coast manufacturer by barge to the Midwest terminal and truck transportation to the farm. This change is brought about by the desire to use low cost rail transportation (relative to the total of rail and truck). The high return on investment (above 12.0 per cent) made the NH_3 retailing facility's cost more than offset the difference between the two transportation schemes; consequently, the NH_3 retailing function was eliminated. With returns equal to or less than 12.0 per cent, however, the savings in transportation cost more than outweighs the cost of utilizing the NH_3 retailer.

Another change occurring when the rate of return on investment was lowered from 12.1 per cent to 12.0 per cent was the switch in source of supply of NH_3 for the Midwest nitric acid, ammonium nitrate, nitrogen manufacturing solutions, and diammonium and monoammonium phosphate producers. Prior to the change, NH_3 came from the Gulf Coast for these producers while all the NH_3 produced in the Midwest went directly to the Michigan farmers (Figure II-1). When the return on investment dropped to 12.0 per cent, however, the anhydrous ammonia used by the Midwest producers originated with the Midwest NH_3 manufacturer, and 36,387 tons of NH_3 from that producer went directly to the farms (Figure II-2 and Appendix B, Table B-2).

One of the constraints in Constrained Optimum forces anhydrous ammonia produced at the Gulf Coast and in the Midwest to be in a fixed ratio to simulate the existing capability of these two locations to provide nitrogen to Michigan. This constraint forced nitrogen to be produced at the Gulf Coast when return on investment was high and the NH_3 retailer was sub-optimal. Consequently, the NH_3 produced there had to be used somewhere; shipment to the farms was the minimal cost option. When return on investment was somewhat lower (between 12.0 and 6.0 per cent, inclusive), the previously mentioned NH_3 forced production at the Gulf Coast moves to the anhydrous ammonia retailers. Moreover, when the return on investment is between 5.9 and 4.4 per cent, inclusive, retailing NH_3 coming from the Gulf Coast is economically desirable to such a degree that there was a decrease in the production of the nitrogen manufacturing solutions at the Gulf Coast (utilizing Gulf Coast NH_3), thereby, allowing an increase in retailing of NH_3 produced there. Simultaneously, the Midwest nitrogen manufacturing solutions producer increases his volume to match the decrease observed at the Gulf Coast.

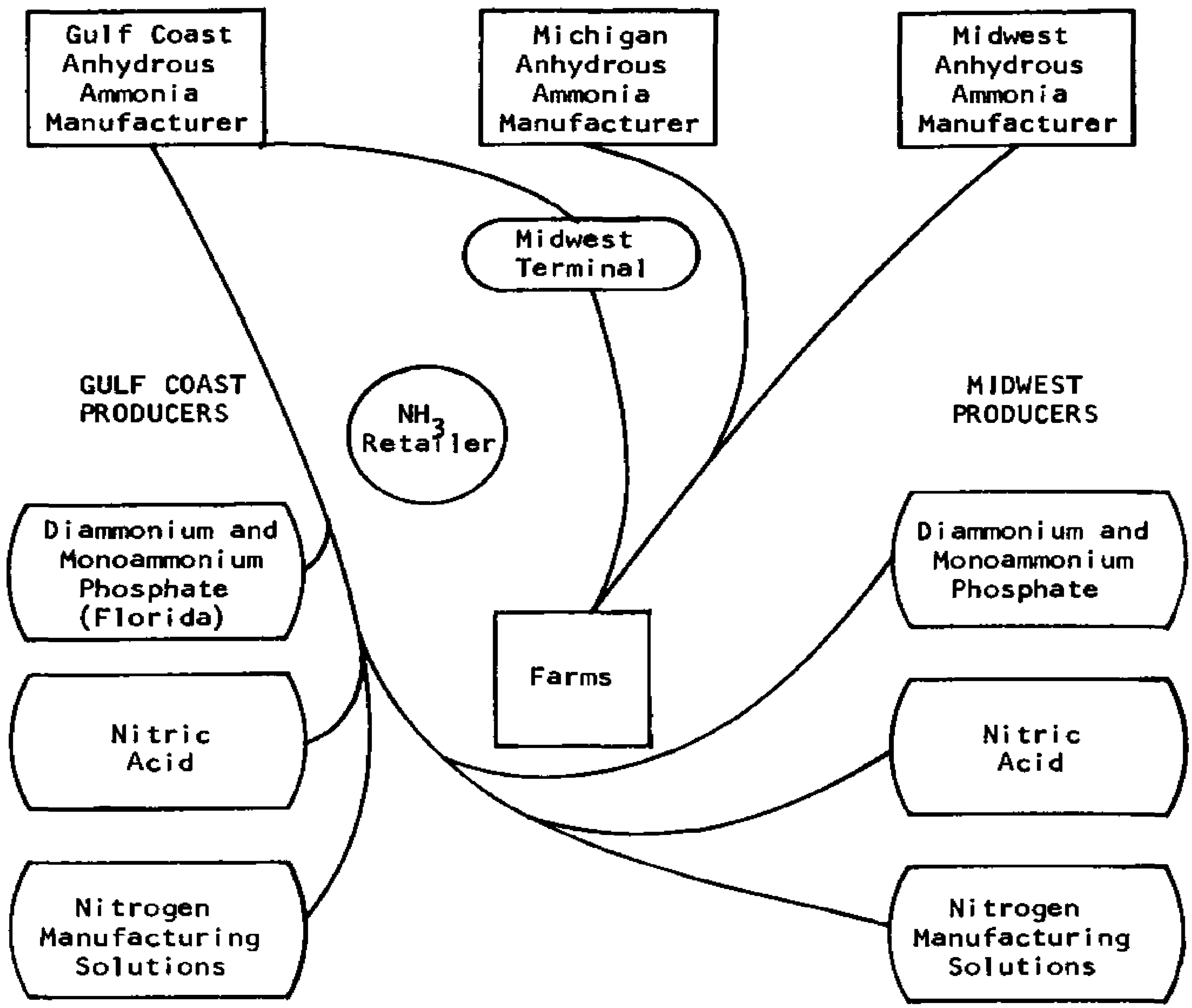

Figure II-1. Anhydrous Ammonia Flow With Interest On Investment Between 20.0 and 12.1 Per Cent, Inclusive (Constrained Optimum).

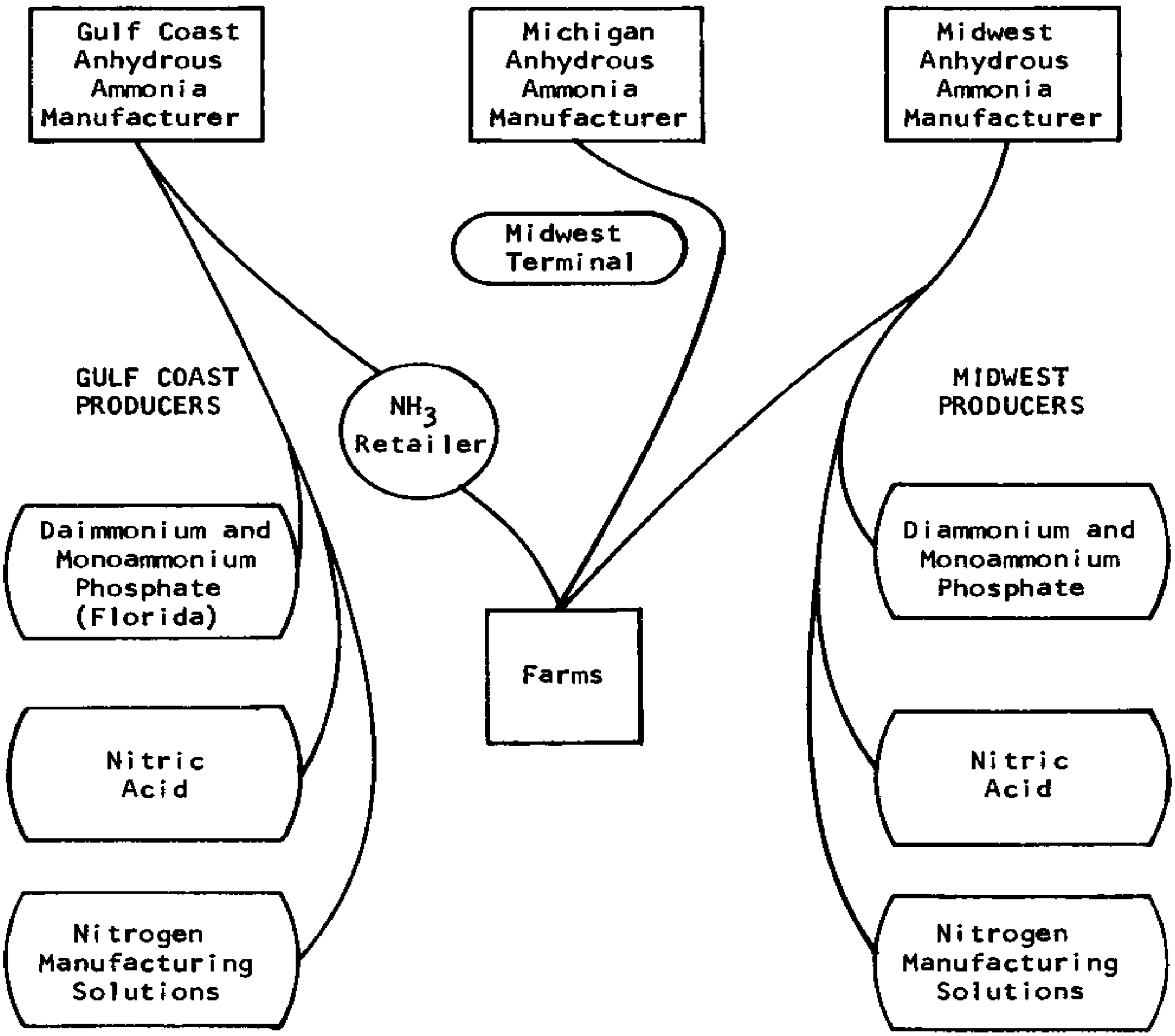

Figure II-2. Anhydrous Ammonia Flow With Interest On Investment Between 12.0 and 4.4 Per Cent, Inclusive (Constrained Optimum).

The result is that the total level of nitrogen manufacturing solutions is essentially constant and the level of NH_3 retailing increases while direct shipments of NH_3 to the farms from the Midwest decrease (Appendix B, Tables B-2 and B-5, and Figures II-1 and II-2).

The transition of rate of return on investment from 6.0 per cent to the range from 5.9 to 4.4 per cent, inclusive, brought about a change in the ammonium nitrate segment as well. Actually, this change is caused by the change in the nitrogen manufacturing solutions segment, since the former is used by the latter. A ratio constant in Constrained Optimum forces ammonium nitrate to be produced in a constant ratio, if at all, between the Gulf Coast and Midwest. Since all the ammonium nitrate produced is used to make nitrogen manufacturing solutions, the decrease in production of the latter at the Gulf Coast caused the ammonium nitrate produced there to be shipped to the Midwest nitrogen manufacturing solutions producer.

A decline of returns on investment from 4.4 to 4.3 per cent completed the trends previously established. That is, at the latter rate of return, all nitrogen manufacturing solutions are produced in the Midwest. Similarly, all the ammonium nitrate produced at the Gulf Coast was shipped to the Midwest nitrogen manufacturing solutions producer. Direct application of NH_3 from the Gulf Coast routed through the anhydrous ammonia retailer continued to increase slightly by 622 tons, while direct shipments of NH_3 from the Midwest producer to the farmers decreased by the same amount (Appendix B, Table B-2).

Although the previous situation was constant for a return on investment of 4.2 per cent, lowering the return to 4.1 per cent had a significant effect in numerous segments of the industry.

Lowering of the rate of return on investment to 4.1 per cent made production of diammonium phosphate in Michigan for direct application economically superior to its use in a granulated dry mixed fertilizer. Thus, direct application of diammonium phosphate was initiated and the level of granulated dry mixed fertilizer production was reduced (Appendix B, Tables B-11 and B-15). The small scale granular mixed fertilizer producer located in outstate Michigan was the one affected by the change; whereas, the large scale one located at central Michigan was unaffected. Reference to "granular mixed fertilizer producer" in the following pages will imply the small one, unless otherwise specified.

The production of diammonium phosphate in Michigan used NH_3 from the Gulf Coast (Appendix B, Table B-2) and caused white phosphoric acid to be produced in Michigan; white acid utilizes elemental phosphorus as an input (Henderson, et al.). Consequently, these latter two products entered the organization when return on investment was set at 4.1 per cent (Appendix B, Tables B-1, B-6, and B-7). White rather than green phosphoric acid was utilized because it is less expensive to transport the highly concentrated elemental phosphorus (229 per cent P_2O_5 equivalent) to Michigan to be used in an inefficient process, relative to green acid production, than it is to transport either rock phosphate (29 per cent P_2O_5) from Florida for production of green phosphoric acid, or diammonium phosphate from the Midwest or Florida. That is, there are three basic schemes for supplying diammonium phosphate to Michigan: (1) ship elemental phosphorus from Florida to Michigan to be made into white phosphoric acid and subsequently diammonium phosphate; (2) ship rock phosphate from Florida to Michigan to be made into green phosphoric acid and subsequently diammonium phosphate; and (3) make the diammonium phosphate in either Florida or the Midwest and ship it to Michigan. The model contains a fourth alternative, namely, produce either white or green acid in either Florida or the Midwest and then ship it to the diammonium phosphate producer in Michigan. However, this last alternative is not very economical owing to high transportation rates imposed on phosphoric acid due to its high corrosive properties.

Of these four methods, the first was selected as being the most economical when return on investment was 4.1 per cent. However, the current capacity in Michigan to produce diammonium phosphate is only 19,800 tons annually. Therefore, continuation of the two options under alternative (3) were needed to meet the total P_2O_5 requirement in Michigan (Appendix B, Table B-11). In fact, both Florida and Midwest production of diammonium phosphate increased slightly. These increases are the result of a change in relative levels of dry blended fertilizers (Appendix B, Table B-1).

Return on investment at rates between 20.0 and 4.2 per cent, inclusive, had 185,535 tons of 7-28-28 bulk blended fertilizer and 86,465 tons of a 1-3-6 nutrient ratio custom blend fertilizer. This latter blend was composed of 6.05, 18.3, and 36.05 per cent N, P_2O_5, and K_2O, respectively, with the phosphate being derived from diammonium phosphate; whereas, the bulk blend fertilizer obtained its phosphate from monoammonium phosphate (Henderson, et al.). When the rate of return on investment was lowered to 4.1 per cent, 135,075 and 136,925 tons of the bulk and custom blend fertilizers, respectively, were supplied (Appendix B, Table B-1). Consequently, this relative change in levels of blend fertilizers caused the amount of diammonium phosphate used to increase, thereby substantiating the increases in the levels of it flowing to outstate Michigan producers, as recorded in Table B-11 of Appendix B. This relative change between blends also accounts for the decrease in monoammonium phosphate supplied as witnessed in Table B-12 of Appendix B. Other effects of the change in the relative levels of the blended fertilizers include increased usage of granular potassium chloride and granular triple superphosphate, both of which are used in the custom blend fertilizer (Appendix B, Table B-1).

The decline of granular mixed fertilizer production was responsible for several organizational changes. Since this type of fertilizer is the sole user of nitrogen manufacturing solutions, the latter also dropped in level of utilization when the return on investment was lowered from 4.2 to 4.1 per cent. Nitric acid, which is used to make the ammonium nitrate used as an input in producing nitrogen manufacturing solutions, also had a drop in its level of production as a result of the decline of granular mixed fertilizers. Thus, a domino effect, involving nitrogen manufacturing solutions, ammonium nitrate, and nitric acid, was created as a result of decreased usage of granular mixed fertilizers.

Two other products were affected by the reduction of granular mixed fertilizers. First, run-of-mine potassium chloride (Appendix B, Table B-13) had decreased shipments to the outstate granular mixed fertilizer producer (the one which decreased). Secondly, run-of-pile triple superphosphate also had a reduction in shipments to the outstate producer. Similar to potassium chloride that had constant flow to central Michigan, run-of-pile triple superphosphate also had constant shipments to central Michigan. However, there was a slight change in the relative levels coming from Florida and the Midwest (Appendix B, Table B-9). The reason for the change in levels is that granular triple superphosphate used run-of-pile as an input. Previously, we saw that the relative change in levels of blended fertilizer caused an increase in the usage of granular triple superphosphate. Consequently, this increase caused an increase need for run-of-pile production in Florida, where granular is made. Thus, while total tonnage of run-of-pile triple superphosphate fell from 115,303 to 112,087 tons (Appendix B, Table B-1), production in Florida increased slightly from 44,234 to 45,066 tons, which is only 832 tons. However, the demand for run-of-pile for the production of granular triple superphosphate increased by 3,139 tons, from 5,380 to 8,519 tons per year. Consequently, there was a reduction in the tonnage shipped from Florida to central Michigan processors, from 38,854 to 36,547 tons. The remainder of the constant usage by central Michigan producers (the large scale granular mixed fertilizer producer) was, therefore, supplied by a slight increase from the Midwest; whereas, there was a decrease in Midwest production of run-of-pile and an even larger decrease in shipments from there to the outstate Michigan granular mixed fertilizer producers.

Thus, we see that a change in the return on investment from 4.2 to 4.1 per cent has numerous effects upon the short run optimal organization of the industry. Briefly recapping the major effects, we see five substantial changes: (1) direct application of diammonium phosphate replaced some of the phosphate formerly being supplied by the granular mixed fertilizers; (2) white phosphoric acid was used to produce diammonium phosphate in Michigan for direct application; consequently, green phosphoric acid production decreased; (3) the decline of granular mixed fertilizers brought about a reduction in the production of nitrogen manufacturing solutions, ammonium nitrate, and nitric acid; (4) run-of-pile triple superphosphate, monoammonium phosphate, and run-of-mine potassium chloride had reduced usage; and (5) there was a change in the relative levels of bulk and custom blended fertilizers.

Further lowering of the rate of return on investment did not induce a change in the optimal industry organization until a return of 2.0 per cent was reached. At this rate of return, increased usage of the anhydrous ammonia retailer became less expensive than transporting NH_3 from the manufacturer in the Midwest directly to the farms by truck. In order to increase the usage of the NH_3 retailer, the quantity of anhydrous ammonia that was previously flowing (at higher rates of return on investment) from the Gulf Coast to the Michigan diammonium phosphate producer is now being supplied by the Midwest NH_3 manufacturer. That is, the diammonium phosphate producer in Michigan uses 4,346 tons of NH_3 (Appendix B, Table B-2), and this amount is supplied by the Gulf Coast anhydrous ammonia manufacturer when the return on investment is between 4.1 and 2.1 per cent, inclusive. When the return on investment drops to 2.0 per cent, however, that quantity of NH_3 is supplied by the Midwest NH_3 manufacturer. Consequently, this frees 4,346 tons of anhydrous ammonia, produced on the Gulf Coast, to be routed through the NH_3 retailer.[8] This is

[8]Keep in mind that Constrained Optimum forces a constant ratio of NH_3 production between the Gulf Coast and the Midwest.

exactly what happened, since we see in Table B-2 of Appendix B that shipments of NH_3 to the retailer increased by 4,346 tons, from 45,739 to 50,085 tons; whereas, total tonnage of NH_3 being applied direct was constant at 125,867 tons per year. No other changes occurred at this rate of return on investment.

The return on investment was lowered to -2.0 per cent without incurring any further changes in the optimal organization. This implies that minor losses on investment result in the same optimal industry as do small positive returns. Furthermore, it implies that those activities in the observed organization are quite efficient in non-investment factors. This follows from the fact that the linear programming routine treats the negative returns on investment as a profit or reward for using investment. Consequently, those items using large investment would be more desirable, given other things equal. Since the organization was not changed when the returns on investment went to -2.0 per cent, any advantage that facilities not selected might have because of their large investment, was out weighed by the efficient usage of other factors by those facilities in the optimal organization.

From a cost standpoint, high returns on investment are serious to the Michigan farmer. When returns on investment are 20.0 per cent, the total cost of supplying Michigan with 1970 levels of consumption of N, P_2O_5, and K_2O is $57,634,445. Of this figure, nearly 14 per cent of it, or $7,971,178 are returns to invested capital (Table II-2). If the industry shifted to the short run optimal organization corresponding to 2.0 per cent return on investment (slightly higher than that experienced in the industry in recent years), then the total cost

Table II-2. The effect of returns on investment in the short run (in dollars)

Return on Investment (per cent)	Total Cost	Investment	Cost[a] N	Cost[a] P_2O_5	Cost[a] K_2O	Returns
20.0	57,634,445	39,855,889	118.96	168.75	110.44	7,971,178
18.0	56,837,333	39,855,889	117.44	166.35	109.17	7,174,060
16.0	56,040,215	39,855,889	115.92	163.94	107.89	6,376,942
14.0	55,241,216	39,970,270	114.41	161.57	106.56	5,595,838
12.0	54,424,856	41,546,854	112.63	159.29	105.26	4,985,622
10.0	53,593,919	41,546,854	110.72	157.04	103.97	4,154,685
8.0	52,762,981	41,546,854	108.81	154.79	102.68	3,323,748
6.0	51,932,044	41,546,854	106.90	152.54	101.39	2,492,811
5.9	51,890,456	41,639,142	106.81	152.43	101.33	2,456,709
4.4	51,265,869	41,639,142	105.37	150.74	100.36	1,832,122
4.3	51,224,209	41,660,694	105.28	150.62	100.29	1,791,410
4.2	51,182,548	41,660,694	105.18	150.51	100.23	1,749,749
4.1	51,140,633	42,453,730	105.09	150.40	100.16	1,740,603

Table II-2. (cont'd.)

Return on Investment (per cent)	Total Cost	Investment	Cost[a] N	Cost[a] P_2O_5	Cost[a] K_2O	Returns
4.0	51,098,180	42,453,730	104.99	150.28	100.10	1,698,149
2.0	50,247,079	42,604,192	103.08	148.02	98.79	852,084
0.0	49,394,995	42,604,192	101.17	145.75	97.48	-0-
-2.0	48,542,911	42,604,192	99.26	143.48	96.17	-852,084

[a]Incremental cost per ton.

of supplying Michigan would be only $50,247,079. This would amount to a savings of nearly 7.4 million dollars as compared to the short run optimal organization associated with 20.0 per cent return on invested capital. More importantly, the cost savings over the current organization is $21,198,588, or more than 42 per cent of the total cost of the short run optimal organization with 2.0 per cent return on investment. Thus, Michigan farmers could save over 21 million dollars if the fertilizer industry would shift to the short run optimum industry organization with a return on investment comparable to that currently being earned in the industry.

A return of only 2.0 per cent on investment is definitely not very attractive. But, even when comparison is made with a more attractive return of, say, 10.0 per cent, the cost savings of the short run optimal industry organization (with 10.0 per cent return on investment) is still nearly 18 million dollars when compared to the current industry organization. The prospect of making more than a five fold increase in the rate of return on investment should provide considerable impetus to the industry participants to shift to the short run optimal organization. At the same time, the Michigan farmers would be receiving a reduction of nearly 25 per cent in their fertilizer bill, if the industry was organized optimally with 10.0 per cent return on investment.

Turning to the sensitivity of the three basic nutrients, we see from Table II-1 that potassium experienced the least change in incremental cost per ton throughout the range of returns investigated. When returns were 20.0 per cent, the incremental cost per ton of K_2O was $110.44; whereas, it fell by $14.27 to $96.17 when returns on investment went to -2.0 per cent. Phosphate, the most sensitive to changes in the rate of return on investment, had an incremental cost of $168.75 corresponding to 20.0 per cent returns and $143.48 per ton of P_2O_5 when returns dropped to -2.0 per cent. This change in incremental cost per ton is $25.27. Over the same range of rates of return, nitrogen had a change in incremental cost of $19.70 per ton, from $118.96 to $99.26.

Although the change in the incremental cost of nitrogen was within the extremes set by potash and phosphate, most changes in the short run optimal organization involve the nitrogen segment of the industry. This results from the important role of nitrogen and, in particular, anhydrous ammonia, in the industry. Anhydrous ammonia is directly or indirectly involved with nearly every nitrogen product in the model. In addition, it is relatively important in the primary phosphate products, such as monoammonium and diammonium phosphate. Thus, changes in the nitrogen segment can occur as the result of impetus outside that segment. Let us now examine the implications of the effects of various rates of return on investment.

Recall that in the short run, only existing facilities were allowed to be used. Consequently, the preceeding changes in the short run optimum industry organization affect only existing facilities. So, any changes in investment have a direct effect upon the number and value of idled facilities. With the 1970 Actual organization of the industry, over 75 million dollars were invested in the industry (Appendix A, Table A-32); whereas, the short run optimum industry organization had investment ranging from 42.6 to 39.8 million dollars (Table II-2). This implies that the level of investment in the short run would be only 53 to 57 per cent of the existing facilities, depending upon the rate of return on investment. Thus, the rate of return on investment had very little effect on the level of total investment in the short run optimal industry organization.

Total investment changed very little, relative to either total cost or returns on investment. As expected, total investment was at its lowest when return on investment was 20.0 per cent. The \$39,855,889 invested at that rate was only \$2,748,303 less than the \$42,604,192 invested at -2.0 per cent (Table II-2). Total cost changed by over 9 million dollars and returns on investment changed by over 8.8 million dollars throughout the range of rates of return on investment examined.

These last two figures indicate that over 97 per cent of the change in total cost can be directly attributed to the change in the returns on investment. Thus, the investment associated with high returns is very slightly less efficient in the use of other factors contributing to total cost than is the investment corresponding to low returns. Consequently, if the industry organization was maintained as that corresponding to 20.0 per cent return on investment, then very little potential cost savings would be foregone as compared to allowing the industry organization to change. If, for example, the optimal organization corresponding to 20.0 per cent return on investment were used for all rates of return, then the only change in total cost would be that associated with the change in total returns. Consequently, if we substract the \$7,971,178 returns to investment, associated with 20.0 per cent returns, from its associated total cost of \$57,634,445, we get \$49,663,267. This would be the total cost corresponding to the optimal industry organization associated with 20.0 per cent return on investment, but with a zero return. Comparing total cost to that of the optimal industry organization associated with zero per cent return on investment, we see that only $268,272 would be saved by changing the organization of the industry. This savings would amount to less than six-tenths of one per cent of the total cost.

Even less difference in total cost could be obtained by maintaining the organization denoted by Constrained Optimum. It is exactly that organization associated with rates of return on investment ranging from 6.0 per cent to 12.0 per cent, inclusive (Appendix B and Table II-1). By maintaining this organization, a return of zero per cent on investment would imply a loss of potential cost savings of only $44,238, which is considerably less than one-tenth of one per cent of total cost. Constrained Optimum organization with 20.0 per cent return on investment would have a total cost of $57,748,604, which is only $114,159 more than the optimal organization corresponding to 20.0 per cent return on investment. This amounts to less than two-tenths of one per cent of total cost. Thus, we see that the Constrained Optimum industry organization is extremely efficient (in terms of minimizing total cost) over a considerable range of rates of return on investment. More importantly, it is <u>the</u> optimal organization over a range of rates of return from 6.0 per cent to 12.0 per cent, inclusive. This range of rates of return on investment would surely be acceptable to the industry participants, especially in view of their current returns.

We have seen that to have the minimum cost industry organization in the short run, over various rates of return on investment, implies considerable changing in the organization to maintain minimal cost. At the same time, however, we have seen that the Constrained Optimum organization is very nearly the minimal cost organization throughout the range of rates of return on investment examined. The use of that organization in the short run implies very small losses of potential cost savings as compared to the optimal organizations over the range of rates investigated.

Implications of the Optimal Short Run Organization

The quantity of N, P_2O_5, and K_2O used in Michigan in 1970 could have been supplied with the existing industry facilities at a considerable cost savings to the Michigan farmers. In order to realize this cost savings, a number of changes would need to be made in the supply and use patterns.

The following is a list of the major changes that would be necessary to bring about the aforementioned cost savings:

1. Increased use of the existing anhydrous ammonia production facilities in Michigan, with direct application utilizing this production;

2. Decreased NH_3 retailing facilities, with the retailing function being performed primarily by NH_3 producers;

3. Increased production and use of monoammonium phosphate and granular potassium chloride;

4. Elimination of dry bagged and liquid fertilizers;

5. A shift in the performance of dry fertilizer retailing activities from the retailer to the processor;

6. A decrease in the number of small dry blenders and a corresponding increase in the number of large blenders; and,

7. An elimination of suboptimum products.

These changes have implications for several groups participating in the industry. The following paragraphs contain discussions of some of the important implications.

The existing capacity to produce anhydrous ammonia in Michigan is being under-utilized. The total existing capacity could be used to produce NH_3 for direct application; whereas, a reduction in the supply of NH_3 coming from the Gulf Coast producer is indicated in the analysis.

From a technological viewpoint, the piston type NH_3 technology appears to be inefficient relative to the centrifugal technology. This is indicated by the complete shut-down of the piston compressor in the Midwest while the centrifugal compressor output is maintained at nearly constant production level when comparing 1970 Actual and Constrained Optimum.

Other nitrogen producers are either shut-down or produce at greatly reduced levels in the Constrained Optimum organization. The only exception to this is the case of nitrogen manufacturing solutions producers; their output in the short run optimum situation is slightly higher than under existing conditions. Hence, in the short run, reorganization of the industry in a minimum cost framework would idle numerous nitrogenous fertilizer producers. It can be concluded that investment in these suboptimal facilities would be no longer desired. Therefore, if such a reorganization were to be made, firms currently producing such products as aqueous ammonia and urea might seek to either scrap their facilities or convert them into the production of other optimum products. This latter alternative, however, is not very practical, owing to the specialized nature of fertilizer production technology.

In the phosphate sector, a comparison of 1970 Actual and Constrained Optimum suggests that monoammonium and diammonium phosphate are more efficient sources of phosphate than rock phosphate or triple or normal superphosphate. Accompanying this shift to ammoniated phosphates is the trend towards relocation of phosphate processing facilities closer to the Florida rock mines.

Phosphate producers could close their normal and/or triple superphosphate facilities in the Midwest in order to minimize total cost to the Michigan farmer. The existing capacity in Florida could be utilized more heavily for the production of monoammonium phosphate.

Granular and run-of-mine potassium chloride appear to be more economical than the standard and coarse grades of potash. It would not be extremely difficult for the potassium producers to alter their screening process to produce the appropriate quantities of granular and run of mine potassium.

Furthermore, a change in the marketing of potash products needs to be made in the quest for minimum total cost. The traditional potash retailers are eliminated in the short run optimum organization. All potash is mixed with other fertilizer products prior to application, given the Constrained Optimum organization.

In the transportation sector of the industry, several important implications arise as the result of reorganization to minimize total cost.

The increase in phosphate production in Florida will require additional rail cars for transporting ammoniated phosphate products to Michigan. In 1970 Actual, phosphoric acid was being shipped to the Midwest and Michigan for the production of phosphatic fertilizers. Under the short run optimum organization, ammonia that was previously going from the Gulf Coast to the Midwest and Michigan for processing and direct application will be partially redirected to Florida for the manufacture of ammoniated phosphate products. Therefore, additional hopper-bottom cars will be necessary to transport these phosphate products to Michigan.

The shift of anhydrous ammonia production away from the Gulf Coast implies that there will be a decreased need for tank cars for transporting NH_3 north. However, at the same time there will be an increased usage of pipeline facilities to bring natural gas from the Gulf Coast into Michigan for NH_3 production.

Elimination of the anhydrous ammonia retailer and the increased usage of direct application of NH_3 calls for more trucking of NH_3 over longer distances. Anhydrous ammonia is trucked from the Midwest producer to the farm in the short run optimum industry organization; whereas, under the current organization of the industry, NH_3 is shipped by rail from the Midwest producer to the Michigan processors. Consequently, Constrained Optimum would imply a decreased usage of rail and increased usage of truck transportation of NH_3.

Farmers stand to benefit the most from a short run optimum organization of the industry. Although fewer products will be available, there will be a very substantial cost savings for those farmers that can readily switch to the optimum products.

There are, however, some additional costs for those farmers currently using liquid fertilizers.[9] Since liquids would no longer be produced, it would become necessary for a conversion to be made to dry products. Liquids have different handling and application equipment than that used for dry fertilizers. Consequently farmers currently using liquids will find it costly to convert to dry products. This cost has not been accounted for in the model.

In practicality, it is doubtful that there would be an immediate shut-down of all liquid plants. Therefore, farmers that are currently using liquids could (and should) continue to do so in the short run. As their equipment depreciates and liquid plants close, they should make the conversion to dry product handling equipment.

Summary

The Constrained Optimum solution is completely insensitive to change in the wage rate over the range of rates examined. It was the short run optimum organization for rates of return from 6.0 per cent to 12.0 per cent, inclusive. For rates of return less than 6.0 per cent, it was suboptimal by less than one-tenth of one per cent of the total cost of the optimal organization, despite the multitude of organizational changes necessary to obtain optimality.

Of the three nutrients, phosphate is the most sensitive, in terms of change in incremental cost per ton, to changes in the rate of return on investment. Potassium is the least sensitive.

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[9] See Henderson, Dennis R., "Fertilizer Consumption and Industry Adjustment," unpublished Ph.D. thesis, Michigan State University, pp. 95-105, for a detailed analysis of these additional costs.

The anhydrous ammonia retailing function is rather sensitive to changes in the return on investment.

In general, the Constrained Optimum organization of the industry is a desirable goal for industry participants. Its primary advantage is that of substantial potential cost savings. At the same time, some producers and retailers would be completely eliminated by an immediate switch to the Constrained Optimum organization. In addition, those farmers currently using liquid products would incur additional handling and application costs, owing to the differences in physical characteristics between dry and liquid fertilizers.

From a practical standpoint, a complete and immediate switch to the Constrained Optimum organization is not desirable. New and nearly new investment in equipment and facilities for handling and processing products that are suboptimal in the Constrained Optimum solution, should be used until they are depreciated. At the same time, farmers currently using these suboptimal products can begin to change to the optimal ones.

CHAPTER III

THE IMPACT OF WAGE RATES AND RATES OF RETURN ON INVESTMENT ON THE OPTIMUM LONG RUN INDUSTRY ORGANIZATION

The Impact of Alternative Wage Rates in the Long Run

The analysis of the impact of wage rates on the Optimum industry organization follows the format used for the constrained optimum organization. Since the N, P_2O_5, and K_2O constraints are the same in both the short and long runs, a comparison of Optimum, Constrained Optimum and 1970 Actual can be made. Unlike the Constrained Optimum model, the Optimum model allowed the purchase of those facilities that would minimize total cost, regardless of whether or not the facilities currently exist. Thus, facilities were not restricted to current capacity as was the case in the short run analysis.

The wage rate was ranged from \$3.00 to \$6.50 per man-hour, just as in the short run analysis. However, this time changes in the optimal organization occurred at wage rates of \$3.75 and \$5.00 (Appendix C). The total cost ranged from 47,886,689 dollars to 49,258,673 dollars, corresponding to wage rates of \$3.00 and \$6.50, respectively (Table III-1).

This increase of nearly 1.4 million dollars was over 200 thousand dollars less than the increase experienced during examination of Constrained Optimum.

The number of man-hours utilized at a wage of \$3.00 was 416,102

Table III-1. The impact of wages in the long run

Wage Rate (Dollars/man-hour)	Total Cost (Dollars)	Man-Hours Labor	Cost[a] N	Cost[a] P_2O_5	Cost[a] K_2O	Cost/ Nutrient Ton[b]	Wage Bill (Dollars)	Wage as % of Tot. Cost
3.00	47,886,689	416,102	87.74	146.28	91.41	109.28	1,248,306	2.61
3.25	47,990,714	416,102	87.79	146.84	91.54	109.51	1,352,332	2.82
3.50	48,094,739	416,102	87.83	147.39	91.66	109.75	1,456,357	3.03
3.75	48,198,377	397,545	87.88	147.94	91.79	109.99	1,490,794	3.09
4.00	48,297,764	397,545	87.92	148.36	91.91	110.22	1,590,180	3.29
4.25	48,397,150	397,545	87.97	148.79	92.04	110.44	1,689,566	3.49
4.50	48,496,536	397,545	88.02	149.21	92.16	110.67	1,788,953	3.69
4.75	48,595,922	397,545	88.06	149.64	92.29	110.90	1,888,339	3.89
5.00	48,695,129	375,697	88.11	150.06	92.41	111.12	1,878,485	3.86
5.25	48,789,053	375,697	88.15	150.34	92.54	111.34	1,972,409	4.04
5.50	48,882,977	375,697	88.20	150.61	92.66	111.55	2,066,334	4.23
5.75	48,976,901	375,697	88.24	150.88	92.79	111.77	2,160,258	4.41

Table III-1. (cont'd.)

Wage Rate (Dollars/man-hour)	Total Cost (Dollars)	Man-Hours Labor	Cost[a] N	Cost[a] P_2O_5	Cost[a] K_2O	Cost/ Nutrient Ton[b]	Wage Bill (Dollars)	Wage as % of Tot. Cost
6.00	49,070,825	375,697	88.29	151.16	92.91	111.98	2,254,182	4.59
6.25	49,164,749	375,697	88.34	151.43	93.04	112.19	2,348,106	4.78
6.50	49,258,673	375,697	88.38	151.70	93.16	112.41	2,442,031	4.96

[a]Incremental cost per nutrient ton (dollars).

[b]Total cost divided by total nutrient tonnage (438,023 tons).

annually; whereas, at $3.75 per man-hour labor utilization dropped to 397,545 and at $5.00 the figure was 375,697. These figures are substantially lower than the 452,182 man-hours used throughout the range of wage rates in the short run analysis. Assuming a work week of 40 hours and a 50 week year, switching from 1970 Actual (at $4.00 per man-hour) with utilization of 645,405 man-hours to Constrained Optimum (again at $4.00 per man-hour) would involve a reduction of 97 employees (Table III-2). The most serious implications on employment involve a shift from 1970 Actual to the long run organization with ending wage rate of $5.00 or more per man-hour. This shift would reduce employment needs by 135 employees, which is nearly 42 per cent of all employees needed to produce Michigan's 1970 fertilizer consumption. While this reduction may be serious for the fertilizer industry, the national employment situation would be relatively unaffected. Even if comparable changes in employment practices were undertaken in the fertilizer industry throughout the U.S., there probably would be no noticeable impact on unemployment and relief programs.[1]

The largest reduction in employees resulting from a single change is that involved in a change from 1970 Actual to Constrained Optimum. The 97 potentially displaced employees were largely utilized to produce suboptimum products or were employed in sub-optimal processes.[2]

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[1]This arises from the low labor usage in the fertilizer industry.

[2]A comparison of 1970 Actual and Constrained Optimum (Appendix A) will readily show which products and facilities would be excluded during such a shift.

Table III-2. Employment in different industry organizations

Organization	Wage Rate	Man-Hours	Employees[a]
1970 Actual	\$4.00	645,405	323
Constrained optimum	\$3.00-\$6.50	452,182	226
Optimum	\$3.00-\$3.50	416,102	208
Optimum	\$3.75-\$4.75	397,545	199
Optimum	\$5.00-\$6.50	375,697	188

Sources: Appendices A and C.

[a]Based on 40 hour week and 50 week year.

The effects of changes in the wage rate in the long run are felt primarily by bulk blenders (Appendix C, Table C-6). When the wage rate changed from \$3.50 to \$3.75 per man-hour there was a decrease of 18,557 man-hours (Table III-2). During this change, bulk blending and the associated retailing function accounted for a total labor reduction of 18,624 man-hours (Table III-3). This indicates that the change in labor utilization of all other activities combined was an increase of 67 man-hours.

The only other major effect that occurred during this change in the wage rate was an increase in the level of direct application of granular potassium chloride (Appendix C, Table C-5). The direct application level, for wage rates between \$3.00 and \$3.50 was 27,163 tons; at \$3.75 per man-hour for labor, application increased to 86,319 tons. Accompanying this change was a change in the bulk blend product mix (Appendix C, Table C-6). Prior to increasing the wage rate to \$3.75 per man-hour, 502,321 tons of a 7-28-28 grade product[3]

[3]7-28-28 denotes that the product contains 7 per cent nitrogen, 28 per cent P_2O_5, and 28 per cent K_2O.

Table III-3. Labor utilization and through-put volume in bulk blending and custom blending (optimum)

	Man-hours per ton	Wage rate (Dollars per man-hour) $3.00 to $3.50	$3.75 to $4.75	$5.00 to $6.50
Bulk blending	0.1905	95,962	62,806	71,293
Custom blending	0.1905	-0-	21,641	-0-
Retailing[a]	0.25	62,790	55,411	46,780
Total (blending and retailing)		158,482	139,858	118,073
Per cent of all labor		38.09	35.18	31.43

Sources: Compiled from Appendix C, Table C-6, and Henderson, et al.

[a]Satellite warehouse product handling.

were bulk blended. For wages between \$3.75 and \$4.75 per man-hour, inclusive, the bulk blenders produced 329,689 tons of 7-28-28 and 113,601 tons of a 10.6-42.55-10.85 custom blend fertilizer.[4] Since it was economically desirable to direct apply granular potassium chloride, the mix of the two bulk blend products was necessary to maintain N, P_2O_5, and K_2O constraints. Thus, the 1-4-1 ratio custom blend material, being relatively high in phosphate and low in potassium, replaced some of the 7-28-28 which has a 1-4-4 ratio, as total bulk blending dropped to 443,290 tons.

It should be pointed out that the probable impetus for the decrease in bulk blending and increase in direct application is the fact that labor costs, in the model, for bulk blending vary directly with changes in the fertilizer industrial wage rate; whereas, the cost of direct application of fertilizer materials does not vary with the industry wage rate. This assumption is based largely upon an assumption that farm workers are the primary source of any labor needed for direct application and their wages are independent of those in the fertilizer industry.

Changing the wage rate from \$4.75 to \$5.00 per man-hour had an effect similar to changing it from \$3.50 to \$3.75. This time, however, the decrease in labor utilization by bulk blending was 21,785 man-hours (Table III-3). The total decrease in labor usage was 21,848 (Table III-2), which implies all other activities decreased their labor utilization by 63 man-hours.

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[4] A Custom blend fertilizer is made specifically to order and is generally in a nutrient ratio, such as 1-3-2, not to be confused with the designation for grades as explained in footnote 3. Thus, 10.6-42.55-10.85 approximates a 1-4-1 ratio of N to P_2O_5 to K_2O.

Direct application of potassium chloride declined by 26 tons to 86,293 tons. At the same time, monoammonium phosphate direct application was used at a level of 68,965 tons. The combination of these two products being applied directly allowed bulk blending to revert to a single product, namely, 7-28-28. The level of blending dropped from 443,290 to 374,243; whereas, the amount of 7-28-28 blended increased from 329,689 to 374,243 tons.

Figure III-1 presents what could be considered as labor "demand" curves for the long and short run optimum organizations.[5] These graphs show the amount of labor required to minimize total cost for the various wage rates, given the constraints associated with each organization. As mentioned previously, the level of labor utilization in the Constrained Optimum industry organization is constant throughout the range of wages examined. This phoenomenon is represented by the continuous vertical line in Figure III-1. Non-zero changes in labor utilization between two consecutive wage rates are represented by dashed lines.

Thus, we have seen that bulk blending is replaced to some extent by direct application of fertilizer materials as the wage rate increases. Nearly a million dollars in total cost could be avoided by reorganizing the industry into the long run optimum scheme. This cost savings reflects only the difference directly attributed to a reduction in labor utilization at constant wages. In the following section, we will further investigate the Optimum industry organization.

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[5]These, of course, are not true demand curves, since the quantity of fertilizer nutrients produced was held constant while the wage rate was varied.

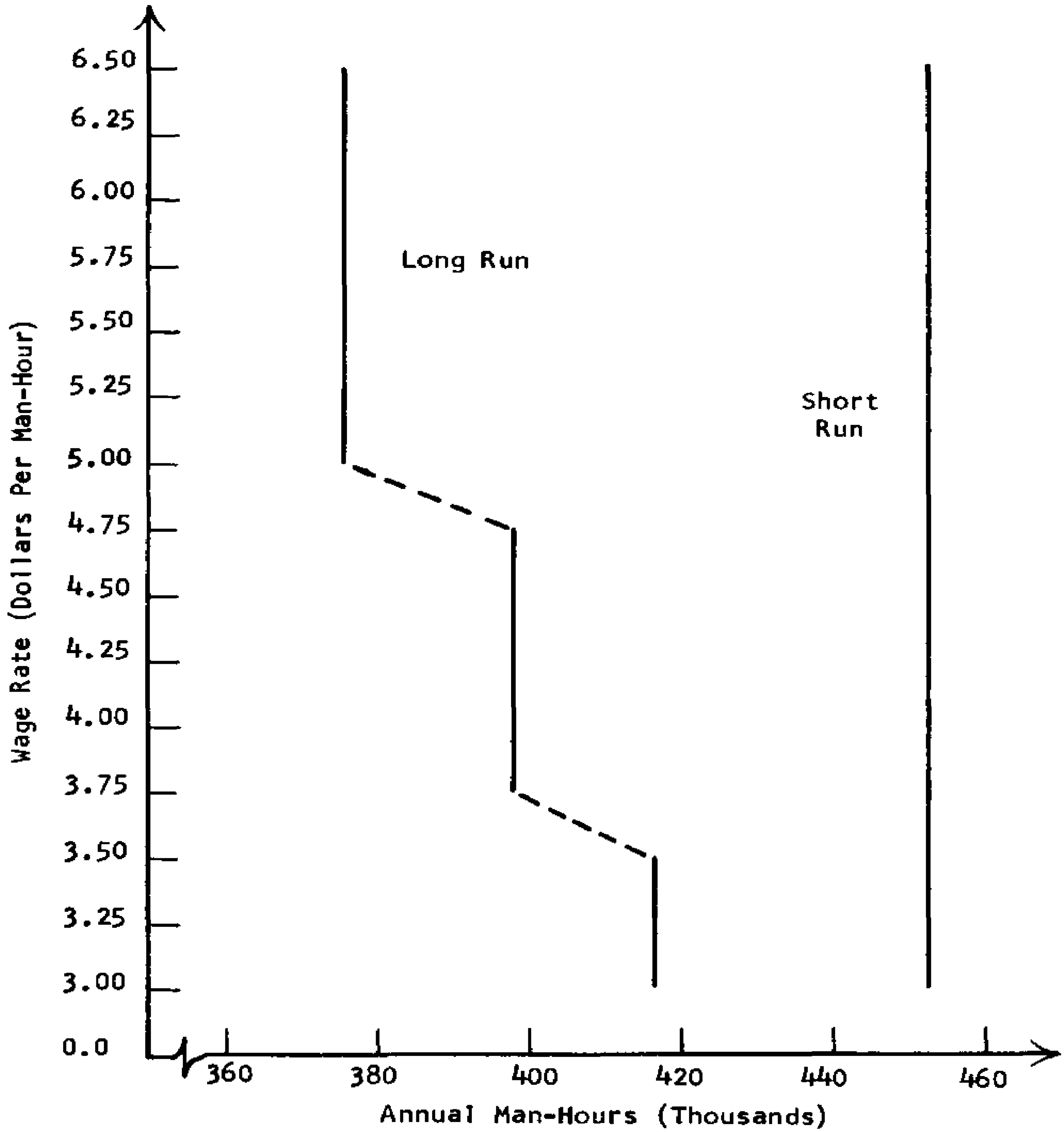

Figure III-1. Labor Usage In the Long and Short Run.

Return on Investment in the Long Run

Similar to the short run analysis, the rate of return on investment was examined for rates from 20.0 to -2.0 per cent. Unlike the short run analysis, the model was allowed to select those activities required to minimize total cost, regardless of whether or not those facilities currently exist. This analysis, then, investigates the effects of various rates of return on investment on the optimal industry organization, given that those facilities desired to minimize total cost would be selected among those known to be currently feasible, but not necessarily in current use.

Return on investment was set at 20.0 per cent and then scaled down by 2.0 per cent increments to -2.0 per cent. In addition, the upper limit of validity of the Optimum organization was determined by 0.1 per cent increments in the appropriate range.

Throughout the entire range of rates examined, there was very little change in the products produced in the optimal organizations (Appendix D, Table D-1). The most noticeable change is that occurring in the dry blending segment of the industry; custom blended fertilizers are not used for either high or low rates of return on investment. This will be explained in greater detail.

When return on invested capital was set at 20.0 per cent, 374,243 tons of bulk blended fertilizer were produced (Appendix D, Table D-6). Additional dry fertilizer being consumed was composed of direct application of granular potassium chloride and monoammonium phosphate. Direct application of the latter product amounted to 68,965 tons (Appendix D, Table D-4); whereas, total production of this product was nearly constant throughout the range of rates of return on investment analyzed. The observed variation in its level of production is completely explained by the rounding errors in the dry blend formulations, since this is the only phosphatic material used and total P_2O_5 required remained constant. Similarly, the variation in the level of production of granular potassium chloride (the other directly applied dry fertilizer) can be explained entirely by the same rounding errors; whereas, the variation in the level of direct application is due largely to changes in the blending segment. Direct application of granular potassium chloride, when returns on invested capital were 20.0 per cent, amounted to 86,293 tons (Appendix D, Table D-5). Anhydrous ammonia was the only other product to be applied directly. Return on investment of 20.0 per cent is associated with 129,890 tons of NH_3 being applied directly (Appendix D, Table D-2).

Lowering the rate of return in increments of 2.0 percentage points did not produce a change in the optimal organization of the industry until 10.0 per cent was reached. Subsequently, incrementation by 0.1 percentage points determined that 10.7 per cent return on investment was the rate at which the optimal organization changed. For rates greater than or equal to 10.8 per cent, the optimal organization is identical to that associated with a return on invested capital of 20.0 per cent. With return on investment set at 10.7 per cent, the long run optimal organization of the industry is identical to that of Optimum, which assumed a rate of 7.5 per cent.

At 10.7 per cent return on investment, the direct application of monoammonium phosphate becomes sub-optimal; consequently, it is no longer a part of the optimal industry organization. Dry blending of fertilizer becomes more economical than direct application of monoammonium phosphate. A slight decrease in bulk blending is augmented with the implementation of custom blending (Appendix D, Table D-1) to result in an increase of 69,047 tons of dry blended fertilizers. This amount is nearly identical to the tonnage of monoammonium phosphate that was previously (at higher rates of return) directly applied. Meanwhile, direct application of granular potassium chloride remained nearly constant as did direct application of anhydrous ammonia (Appendix D, Tables D-2 and D-5).

The causal factor of the decrease in direct application of monoammonium phosphate is that of returns on investment. At high returns on investment (above 10.7 per cent), the cost of operating the dry blender is sufficiently high that direct application of monoammonium phosphate becomes economically superior, despite the fact that only two nutrients (monoammonium phosphate contains 13 per cent N and 52 per cent P_2O_5) are being applied; whereas, the blended material contains all three. Thus, direct application of monoammonium phosphate requires that an extra application charge be met, since it and the blended material must be applied; whereas, with returns on investment less than or equal to 10.7 per cent but at least as great as 8 per cent, the decreased cost of blending makes that additional application charge sub-optimal. Actually, as we will see momentarily, the extra application charge remained sub-optimal through and including returns on investment of -2.0 per cent.

The remainder of the organization was essentially unchanged by the lowering of the rate of return on invested capital to 10.7 per cent. Furthermore, this organizational scheme, which is identical to that of the long run Optimum organization, remained unchanged until the rate of return reached 6.0 per cent.

With returns at 6.0 per cent, the trend toward increased dry blending of fertilizer continued. Total blending increased by 59,031 tons to 502,321 tons, of which all of it was bulk blended fertilizers (Appendix D, Tables D-1 and D-6). Given this same rate of return, direct application of granular potassium chloride was 27,163 tons annually, which is 59,156 tons lower than at previously higher rates of return on invested capital (Appendix D, Table D-5). Thus, the reduced rate of return has caused some of the direct application of granular potassium chloride to be replaced by dry blended fertilizer. In order to accomplish this change and continue to meet the N, P_2O_5, and K_2O constraints, the observed switch from a combination of bulk and custom blend fertilizer to solely bulk blending was necessary.

When the custom blended fertilizer was being made, the formulation of it had a nutrient ratio of 1-4-1, which contained 10.6, 42.55, and 10.85 per cent N, P_2O_5, and K_2O, respectively. The bulk blend fertilizer used throughout the entire range of rates examined was composed of 7 per cent nitrogen and 28 per cent of each P_2O_5 and K_2O. Thus, it is easily seen how the bulk blend fertilizer used up the 59,156 tons of granular potassium chloride that were previously directly applied. The low nitrogen and phosphate content of the bulk blend fertilizer, relative to the custom blend, allowed NH_3 direct application to remain nearly constant and used all of the phosphate required to meet the P_2O_5 specification; thus, no direct application of P_2O_5 was required.

As mentioned earlier, the direct application of monoammonium phosphate becomes sub-optimal when sufficiently low rates of return are imposed, viz., rates of return below and including 10.7 per cent. Consequently, blending all P_2O_5 becomes an implied constraint for minimizing total cost, given rates of return less than or equal to 10.7 per cent. With rates of return less than or equal to 6.0 per cent, direct application of K_2O becomes sub-optimal, as witnessed by the decrease of 59,156 tons of direct application of granular potassium chloride. Therefore, we can now readily understand why the 7-28-28 bulk blend fertilizer was used at such a high level. In attempting to blend all P_2O_5 and K_2O, without producing excess of either, each ton of 7-28-28 contained a total of 56 per cent of P_2O_5 and K_2O combined; whereas, the previously used custom blend could only supply a total of 53.4 per cent of P_2O_5 and K_2O per ton. Moreover, the 7-28-28 formulation exhausted the P_2O_5 requirement before it had met the K_2O needs (this follows from the fact that all P_2O_5 is blended and some K_2O is still being applied directly); whereas, had the custom blend fertilizer been used, its 4 to 1 ratio of P_2O_5 to K_2O would have required that a larger number of tons of granular potassium chloride be applied directly, relative to the use of 7-28-28.

The cost situation in the long run analysis is similar to that viewed in the short run. When returns on invested capital are set at 20.0 per cent, the total cost of supplying the 1970 levels of N, P_2O_5, and K_2O in the long run is \$52,936,032. Just under 14 per cent of this figure can be attributed to the \$7,386,560 in returns (Table III-4). If the industry would switch to the long run optimal industry organization corresponding to 2.0 per cent return on invested capital, which is a slightly greater rate than that received in recent years in

Table III-4. The effect of returns on investment in the long run (in dollars)

Return on Investment (per cent)	Total Cost	Investment	Cost[a] N	Cost[a] P_2O_5	Cost[a] K_2O	Returns
20.0	52,936,032	36,932,798	95.98	162.04	96.34	7,386,560
18.0	52,197,376	36,932,798	94.69	159.95	95.63	6,647,904
16.0	51,458,720	36,932,798	93.40	157.86	94.92	5,909,248
14.0	50,720,064	36,932,798	92.11	155.76	94.21	5,170,592
12.0	49,981,408	36,932,798	90.82	153.67	93.51	4,431,936
10.7	49,501,018	37,601,696	89.99	152.31	93.05	4,023,381
10.0	49,237,806	37,601,696	89.53	151.44	92.80	3,760,170
8.0	48,485,772	37,601,696	88.25	148.98	92.09	3,008,136
6.0	47,726,487	38,420,188	86.96	146.31	91.38	2,305,211
4.0	46,958,084	38,420,188	85.67	143.39	90.67	1,536,808
2.0	46,189,680	38,420,188	84.38	140.47	89.96	768,404
0.0	45,421,276	38,420,188	83.09	137.54	89.25	-0-
-2.0	44,652,872	38,420,188	81.81	134.63	88.55	-768,404

[a] Incremental cost per ton.

the industry, the total cost of supplying that same quantity of fertilizer would be only $46,189,680. This lower return on investment would save Michigan farmers over 6.7 million dollars as compared to a return of 20.0 per cent. More importantly, the cost savings as compared to the nearly 71.5 million dollars of the current organization (Appendix A, Table A-1) is $25,255,987, which is over 55 per cent of the total cost of the long run optimal organization, given that return on investment is 2.0 per cent.

If, on the other hand, industry participants switched to the long run optimal industry organization associated with a return on invested capital of 10.0 per cent, the cost savings to Michigan farmers would still be over 22 million dollars, when compared with the current industry organization. The return of 10.0 per cent would certainly be attractive to the industry entrepreneurs, while at the same time, Michigan farmers would obtain an effective 31 per cent reduction in their expenditures on fertilizer.

Similar to the results in the short run analysis, potassium experienced the least change in its incremental cost per ton. A rate of return of 20.0 per cent is associated with an incremental cost of $96.34 per ton of K_2O; whereas, the figure was $88.55 per ton when returns were -2.0 per cent. This change amounts to only $7.79 per ton. During the same change in the rate of return, phosphate had a decrease of $27.41 in cost per incremental ton. The 20.0 per cent rate of return figure for P_2O_5 was $162.04 while the lowest figure was $134.63, to give P_2O_5 the greatest change among the three nutrients. Nitrogen, having a change in incremental cost per ton of $14.17, was in between the other two. Its high and low incremental costs were $95.98 and $81.81 per ton, respectively.

Total investment changed by less than 1.5 million dollars, given the range of rates of return to invested capital examined. A rate of return on investment of 20.0 per cent corresponds to an optimal level of investment of $36,932,798, given that cost minimization is the objective. This figure increases to $38,420,188 when the rate of return drops to 6.0 per cent (Table III-4). Total cost changed by $8,283,160 and returns on invested capital changed $8,154,964 over the range of rates examined. Consequently, 98.5 per cent of the change in total cost is accounted for by the change in return on investment. Thus, the long run optimal industry activities are relatively efficient users of non-investment factors.

The relatively small change in total investment noted above is somewhat surprising, given the range of rates examined. On the other hand, the fertilizer industry is largely technology oriented; consequently, once the minimum cost product mix is established, changes in the rate of return on investment are not likely to result in a change in that mix. Furthermore, the relatively high capital intensive nature of the industry combined with a limited number of alternative technologies make the least cost product mix rather stable. Once a capital intensive technology has been selected as being mimimum cost, increases in the rate of return would cause it to be replaced only if an alternative product or technology resulted in a lower total cost. The high degree of inter-dependence among the various activities in the linear programming model would tend to make changes from one product to another rather complex; this arises because a particular product or technology in the least cost solution is directly or indirectly connected with several other activities forming an interwoven group. In order for one activity in that group to be replaced, a major portion of the group would have to change. For example, suppose that monoammonium phosphate (MAP) is used in a dry bulk blend formulation with some other unspecified products. In order for, say, triple superphosphate (TSP) to replace MAP, several activities must change. Among those that would need to change are: the bulk blend formulation; the transportation activities for MAP, TSP, and the other products composing the formulations; MAP and TSP storage; other nitrogenous fertilizers (since TSP does not contain N, but MAP does) and their related activities; etc. Thus, we see that once the minimum cost solution has been established, an alternative product or technology would need to have a considerable cost saving advantage over an activity in the least cost solution before the solution would change.

If the Optimum organization (Appendix A) were imposed throughout the range of rates of return examined, then only small improvements could be made towards cost minimization for those rates of return on investment for which the Optimum organization is sub-optimal. For rates of return between and including 6.0 and 10.7 per cent, the Optimum industry organization results in minimum cost.

If the return on investment was 20.0 per cent, the Optimum organization would result in a cost equal to $52,997,976, which is only $61,944 more than the optimal organization for that rate of return. The minimum cost organization would, thus, save just over one-tenth of one per cent of the total cost of the Optimum organization. On the other hand, if the rate of return on investment was zero per cent, use of the Optimum organization would result in an increase of $56,360 in total cost, which is just more than one-tenth of one per cent of the total cost of the minimum cost organization. The Optimum industry organization is, therefore, very nearly the optimal organization over the range of returns to investment investigated.

Implications of the Long Run Optimum Organization

The stability of the Optimum solution under various wage rates and rates of return on investment and its potential cost savings suggest that it is an appropriate long term goal for the industry. Optimum has rather dire implications for the suboptimal product manufacturers and processors. On the other hand, it implies growth in the use of the optimal products. Let's examine more closely some of the specific implications of the Optimum solution.

The major long run adjustments are:

1. Increased use of anhydrous ammonia produced in Michigan along with a shift to centrifugal compressor technology and to distribution of NH_3 directly to the farms;

2. Increased usage of large-scale blenders and elimination of small-scale blenders and all granulators;

3. Construction and operation of large terminating facilities in Michigan for the distribution of potassium chloride directly to farms;

4. Usage of monoammonium phosphate as the only source of phosphate; and,

5. Elimination of all local retailing outlets with the retailing function being performed by manufacturer, blenders, and terminals.

Let's examine these adjustments to see what they imply.

The Optimum solution implies that it is more economical to produce anhydrous ammonia in Michigan for direct application than at the Gulf Coast. Currently, most of the NH_3 manufacturing is done on the Gulf Coast because of the availability of natural gas from which anhydrous ammonia is made. The Optimum solution indicates that it is cheaper to pipe the natural gas to Michigan to make NH_3 than it is to ship NH_3 from the Gulf Coast to Michigan. However, NH_3 production at the Gulf Coast is still important for the ammonia input in ammoniated phosphates produced in Florida.

About one-fourth of the nitrogen supplied under the Optimum solution comes from monoammonium phosphate. The NH_3 production on the Gulf Coast is very important for the economical production of ammoniated phosphate in Florida. No other phosphate product is used in the long run. Consequently, phosphate producers might strive to phase out the normal and triple superphosphate facilities in the Midwest. Furthermore, the existing capacity to produce ammoniated phosphate near the Florida mines could be used to produce monoammonium phosphate. Priority on new investment in phosphate production should be placed on ammoniated phosphate facilities in Florida, if the Optimum organization is to be installed.

In the remainder of the nitrogen sector, improved coordination will be needed to move anhydrous ammonia directly from the producer to the farmer, since the local retailer is eliminated in the long run. Until such improved coordination is realized, NH_3 from the Gulf Coast producer is competitive with Michigan production. Thus, as centrifugal compressor technology is installed in Michigan and the necessary coordination is obtained, Gulf Coast NH_3 for direct application in Michigan should be phased out with the anhydrous ammonia retailer to fully realize the Optimum organization.

Facilities for the production of other nitrogenous products would not be replaced as they depreciate. The long run optimal solution indicates that NH_3 and monoammonium phosphate would be the only sources of nitrogen. Thus, nitrogen producers in Michigan would make new investment only in centrifugal NH_3 production facilities.

In the potassium sector, the Optimum solution indicates that granular potassium chloride is the optimum source of K_2O. It might be difficult for the producers to make a sufficient supply of granular grade potassium chloride. Thus, efforts may be needed to develop improved refining processes in order to produce sufficiently large quantities of granular grade potassium chloride.

The processing/mixing sector of the industry will be dominated by large bulk blending facilities. Granular mixers, liquid mixers and small bulk blending facilities would not be replaced as attrition and deterioration cause them to fold. In all, about 50 large blenders capable of blending 9,000 tons annually would be required to meet the level of blending indicated in the Optimum solution. It is estimated that 28 such facilities currently exist; therefore, 22 new 9,000 ton blenders will be needed to meet the long run blending volume of the optimal industry organization.

The optimality of the larger blenders indicates that in the long run, greater capital outlay will be needed for entry into the processing/mixing sector of the industry as compared to recent years. In addition, improved marketing programs will need to be implemented to handle the larger volume through-put of the new blenders.

The long run Optimum industry organization has implications for several segments of the transportation sector of the industry.

The shift of anhydrous ammonia production from the Gulf Coast to Michigan has implications for rail and pipeline modes of transportation. Currently, a large portion of NH_3 used in Michigan is shipped by rail from the Gulf Coast to Michigan. If industry evolves as outlined by the Optimum solution, then the use of rail for NH_3 transportation will decrease. At the same time, increased usage will be made of the pipeline for natural gas shipment to Michigan from the Gulf Coast. Limited pipeline availability has been one of the expressed factors attributing to the shortage of natural gas in the Michigan area. Thus, the suggested shift in the nitrogen sector could be hampered by the limited availability of pipeline transportation facilities in the short run. In the long run, additional pipeline facilities is an investment item that should be given considerable thought by the nitrogen sector.

If phosphate production shifts primarily to Florida, then there will be a need for additional rail capacity to haul monoammonium phosphate to Michigan. This will increase the burden on an already taxed rail fleet. Therefore, in order to successfully complete the indicated shift in phosphate production, the supply of rail cars suitable for hauling ammoniated phosphate products will need to be augmented.

It is quite possible that some of the rail cars needed for phosphate products are currently being used by the potash sector. The implementation of terminals for potash will free some of the previously needed rail cars. This will come about since some of these cars were used primarily to meet the peak season rush period. With the installation of the terminals, the effect will be that of reducing some of the seasonality, since one function of the terminal is to stock-pile fertilizer; consequently, a smaller number of rail cars making more hauls should be able to keep up with demand, if they have the terminal system in which to stock-pile during the off-season.

Truck transportation within Michigan will come under heavy use for a very short period of time during the year. Distribution of potash and anhydrous ammonia from the Michigan terminal and producer, respectively, directly to the farm is highly seasonal work. The current available supply of such trucks is unknown, but it is likely that the supply is insufficient to meet the peak seasonal demand. Currently, the variety of product forms and the numerous retailers and small processors tend to diminish the effect of seasonality on transportation, since the product is spread out over the state in these facilities rather than being concentrated in a central terminal and a small number of large blenders.

One of the most important changes involves the farmer. Analysis of the Optimum solution indicates that there will be a significant change in the products used by farmers. The ability and willingness of farmers to shift to products other than those they are currently using is a very necessary step in the switch to the Optimum industry organization.

The most serious implications involve those farmers currently using liquid fertilizers. Since these products are suboptimal in the long run, farmers currently using them will need to switch to other fertilizers if the cost savings potential of the Optimum organization is to be realized. As pointed out in Chapter II, the model has not taken into account the cost of switching from liquid to dry fertilizer handling equipment. In the short run, there is likely to be a gradual phase-out of liquid products, during which time farmers that are currently using liquids should switch to dry blended fertilizers and their associated handling equipment.

Summary

The Optimum solution has proved to be very nearly optimal when subjected to various wage rates and rates of return on investment.

Changes in the wage rate had a minimal impact upon the Optimum solution; direct application of monoammonium phosphate and granular potassium chloride replaced some of the dry blending activity as increased wages were imposed upon the model.

The Optimum solution is the long run optimal industry organization for rates of return on investment from 6.0 per cent to 10.7 per cent, inclusive. For rates less than 6.0 per cent, Optimum would result in a maximum increase in total cost of $56,360. This figure is equivalent to an increase of $0.129 per nutrient ton of consumption in 1970 in Michigan. On the other hand, implementation of Optimum could save Michigan farmers $25,255,987 when compared to the 1970 Actual solution. This savings is equivalent to $57.66 per nutrient ton.

Direct application of monoammonium phosphate and granular potassium chloride are affected as changes in the dry blending segment take place in attempting to minimize total cost to the Michigan farmers over various rates of return.

Implementation of the Optimum solution would have a significant impact upon the organization and operation of the fertilizer industry in Michigan. Most notable among the numerous impacts would be the elimination of suboptimal products and the producers and marketing network associated with them.

For the farmer, the Optimum solution to industry organization has two very important implications. First, Michigan farmers could stand to receive a decrease in fertilizer expenditures equivalent to 32 per cent of the amount they spent in 1970. Secondly, the elimination of some products, liquids in particular, will mean an increase in the cost of handling and application of fertilizer for some farmers. Thus, not all farmers could receive the full 32 per cent reduction in fertilizer expenditures.

CHAPTER IV

THE TRANSITION FROM THE CURRENT INDUSTRY ORGANIZATION TO THE LONG RUN OPTIMAL

The Problem

In view of the potential reduction in cost to farmers and/or increased returns to industry participants discussed in the previous chapters, an optimal transition from the current industry organization (as simulated by 1970 Actual in Appendix A) to the long run Optimum (Appendix A) organization is desirable. Since this long run optimal industry organization utilizes some facilities which do not currently exist, it is appropriate to analyze the investment required to transform the current industry into that optimal organization.

In making such a transition, several important questions need to be answered. Industry investors need to know which products to produce and the appropriate technology to employ for that production. Moreover, the timing of the investment in new facilities must be closely coordinated with the scrapping of old facilities. The crucial questions here are those of which products and technologies would replace current products and technologies; what level of annual investment in new facilities would be immediately scrapped and which would remain in use; and which investment would be made first. This chapter is devoted to answering these questions. In addition, this chapter will supply answers to questions concerning the necessary levels of services, such as transportation, that would be required by the proposed transformation of the industry. To answer these questions the transition was made in accordance with certain assumptions.

The Assumptions

The following is a list of assumptions made concerning the transition from 1970 Actual to the long run Optimum industry organization:

1. Since the Constrained Optimum organization is composed of only existing facilities, it is assumed that the transition could be made to this organization within the time period of one year. An implied assumption that is closely related to this first year of transition, as well as to the remainder of the transition years, is that farmers would willingly purchase the products supplied, given the reduction in cost to them.

2. Existing facilities were assumed to be at their midlife. This is based on the tremendous growth in the industry that took place five to six years ago. Therefore, most of the facilities would be at least five years old and would be in the declining years of their productivity. Normal attrition plus the relatively poor returns on investment experienced in recent years suggests that a 20 per cent rate of deterioration of physical capacity would be appropriate for the existing facilities that are used each year. If, however, existing facilities are not used, it is assumed that 40 per cent of their capacity would be eliminated. This is based on normal attrition and poor economic conditions in the industry and the belief that these forces (and others) that caused the facilities to be idled would con-

tinue to harass them, such that only half of those shut down would again be operated. Thus, current facilities could be used for a maximum of five years if they were used every year; whereas, they would no longer be available after three years if they were not used at all.

3. New facilities could not be "purchased" until after the transition was completed from the 1970 Actual organization (Year 0) to the Constrained Optimum organization (Year 1). In addition, the model was not allowed to purchase new facilities that were not used in the long run Optimum organization. Since the model is not recursive, it could not simultaneously determine the long run optimal industry organization and the optimal transition path to achieve that organization. Consequently, to prevent the model from possibly selecting, during each step of the transition, facilities that are not used in the Optimum organization, the purchasing restriction was imposed. Without that restriction, the model could have possibly selected facilities that are not in Optimum. Such selection would have caused additional investment in attempting to minimize the short run total cost and would have prolonged the complete attainment of the long run optimal organization, since new facilities are assumed to have a ten year life.

4. New facilities, those "purchased" by the model, were assumed to physically deteriorate at the rate of 10 per cent of their original capacity annually. This is based on the fact that a facility would normally lose some of its original capacity and on the recent economic record of the fertilizer industry. This figure may be somewhat high and could, thereby, result in upward bias of the new investment costs of the transition.

5. Return on investment of existing facilities and those at least one year old was assumed to be zero. This is consistent with the classical economic theory of the short run. This theory states that a productive process (facility) will be used in the short run if its returns are at least equal to its variable costs. Thus, a facility need not obtain any returns to be applied towards its fixed costs (investment) in the short run, provided its variable costs are met. In other words, once an investment has been made, it will be utilized in the short run regardless of investment (fixed) cost, if its variable costs are recovered; thus, it is as though fixed costs were zero, which is what this assumption implies.

6. Return on investment of new facilities, i.e., those purchased during the current transition year, was set at 15.0 per cent. This not only imposed fixed costs upon these facilities, but also reflected management's insistence on receiving an equitable return on new investment. After this first year of utilization, the facility then became a member of that group described under assumption 5, that is, its return on investment was set to zero.[1]

7. Salvage values of all facilities were assumed to be zero. Since there are essentially no alternative uses for most fertilizer production equipment, the zero salvage value becomes appropriate. In essence, this assumption implies that any cost involved in scrapping

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[1]The 15.0 per cent return on new investment was selected to allow for the risk associated with such ventures. The 15.0 per cent plus the 10.0 per cent depreciation approximates the often expressed rule of thumb in manufacturing industries of not making an investment unless it could be expected to be "paid off" within four years.

a facility is just offset by the sale of its components. Actual salvage values of the facilities are not known to exist. Furthermore, incorporation of non-zero salvage values would have nearly doubled the size of the model, which already had 771 rows and 2,654 columns. The effect of this assumption is to allow facilities to sit idle without imposing a maintenance cost for such idleness. However, as pointed out under assumption two, an idle facility was assumed to physically deteriorate at twice the rate of one that is utilized.

8. For existing facilities not in Michigan it is assumed that the maximum amount they could supply to Michigan is the greater of their level of supply under the 1970 Actual or Constrained Optimum organizations. That is, for supplying fertilizer to Michigan, those existing facilities outside the state could not supply more than that quantity supplied under either 1970 Actual or Constrained Optimum. This was done to approximate the current situation and establish an upper limit on existing facilities.

9. Specific products would not be forced into production after Year 0. That is, 1970 Actual (Year 0) would be the only year in the transition in which specific products would have forced production. Thereafter, only N, P_2O_5, and K_2O levels would be forced. In Year 1, Constrained Optimum production of products would be limited to those technologies and facilities currently in existence; therefore, capacity constraints were used during Year 1 to limit production to the existing capacities.

10. The "demand" for N, P_2O_5, and K_2O were maintained at the 1970 levels of consumption. This was done to serve as a basis for comparison among the various stages of transition.

11. It is assumed that there is no effective capital rationing, either internal or external to the firm. In other words, the necessary investment funds are assumed to be available regardless of the desired quantity. This assumption may not be very realistic, but it allows us to determine the amount of investment that should be made to minimize total cost.

Procedure

As previously mentioned, the 1970 Actual organization is used as the point of departure for tracing the transition to the long run optimal industry organization. Furthermore, the first year was assumed to be utilized to make the appropriate organizational changes necessary to be consistent with the Constrained Optimum organization. Thus, the capacity constraints necessary to make the first year's transition are exactly those of Constrained Optimum (Appendix E, Table E-1). The constraints on non-existing facilities were all set equal to zero for this first year of transition. The non-zero capacity constraints in Table E-1 were derived after a careful study of the existing facilities in Michigan.[2]

The Constraints to be used for the second year of transition were derived by applying assumptions 2 and 8. Some example calculations will aid in understanding the procedure. The constraint for Year 2 for Gulf Coast production of anhydrous ammonia by the centrif-

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[2]See Bell, <u>et al</u>., for a thorough description of the Michigan fertilizer industry.

ugal process (Appendix E, Table E-2) was obtained as follows: since this particular facility was used in both 1970 Actual and Constrained Optimum, the maximum of either 60 per cent of its level of use in 1970 Actual or 80 per cent of its level of use in Constrained Optimum was the constraint value used for the second year. From Appendix A, Table A-2, we see that this facility was used at a level of 73,033 tons under 1970 Actual; whereas, 80,308 tons were processed through it under the Constrained Optimum organization. Clearly, 80 per cent of the latter figure (64,846) is greater than 60 per cent of the former (43,820). Thus, 64,846 tons is the constraint for the facility in question for the second year. In the case of non-pressure nitrogen solutions produced in the Midwest (Appendix A, Table A-6), the level of use under the 1970 Actual organization is 40,912 tons; whereas, the facility was idle under the Constrained Optimum organization. Consequently, a reduction in potential capacity of 60 per cent was made (20 per cent for going from 1970 Actual to Constrained Optimum plus 40 per cent for being idle under Constrained Optimum). This left only 40 per cent of 40,912, or 16,365 tons, as the capacity for the second transition year (Appendix E, Table E-2).

The constraints for the third year were made in a similar manner, except that 90 per cent of the capacity of the facilities purchased during the second year (using assumption number 4) was added to the new capacity calculation, reflecting an additional year of physical deterioration (Appendix E, Table E-3). This procedure was repeated to establish the capacity constraints for the ensuing years (Appendix E, Tables E-4 through E-6). When all of the currently existing facilities were fully deteriorated, the process was halted.

After the transition to Year 1 and prior to that of Year 2, the ratio constraints were removed from all facilities. That is, the constraints utilized under the first transition (to Constrained Optimum) to maintain a constant ratio of production between specific facilities (e.g., NH_3 production in the Midwest and Gulf Coast), for the purposes of simulating reality, were removed prior to making the transition to Year 2. They were no longer needed, since, beginning with the transition to Year 2, new facilities could be purchased; whereas, previously the purchase activity was not allowed.

Since the return on investment on new facilities is set at 15.0 per cent, it is necessary to compare the transition organizations with a variation of Optimum that embodies a higher rate than the 7.5 per cent imposed on it. The results obtained in the previous chapter when return on investment was greater than 10.7 per cent in the long run are exactly what we need for a basis of comparison. Actually the facilities used are the same whether comparison is made to Optimum with 7.5 or 20.0 per cent return on investment, but there is a small change in the relative levels of the various facilities. Therefore, the column headed by "20.0% to 10.8%" in all the tables of Appendix D should be referred to if the specific quantities of each facility are desired; otherwise, reference can be made to Optimum in Appendix A when comparing the transitional organizations to the desired long run optimal organization of the industry.

The Transition

The complete transition will be discussed year by year. First, those activities affected will be analyzed, then a cost analysis will be undertaken. In the next section, the costs will be related to the needed investment and potential savings.

Year 0 to Year 1

During the first year of transition (from 1970 Actual to Constrained Optimum), numerous changes in the organization of the industry were realized. Sixteen products made during Year 0 were not made during Year 1 (Appendix A, Table A-1). In addition, seven other products decreased in the level of their supply to Michigan; whereas, seven products increased in the level of their utilization.

In the anhydrous ammonia sector, Gulf Coast and Midwest production declined slightly; whereas, Michigan production increased more than one-third (Appendix A, Table A-2). Most notable was the complete shut down of the Gulf Coast piston type production for Michigan consumption and the more than doubled use of direct application of NH_3. Year 0 utilized only 62,082 tons of NH_3 for direct application, while Year 1 used 128,338 tons. The use of direct application of anhydrous ammonia as a primary source of nitrogen in Year 1 caused aqueous ammonia, non-pressure nitrogen solutions, low-pressure nitrogen solutions and urea (all of which are nitrogen products) to no longer be utilized. Anhydrous ammonia, being extremely high in nitrogen content, 82.2 per cent N, makes it a very economical source of nitrogen relative to the other products mentioned.

Nitric acid production dropped nearly 50,000 tons during the transition to Year 1. The impetus for this decrease came solely from the reduction of ammonium nitrate (Appendix A, Tables A-4 and A-5). Prior to the transition, ammonium nitrate was being used in the production of nitrogen manufacturing solutions, low and non-pressure nitrogen solutions, and granulated mixed and dry blended fertilizers. In addition, 27,704 tons were used for direct application. During Year 1, however, it was used only for the production of nitrogen manufacturing solutions which were eventually used to make granulated mixed fertilizer. Furthermore, ammonium nitrate was not used for direct application during Year 1.

The major portion of nitrogen manufacturing solutions production switched from the Midwest to the Gulf Coast as a consequence of the reorganization in the NH_3 sector (Appendix A, Tables A-1 and A-8). Year 1 had over 80 per cent of the Midwest NH_3 going directly to the farms; whereas Year 0 had none. The production constraints of Year 0 forced most NH_3 to be used for the production of products that were consumed in 1970, but are sub-optimal given the organization and capacities of the existing facilities.[3] Therefore, when these constraints were removed for making the transition to Year 1, those sub-optimal products were replaced with ones that are more economical. As a result, the NH_3 produced in the Midwest was no longer needed for Midwest and Michigan producers of those sub-optimal products, and it could then flow directly to the farms. Similarly, production of sub-optimal products at the Gulf Coast and Florida, using Gulf Coast NH_3, ceased upon the removal of the aforementioned product constraints. Thus, NH_3 was available at the Gulf Coast to produce the nitrogen manufacturing solutions that had previously been produced in the Midwest.

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[3]See assumption number nine.

The trade-offs between shipping NH_3 from the Gulf Coast through the retailer and then to the farm for direct application, shipping NH_3 directly from the Midwest NH_3 producer to the farms, and production and shipment of nitrogen manufacturing solutions in the Midwest and Gulf Coast to the Michigan granulated mixed fertilizer producers are such that they favor production of a majority of nitrogen manufacturing solutions at the Gulf Coast (Appendix A, Table A-8).

The production of elemental phosphorus during Year 0 was abandoned in Year 1. Elemental phosphorus was used in the production of white phosphoric acid in Michigan which in turn was used by the Central Michigan diammonium phosphate producer. Reduction of granulated mixed fertilizer production during Year 1 resulted in a shut-down of the Central Michigan diammonium phosphate producer, thereby indirectly eliminating elemental phosphorus production. Elemental phosphorus was also used for producing superphosphoric acid in the Midwest. This acid was used in the production of ammoniated polyphosphate liquids, which became sub-optimal in Year 1. Consequently, elemental phosphorus and white and super-phosphoric acids were not produced in Year 1 (Appendix A, Tables A-11, A-12, and A-14).

Normal superphosphate, which is only 20 per cent P_2O_5, was replaced in Year 1 by monoammonium phosphate as a source of P_2O_5 in granulated mixed and dry blended fertilizers (Appendix A, Table A-17). The extremely high analysis of monoammonium phosphate, 13 per cent nitrogen and 52 per cent P_2O_5, makes the use of normal superphosphate uneconomical. Similarly, monoammonium phosphate replaced a major portion of diammonium phosphate for use in granulated mixed and dry blended fertilizers (Appendix A, Tables A-20 and A-21). In the transition from Year 0 to Year 1, production of monoammonium phosphate increased from 26,244 to 99,910 tons, while diammonium phosphate production decreased from 105,205 to 77,810 tons (Appendix A, Table A-1).

Green phosphoric acid became the sole source of phosphate during Year 1. In Year 0, phosphate was supplied by green, white, and superphoric acids. In Year 1, however, the latter two acids gave way to an increase in production of green phosphoric acid from 195,455 to 236,748 tons (Appendix A, Tables A-1, A-12, A-13, and A-14).

The continued use of granulated triple superphosphate in dry blended fertilizers was its only utilization in Year 1; whereas, it had been used for direct application in addition to blending in Year 0 (Appendix A, Table A-19). Run-of-pile triple superphosphate, used to make granulated triple superphosphate, decreased slightly from 138,945 to 115,303 tons in Years 0 and 1, respectively. Much of the decrease is the result of decreased granulated mixed fertilizer production from 388,555 to 303,655 tons (Appendix A, Tables A-1, A-27, and A-28). In addition, however, some of the decreased usage of run-of-pile triple superphosphate is the direct result of decreased usage of granular triple super-phosphate, which is made from run-of-pile (Appendix A, Table A-18).

In the potash sector, the major change that occurred as a result of the transition from Year 0 to Year 1 is the increased usage of granular potassium chloride. Increases in dry blended fertilizer's usage of it are responsible for this reaction (Appendix A, Tables A-1 and A-25). Although dry blended fertilizer production decreased in total volume produced from 203,213 to 185,535 tons, the average potassium content obviously increased, since more potassium is going into fewer tons of blended fertilizer. Similarly, run-of-mine potassium chloride usage in granulated mixed fertilizers increased, although the latter decreased. Other notable changes in the potash sector of the industry include the abandonment of direct application of granular and coarse potassium chloride.

Bagged fertilizers were not used at all in Year 1; whereas, 208,617 tons were supplied in Year 0. This tonnage was composed of 155,400 tons of granulated mixed fertilizers and 53,217 tons of dry blended fertilizers (Appendix A, Tables A-27 and A-29). The elimination of bagged fertilizer is consistent with the current trend toward bulk material. The small farmer would probably rely on custom application service rather than purchase application and handling equipment.

Implications of the First Transition Step

The transition from Year 0 to Year 1 has significant implications for various groups participating in the industry. The following paragraphs will point out some of the anticipated problems associated with this first step of the transition.

A total of 16 products that were produced in Year 0 are not produced in Year 1. For the farmer, adjusting to new products could present some problems. For example, none of the fertilizer produced in Year 1 reaches the farm in a liquid state (excluding anhydrous ammonia). If a farmer was previously using liquid fertilizer, his fertilizer application equipment would no longer be useful. Furthermore, he would need to either buy or borrow dry bulk application equipment or make arrangements for custom application. Thus, some farmers would find they would be paying more for application of fertilizer, but the reduction in cost of the fertilizer material should easily offset it.

In addition to the change in product form, the farmer will need to become acquainted with new products. Although the industry is not producing any new products, many farmers will be using a fertilizer material that they had not previously encountered. In Year 0 there were 19 basic products being applied on the farm; whereas in Year 1 there were only three distinct products being applied (counting all bulk and custom blend products as a single product). Thus, a farmer that was previously using urea as a direct application source of nitrogen will need to become acquainted with anhydrous ammonia. These two products differ not only in physical form but in their nitrogen content.

Another problem directly affecting farmers is that of distribution. The industry organization in Year 1 would likely have fewer firms supplying fertilizer to farmers. Consequently, each farmer might not be able to get his fertilizer exactly when he wants it, since each firm would be serving more farmers.

Most firms in the industry are going to be hesitant to switch to the organization of Year 1. They will most likely want to continue operating those facilities that produce suboptimal products such as urea or liquid mixes. If farmers are sufficiently informed (probably by an extension program) about the potential cost savings of the Year 1 products, then those firms that continue to operate facilities producing suboptimal products will quickly learn that they no longer have a market for those products. Consequently, they would not be able to recover even their variable costs and would find it unprofitable to continue production.

On the other hand, those firms that would stand to increase their production such as anhydrous ammonia or green phosphoric acid, would readily support a switch to the industry organization of Year 1. Their total sales would increase and it is likely they could also increase their profit, but these producers would not be without problems. In Year 0, nearly 74 per cent of all fertilizer production flowed through retailers; whereas, in Year 1 this figure dropped to less than 6.5 per cent. A major portion of the retailing function was absorbed by these producers, while some of it was taken on by dry mixers. Thus, these producers could not only increase their total production but they could also provide additional services with their product.

The fertilizer retailer is affected very significantly. All dry and liquid retailers are idled by the transition from Year 0 to Year 1. In addition, the anhydrous ammonia retailer decreases his activity by more than 25 per cent. No longer can the farmer rely on his neighborhood fertilizer retailer to supply the products and services he desires. Instead, the farmer will find it necessary to transact his business with the regionally located producer or mixer. This could have some undesirable income redistribution effects on small agricultural communities.

The transportation associated with fertilizer products will be affected in three basic ways. First, the change in product forms (elimination of liquids, etc.) will affect the type of transporting vehicle required. Secondly, the average distance of a typical haul to a farm will be increased, since the local retailers have been essentially eliminated. Thirdly, the total volume hauled will be nearly 20 per cent less in Year 1 as compared to Year 0. This last factor arises from an increase in average total analysis from 49.9 per cent to 62.2 per cent (Appendix A, Table A-32), while total nutrient tonnage remained constant; in dry blended products, over 15,000 tons of limestone filler were eliminated.

The most significant implication of the first step of the transition is the reduction in total cost (this will be discussed in greater detail later). Total expenditures for fertilizer (including transportation and application) would be about 18 million dollars (or about 26 per cent) less in Year 1 than in Year 0. This savings, if passed on, would be a welcome break for farmers who have been faced with increasing input prices in recent years; fertilizer prices, however, have been stable or declining in recent years.

The remaining steps of the transition have important implications for investment decision making; but, first, let's examine those steps.

Year 1 to Year 2

The transition to Year 2 marked the beginning of the purchasing of new facilities. At the same time, the capacity constraints on existing facilities were updated to reflect physical deterioration. Table E-2 of Appendix E shows the updated constraints, the level of use of old facilities, purchases of new facilities in tonnage capacity, and total utilization for each constrained facility. The only constraints omitted from Appendix E are those used to prevent the purchase of facilities that are not in the long run Optimum organization.

A comparison of Table F-1 and Table A-1, in Appendices F and A, respectively, shows that nearly the same products were used in Year 2 as in Year 1 (Constrained Optimum). The noticeable exceptions are elemental phosphorus and white phosphoric acid. In addition, coarse potassium chloride was used in Year 2.

The utilization of these products with interest on investment at zero per cent (assumption number 4), while they were not used in Optimum with interest on investment at 7.5 per cent, suggests that they are just barely sub-optimal in the long run. On the other hand, they were not optimal in the short run with interest on investment at 7.5 per cent, but when their interest is dropped to zero, they become optimal, given they exist and other facilities are charged 15.0 per cent on investment.

Anhydrous ammonia underwent considerable change during the transition to Year 2. The most noticeable change was the purchase of 86,244 tons of NH_3 productive capacity in Central Michigan (Appendix F, Table F-2). Additional productive capacity was purchased on the Gulf Coast; the existing 64,246 tons of capacity were supplemented with the purchase of 10,522 tons of new capacity. Meanwhile, 11,315 tons of NH_3 were produced in the Midwest, all of which was produced with existing facilities. Interestingly enough, not all of the available capacity at the Midwest NH_3 manufacturer was utilized. Less than one-third of the available 36,140 tons of capacity were used (Appendix E, Table E-2). The implication is that Gulf Coast and Central Michigan NH_3 production are cheaper than the Midwest production for NH_3 uses, other than direct application and production of nitrogen manufacturing solutions, nitric acid, and ammonium nitrate, which are all used directly or indirectly by the granulated mixed fertilizer producer. This is true even when the Midwest producer is not charged for interest on investment and the other two are each charged 15.0 per cent. If this were not true, then all of the capacity in the Midwest would have been utilized; whereas, sufficient capacity was used to produce NH_3 for some direct application and production of nitric acid, ammonium nitrate, and nitrogen manufacturing solutions, while the remainder of the capacity was left idle.

A factor of prime importance that enters into the explanation of the idle NH_3 capacity in the Midwest is that of nitrogen storage. As you will recall, the model forces 50 per cent of each nutrient to be stored. In Year 2, all of the available NH_3 storage capacity at the Midwest and Gulf Coast producers was utilized. In addition, 19,972 tons of NH_3 storage were purchased at the Central Michigan NH_3 manufacturer, which was the only location NH_3 storage could be purchased as a consequence of assumption number seven. Exactly all of the NH_3 produced in the Midwest that is used for direct application is stored at the manufacturer; no other NH_3 is stored there. Consequently, direct application of NH_3 from the Midwest manufacturer is optimal only if storage can be used without paying a charge for capital investment. For example, the model would have allowed full use of the available NH_3 productive capacity in the Midwest and correspondingly lower new production capacity in Central Michigan, with the same level of NH_3 storage at the Central Michigan manufacturer. That is, production of 36,431 tons of NH_3 in the Midwest (25,116 tons more than optimally produced there) and production of 25,116 <u>fewer</u> tons in Central Michigan (61,128 tons of NH_3 at the new manufacturer) could have taken place. Storage at the Central Michigan manufacturer could still have been 19,972 tons, which would imply that a larger percentage of Central Michigan and smaller percentage of Midwest production would have been stored. Although this solution would have had less new investment on which to pay interest charges (since fewer tons of new NH_3 production capacity would have been purchased at Central Michigan), the solution with higher interest costs was cheaper. The explanation of this seemingly paradoxical situation is that transportation from the Midwest is more expensive than from Central Michigan to the farms. The NH_3 was railed at a cost of $9.80 per ton (Henderson, et al.) from the Midwest manufacturer to the Michigan terminal. From there the transportation cost by truck to the farms is exactly the same as it is from the Central Michigan NH_3 manufacturer. Consequently, the optimal organization utilizes all the cheap storage at the Midwest manufacturer and then avoids the $9.80 extra transportation charge.

Another interesting phenomenon occurred in Year 2. The available capacity of piston compressor type NH_3 production for Michigan consumption was diverted from the Gulf Coast producer to other areas, and the Central Michigan producer was idled. A total of 41,274 tons of capacity were idled or diverted, while new centrifugal compressors were purchased at both locations. This implies that the piston compressors are not economically competitive with the centrifugal compressors, even when they are given the advantage of zero return on investment. This indicates that the centrifugal compressor technology is much more efficient in its utilization of non-investment factors. Furthermore, it is even cheaper to pay for transportation of NH_3 from the Gulf Coast to Michigan than to utilize the existing piston type NH_3 production technology in Michigan. Thus, investment plus transportation charges would not prevent the centrifugal type technology from replacing the piston type.

A service activity that is not used in the long run Optimum organization, but is used during the transition, is the no-store option at the Michigan terminal. Years 0 and 1 both used the anhydrous ammonia retailer as a means of transferring from one transportation mode to another; however, Year 2 uses the Michigan terminal for this function. No product is stored in either case. The terminal was selected as having minimal cost, even though the retailer was not charged with interest on investment. Since the transportation transfer is a service, it, like transportation, does not incur investment charges.

Although neither nitric acid nor ammonium nitrate utilize their full available capacity during Year 2, they are directly linked with the Midwest nitrogen manufacturing solutions producers which operate at full capacity (Appendix E, Table E-2, and Appendix F, Tables F-3, F-4, and F-5). While the Midwest nitrogen manufacturing solutions producer is at full capacity, the Gulf Coast producer is not used at all. This creates excess capacity in the nitric acid and ammonium nitrate sectors of the industry. Furthermore, ammonium nitrate is no longer used either for direct application or in dry blended fertilizers, thereby creating additional excess capacity on the Gulf Coast and in the Midwest in the ammonium nitrate and nitric acid sectors.

Directly connected with these three sectors (viz., nitric acid, ammonium nitrate, and nitrogen manufacturing solutions) is the granulated mixed fertilizer producer. It is difficult to determine whether the shut down of the outstate Michigan granulator caused the excess capacity in the three mentioned sectors, or whether the causal relationship is in the opposite direction. Regardless of the direction of causality, all four sectors possess excess capacity. Granulation of mixed fertilizers has 104,147 tons of excess capacity as a result of the transition from Year 1 to Year 2, while nitric acid, ammonium nitrate, and nitrogen manufacturing solutions have 30,752; 40,197; and 11,053 tons of excess capacity, respectively (Appendices E and F, Tables E-2, F-1, F-3, F-4, F-5, and F-15).

Non-pressure and low-pressure nitrogen solutions and urea are all unused during Year 2. Their idled capacities are 16,365; 11,268; and 20,802 annual tons, respectively (Appendix E, Table E-2). Their idleness is a continuation of the trend established in Constrained Optimum (Year 1). All three are products currently used in considerable quantities in Michigan, but they become sub-optimal when they no longer have forced production.

White phosphoric acid is used to its full existing capacity, while elemental phosphorus, which is used in the production of white acid, is just slightly below its constrained capacity. Elemental phosphorus production used 1,591 of the available 1,602 tons of capacity, while production of white phosphoric acid was 6,746 tons in Year 2 (Appendices E and F, Tables E-2, F-6, and F-7).

Green phosphoric acid, on the other hand, utilized its full capacity in Florida and purchased an additional 111,918 tons of annual capacity, making total production in Florida 242,603 tons. Although 58,714 tons of available capacity exist in the Midwest, none of it was used. This idle capacity in the Midwest is largely a result of the idleness of the major phosphate product manufacturers there. Diammonium and monoammonium phosphate have idle capacities of 10,582 and 13,588 annual tons, respectively, in the Midwest. In Florida, however, all diammonium capacity is utilized and monoammonium production was augmented with the purchase of 103,980 tons of annual capacity (Appendices E and F, Tables E-2, F-8, F-10, and F-11). In addition, granulated triple superphosphate has 15,959 tons of idle capacity in Florida, and run-of-pile triple superphosphate has 53,019 tons idled in the Midwest.

These idle tonnages are caused largely by the changes in granulated mixed and dry blended fertilizers. The former decreased from 272,000 to 245,699 annual tons. Furthermore, the change in dry blending formulations was such that no diammonium phosphate was used in Year 2 in blended fertilizers; on the other hand, monoammonium phosphate supplied all the phosphate for blended products during that same year. In addition granular triple superphosphate, that was blended in a custom blend fertilizer in Year 1, is not used for blending during Year 2.

Direct application of diammonium phosphate (Appendix F, Table F-10) amounted to 35,386 tons in Year 2; whereas it was not applied directly in any of the preceeding years. The zero investment charges for its production make it rather economical, but not to the extent that additional blending facilities would be purchased to maintain the formulation which had previously used it.

Although diammonium facilities were left idle in the Midwest, production of it for direct application was undertaken in the existing facilities in Florida, where cheaper anhydrous ammonia is available (from the centrifugal compressor on the Gulf Coast) and green phosphoric acid is produced. It is less expensive to ship the relatively high analysis diammonium phosphate (18-46-0) from Florida to Michigan than it is to ship anhydrous ammonia from the Gulf Coast and green phosphoric acid from Florida. Alternatively, the existing green acid and piston compressor NH_3 manufacturers in the Midwest could have supplied the production inputs to the idled Midwest diammonium phosphate producer, but this, too, was more expensive than the optimal scheme.

Similarly, monoammonium phosphate was produced in Florida with existing and new facilities despite the existence of the available input and processing facilities in the Midwest. Again the combination of cheaper inputs and less transportation expenditures resulted in idle facilities in the Midwest.

In the potassium sector of the industry, standard potassium chloride was not used; this continued the trend established after Year 0. Standard potassium chloride (in Year 0) was originally used to make clear mixed liquid fertilizers; however, the removal of their forcing constraints rendered them suboptimal.

Coarse potassium is still used for direct application. Its original 50,000 tons of capacity were reduced to 20,000 tons, because this potash product was not used during Year 1 (Appendices A and F, Tables A-1 and F-14).

Run-of-mine potassium chloride used only part of its 97,170 tons of existing capacity. Its decrease is due primarily to the decreased production of granulated mixed fertilizers. In Year 2, granulators used 59,323 tons of this potash product; whereas, in Year 1 they used 121,462 tons annually.

Dry blending of fertilizer used only 113,390 tons of granular potassium chloride in Year 2; whereas, 137,590 tons were used for the same process in Year 1. Furthermore, the amount of granular potassium chloride per ton of blended fertilizer decreased from 50.58 per cent in Year 1 to 46.15 per cent. At the same time, however, total granular production increased by 42,114 tons, while 69,632 tons of new production capacity were purchased. Direct application, not previously used, accounted for 66,314 tons of the 179,704 tons of total production. Similar to anhydrous ammonia, granular potassium chloride, destined for direct application, changed transportation modes at the Michigan terminal (Appendix F, Table F-13).

Dry blending fertilizer production, while down slightly from the previous year, obtained 44,099 tons of new capacity in outstate Michigan. At the same time, the 16,000 tons of available capacity at Central Michigan were left idle (Appendices E and F, Tables E-2 and F-16). In addition to the new production facilities purchased in outstate Michigan, 22,050 tons of new retailing capacity were purchased to supplement the existing 100,800 tons.

The major facilities purchased for use during Year 2 include: 86,244 tons of centrifugal compressor capacity to produce NH_3 in Central Michigan; 111,918 tons of green phosphoric acid capacity in Florida; 103,980 tons of monoammonium phosphate production in Florida; 69,632 tons of granular potassium chloride facilities in Saskatoon; and the outstate Michigan purchase of 44,099 annual tons of dry blending capability. These five new facilities should be given highest priority if a transformation of the fertilizer industry is to be made. On the other hand, facilities such as the piston technology for producing NH_3, the production of urea, ammoniated polyphosphate liquids and granular triple superphosphate should be among the first ones to be scrapped.

The general trend of the transition has been established; the ensuing years will continually bring the organization of the fertilizer industry closer to the long run optimal organization.

<u>Year 2 to 3</u>

The products produced in Year 3 are exactly the same as those supplied during the previous year (Appendix F, Table F-1); only the quantities varied.

An increasingly larger share of total anhydrous ammonia production is produced at Central Michigan. In Year 2, 50.0 per cent was produced there; while in Year 3 the 96,721 tons produced there accounted for 56.1 per cent of the total NH_3 produced to supply Michigan with nitrogen. At the same time, Midwest and Gulf Coast production continued to decrease, despite the fact that 10,044 tons of new capacity were purchased on the Gulf Coast (Appendix F, Table F-2).

Direct application of NH_3 increased slightly to 127,764 tons with 95,852 tons coming from Central Michigan. The remaining 869 tons of Central Michigan NH_3 production went into the production of diammonium phosphate.

The Gulf Coast NH_3 manufacturers continued to supply the Midwest nitric acid, ammonium nitrate, and nitrogen manufacturing solutions producers. These three Midwest producers continued to decrease in volume of production, with the pace determined by the constraint on nitrogen manufacturing solutions. The other two had excess capacity (Appendices E and F, Tables E-3, F-3, F-4, and F-5).

Elemental phosphorus and white phosphoric acid were again utilized to the constraint established for white acid (Appendix E, Table E-3). Total production of white acid was 3,373 tons during Year 3 in which 795 tons of elemental phosphorus were used. Since phosphoric acid is the sole source of phosphate for fertilizer manufacturing, the decrease in production of white acid necessarily implies increased production of green acid, given constant demand for phosphate. Consequently, total green phosphoric acid increased by 7,085 tons, from 242,603 tons in Year 2 to 249,688 tons in Year 3 (Appendix F, Table F-8).

Run-of-pile triple superphosphate production was again at its limiting constraint in Florida, but was considerably below the constraint on Midwest production. Just as in the previous year, the total production of run-of-pile triple superphosphate was utilized by the granulated mixed fertilizer producers (Appendix F, Table F-9).

The continued decrease in granulated mixed fertilizer production was responsible for much of the decreased production of diammonium phosphate. In addition, direct application dropped by nearly 9,000 tons, leaving total production of diammonium phosphate at 42,709 tons for Year 3 (Appendix F, Tables F-1 and F-10).

In Year 3, 57,732 tons of new productive capacity of monoammonium phosphate were purchased in Florida to augment the existing 143,338 tons of capacity. This resulted in an increase of over 30,000 tons of production of which nearly all went to dry blended fertilizer production (Appendix F, Table F-11). About 23 per cent of the total production, 45,690 tons, went to the farms for direct application. This figure marks an increase of over 7,500 tons for this same procedure in the previous year.

The potash sector of the industry experienced the same types of changes as in the previous year. Run-of-mine and coarse potassium chloride continued to decrease in utilization, while 64,246 tons of new capacity of granular potassium chloride were purchased in Saskatoon. The decrease in coarse was forced by the capacity limitation; whereas, the decrease in run-of-mine production was induced by the decreased production of granular mixed fertilizers. Increases in dry blending usage of granular potassium chloride, supplemented by increased direct application, were responsible for the nearly 30,000 ton increase in its production (Appendices E and F, Tables E-3, F-12, F-13, and F-14).

Dry blended fertilizer production increased by more than 40,000 tons annually. To the existing 190,889 tons of utilized capacity, 97,654 tons of new capacity were added. The Central Michigan blending facilities remained idle, as they were in the previous year (Appendix E, Table E-3). Nearly 50,000 tons of retailing capacity were purchased, bringing the total retailing capacity to 144,271 tons (Appendix F, Table F-16).

Year 3 was highlighted by increased purchases of those facilities required to supplement the existing ones in minimizing the total cost of supplying fertilizer to Michigan. Additional NH_3 productive capability was built in Central Michigan and on the Gulf Coast. Green phosphoric acid and monoammonium phosphate facilities were augmented in Florida, and granular potassium chloride production in Saskatoon received increased capacity. The trade-off between increased dry blending and decreased granular mixing was largely responsible for the decline or rise of particular products. In addition, the reduced capacity constraints forced decreased production of some products.

Year 3 to 4

The transition to Year 4 brought the transformation of the industry considerably closer to the long run optimal organization. Three products that are sub-optimal in the long run became sub-optimal in Year 4; elemental phosphorus, white phosphoric acid, and coarse potassium chloride were not produced. In addition, several other products were nearly phased out.

None of the original piston compressor technology for production of anhydrous ammonia existed in Year 4. At the same time, centrifugal compression technology was continuing to increase in Central Michigan. During Year 4, 21,012 tons of new capacity were purchased in Michigan. This brought the total capacity there to 107,198 annual tons, all of which was used to supply NH_3 for direct application. In addition 11,050 tons of NH_3 capacity were purchased on the Gulf Coast, bringing the total capacity there to 60,630 tons (Appendices E and F, Tables E-4 and F-1). The Midwest NH_3 manufacturer continued to operate well below his capacity in Michigan, direct application of NH_3 continued to rise slowly despite the decreased contributions of the Gulf Coast and Midwest producers.

Year 4 will be the last for nitric acid, ammonium nitrate, and nitrogen manufacturing solutions, since they have reached the end of their deterioration schedule. Their levels of utilization are 1,716; 2,243; and 3,213 tons, respectively. Once again, the nitrogen manufacturing solutions constraint is the limiting one; the other two products have excess capacity (Appendices E and F, Tables E-4, F-3, F-4, and F-5).

Green phosphoric acid has completely replaced white phosphoric acid. Total green acid production in Year 4 was 256,774 tons, of which 56,044 tons was newly purchased. Over 99.67 per cent of all green acid produced in Florida during Year 4 is used in Florida to make phosphate products. The other four-tenths of one per cent is shipped to the Midwest to be made into run-of-pile triple superphosphate (Appendix F, Tables F-8 and F-9).

Diammonium phosphate production in Florida dropped to 25,833 tons, while the Central Michigan plant was completely shut-down. Of the total production, 17,924 tons, or nearly 70 per cent, were shipped to Michigan to be applied directly. The remaining 7,909 tons went to the Central Michigan granulated mixed fertilizer manufacturer.

The 63,510 tons of new monoammonium phosphate capacity in Florida brought the total up to 231,823 and resulted in more than a 30,000 ton increase in total capacity, as compared to Year 3 (Appendix F, Table F-11). Direct application increased by nearly 8,000 tons, while dry blended fertilizer's consumption of monoammonium phosphate increased more than 22,000 tons to a total of 178,459 tons annually. New storage facilities with 39,846 were purchased for the Florida manufacturer to make total storage capability 133,844 tons.

Coarse potassium chloride production fell to zero during Year 4 as a result of the deterioration scheme. Run-of-mine potash was supplied to granulated mixed fertilizer producers in the amount of 19,772 tons. The other potash product, granular potassium chloride, necessarily picked up the slack left by coarse and run-of-mine, since K_2O demand was held constant. New capacity of 70,678 tons augmented the existing 168,563 tons to make total annual capacity 259,006 tons (Appendix F, Tables F-12, F-13, and F-14). To the existing storage capability of 86,318 tons, 43,217 tons of new storage facilities were added. Direct application of granular potassium chloride increased nearly 10,000 tons from 76,307 tons in Year 3 to 86,300 tons in Year 4. Dry blended fertilizers used 152,941 tons during Year 4; this amount is over 59 per cent of the total production.

Granulated mixed fertilizer production for Year 4 was 49,431 tons, which is less than half of the 100,000 ton capacity constraint (Appendix E, Table E-4). Dry blended fertilizers continued to replace granulated mixed products as production of the former increased almost 43,000 tons, and the latter's production decreased more than 49,000 tons (Appendix F, Table F-1).

Year 4 purchases of new dry blending capacity were 107,432 tons, all of which were located in outstate Michigan. Total blending capacity for the year was 331,400 tons. The Central Michigan dry blended fertilizer manufacturer was phased out by the deterioration schedule; consequently, all blending capacity was in outstate Michigan. Nearly 60,000 tons of new retailing facilities were purchased to supplement the existing 128,041 tons (Appendix F, Table F-16).

In Year 4, additional purchases of new facilities and reduction or total elimination of other facilities brought the transition of the industry very near to the long run optimal organization. Those facilities that are not in the long run optimal organization but were still used in Year 4 are all in the last year of their deterioration schedule, except for the anhydrous ammonia producer in the Midwest.

Significant purchases of new facilities were made during the year. Most notable were the 24,692 tons of NH_3 production capacity in Central Michigan; the 56,044 tons of green phosphoric acid and the

63,510 tons of monoammonium phosphate capacity in Florida; the 70,678 tons of granular potassium chloride production facilities in Saskatoon; and finally the installation of 107,432 tons of dry blending capacity in outstate Michigan.

Three major products were phased out during the year, namely, elemental phosphorus, white phosphoric acid, and coarse potassium chloride.

The transition to Year 5 will nearly complete the transformation of the fertilizer industry.

Year 4 to 5

From the standpoint of products supplied, Year 5 is identical to the long run optimal organization of the industry. However, the facilities used to supply those products differ slightly from those composing the long run Optimum. The anhydrous ammonia and dry blending sectors of the industry are the only ones in which the facilities are not equivalent to those used in the optimal long run organization.

The continued use of the Midwest anhydrous ammonia manufacturing facilities caused the Year 5 organization to differ from the long run optimal organization. Although 9,035 tons of capacity were available there, only 1,529 tons were produced (Appendix E, Table E-5). This production, combined with the 41,407 and 94,562 tons of existing capacity at the Gulf Coast and in Central Michigan, respectively, and supplemented by the 10,574 and 24,691 tons of new capacity purchased at the Gulf Coast and in Michigan, respectively, brought total production up to 172,763 annual tons (Appendix F, Tables F-1 and F-2). The small volume of production by the Midwest producer just fully utilized his available storage capacity. In previous years, a portion of his production was converted into nitric acid, ammonium nitrate, and nitrogen manufacturing solutions, the remainder being shipped to Michigan for direct application. However, in Year 5, the three mentioned processors were phased out, leaving only direct application to utilize his production. Just as in the previous year, all of the NH_3 manufactured by the Central Michigan plant went for direct application. In addition, 9,108 tons of the Gulf Coast's production were applied directly, making a total of 129,890 tons of NH_3 used for direct application by Michigan farmers (Appendix F, Table F-2).

Nitric acid, ammonium nitrate, and nitrogen manufacturing solutions were among the seven products and processes that were used in Year 4, but were phased out in Year 5. The others in the group were: run-of-pile triple superphosphate, diammonium phosphate, run-of-mine potassium chloride, and granulated mixed fertilizer production (Appendix F, Table F-1).

Green phosphoric acid production increased slightly from the previous year's level of 256,774 to 260,487 tons. All of the production, of which 58,275 tons were from new facilities, took place in Florida. In Year 4, 822 tons were shipped to the Midwest manufacturer of run-of-pile triple superphosphate. However, in Year 5, the phase out of that Midwestern manufacturer freed all green acid to be made into monoammonium phosphate in Florida (Appendix F, Table F-8).

Replacing both run-of-pile triple superphosphate and diammonium phosphate, monoammonium phosphate production spurted upward by nearly 40,000 tons. Total production in Year 5 was 270,495 tons, of which 201,530 tons were used in dry blended fertilizer production and the remaining 68,965 tons went for direct application. The existing 192,716 tons of productive capability were supplemented with 77,779 tons of newly purchased capacity (Appendix F, Table F-11).

In Year 5, the only source of K_2O was granular potassium chloride. Its total production for the year was 259,006 tons, of which dry blended fertilizer took 172,713 tons and direct application accounted for the remaining 86,293 tons. New purchases of production capacity of 67,739 annual tons augmented the existing 191,267 tons of capacity in Saskatoon (Appendix F, Table F-13).

With a jump in total production of nearly 43,000 tons, dry blending of fertilizers replaced most of the foregone granulated mixed production of the previous year. All of the 374,243 tons of total production were produced in outstate Michigan. Existing facilities with a total capacity of 256,081 tons were supplemented with the purchase of 118,162 tons of new capacity. In addition to the 128,041 tons of existing dry blended retailing facilities, 59,081 tons of new retailing capacity were purchased in Year 5 (Appendix F, Table F-16).

The continued use of the horizontal dry blending plant in outstate Michigan (Appendix F, Table F-16) and the Midwest anhydrous ammonia manufacturer were the only two exceptions in which the facilities of Year 5 differed from those of the long run optimal organization (Appendix D). In all other sectors of the industry, the purchases of new facilities when combined with the existing facilities exactly duplicated those utilized in the long run optimal organization.

In the next section we will see which purchases of new facilities are necessary to complete the transition. Then, attention will be focused on the costs of supplying fertilizer to Michigan in each of the transitional years and on how they compare to the 1970 Actual and the long run optimal organizations.

Year 5 to 6

The transition to Year 6 completes the transformation of the industry into an organization that supplies Michigan farmers with the 1970 levels of consumption of N, P_2O_5, and K_2O at the least possible cost, given current feasible technology.

In order to complete the transformation, 25,741 tons of anhydrous ammonia capacity were purchased in Central Michigan and 11,172 tons were purchased on the Gulf Coast. Although the total levels of production at the two locations are somewhat different than they were in Year 5, the total production of NH_3 is exactly the same (Appendix F, Tables F-1 and F-2). In addition, the flow of anhydrous ammonia to direct application and other uses is at the same tonnage levels of the previous year; however, the sources are somewhat different.

The 60,390 tons of new green phosphoric acid production capacity purchased in Florida just off-set the deterioration of the existing facilities to yield the same level of total production as in Year 5 (Appendix F, Table F-8). All of the 260,487 tons of green acid production went to the Florida monoammonium phosphate manufacturer.

Nearly 47,000 tons of new monoammonium phosphate productive capacity were necessary to offset the deterioration of the existing facilities. Total production remained constant as did the distribution between dry blending and direct application (Appendix F, Table F-11).

Similarly, 54,747 tons of new granular potassium chloride capacity were purchased in Saskatoon to maintain a constant level of production. With the distribution equivalent to that of the previous year, dry blending used 172,713 tons of K_2O and direct application accounted for 86,293 tons (Appendix F, Table F-13).

The transition to Year 6 resulted in elimination of the horizontal dry blender in outstate Michigan. To compensate for its previous production and deterioration in existing vertical blenders, 87,134 tons of new vertical blending facilities were purchased in outstate Michigan (Appendix F, Table F-16). In addition, 43,567 tons of retailing facilities were purchased to accompany the 143,555 tons of existing retailing capacity. Total dry blending remained constant at 374,243 annual tons.

Relatively few organizational changes were made in the transition from Year 5 to Year 6. Elimination of the Midwest anhydrous ammonia manufacturer and the horizontal dry blended fertilzier producer were the two major changes that took place during the transition. Some accompanying minor changes were needed to adjust the flow of the NH_3 as a consequence of the phase-out of the Midwest producer. Otherwise, the production and distribution of all other products were exactly the same as in the previous year.

Having completed the transition, let's examine the implications of its final steps.

<u>Implications for Years 2 through 6</u>

New investment in centrifugal type anhydrous ammonia production facilities is very important. Although piston type production capability was available, it was left idle in Year 2 while over 85,000 tons of new centrifugal production were purchased in Michigan. For the Michigan NH_3 producer, the implication is that his current technology is clearly inefficient as compared to the centrifugal technology. From the standpoint of minimizing total cost to Michigan farmers the obsolete piston technology should be replaced with centrifugal technology, given the assumptions of the model. Even from the standpoint of the NH_3 firm, the total cost of production with the centrifugal technology (including 15 per cent return on investment) is less than just the variable costs of the piston technology, and would indicate that the cost minimizing procedure would be to purchase the centrifugal technology. The assumption concerning zero salvage values is crucial in this case, but it seems to be an appropriate assumption. If the salvage value should happen to be negative, then the centrifugal technology might not be competitive. However, it is more reasonable that the salvage value of the old (piston) technology would be either zero or positive, in which case the centrifugal technology is clearly more efficient. Thus, the NH_3 producers should willingly support the switch to centrifugal technology.

For several of the other products involved in the transition, the purchase of production facilities to either replace an obsolete technology (as was the case with anhydrous ammonia) or to replace an inefficient product, is based upon essentially the same economic criteria presented above. For some products, it is clear that the total cost per nutrient ton of the new production facilities (including 15 per cent return on investment) exceeds the variable cost of the product being replaced. This is true, for example, in the case of the large <u>horizontal</u> bulk blender in outstate Michigan. In

Year 0 and Year 1, there were no vertical bulk blenders in outstate Michigan; all of the large blenders there were of the horizontal type. In the long run Optimum organization, all bulk blenders are of the vertical type; consequently, it was the only type allowed to be purchased during the transition, while the horizontal ones were being phased out. Since existing facilities had their fixed cost set to zero, the total cost of the horizontal blender per ton was exactly that of its variable costs plus depreciation; whereas, the vertical blenders had a total fixed cost equivalent to 15 per cent of the investment cost. That the horizontal blenders total cost was less per ton than that of the vertical blender (with fixed costs) is evident from noting that the horizontal blender was always used to its full capacity and then additional blending capacity was obtained by purchasing some vertical blenders. If the vertical blender had the lowest cost, the horizontal blenders would have sat idle, but this was not the case. We can conclude from this that some of the products and/or technologies that are sub-optimal in the long run can be quite competitive during the transition.

From the preceeding discussion we can infer several things about the transition. In cases similar to the NH_3 example in which the new technology or product is clearly more efficient than that which it replaces, firms in the industry would likely invest in it quite rapidly, thereby bringing about the realization of a portion of the long run optimum organization in a period of time that would probably be shorter than the 6 year transition presented above. At the same time, however, some products or technologies (such as the case of the bulk blenders) will not readily attract new investment. The transition for these products or technologies would likely evolve at the same rate as the attrition of old plants and, therefore, could be somewhat slower than the transition prescribed above. Of course, the extent to which the various products and processes are interdependent could effect the realized rate of the transition.

It is interesting to note that on an industry basis, there is sufficient cost savings generated by the transition to pay for the new investment for the following year. But it is not likely that such cost savings could be actually realized by individual firms, within the industry, except to the extent that the savings are generated by that same firm.

The substantial cost savings of the completed transition could be partially retained by the firms within the industry to reflect an equitable return on their investment and the remainder could be passed on to the farmer. The reduction in cost to farmers could result in an increase in fertilizer usage in Michigan. Recall that the transition outlined above was made under the assumption that the quantity of N, P_2O_5, and K_2O demanded each year is constant. Subsequent analysis with projected increases in the three nutrients revealed that the transition would be essentially identical to the one outlined here, except that the levels of purchases of new facilities would be changed slightly, while the products and facilities in the transition and in the long run optimum industry organization would be the same. The N, P_2O_5 and K_2O demands were increased by making simple straight-line projections to the year 1975. The levels of N, P_2O_5, and K_2O resulting from the projections were 191,622, 160,650 and 198,276 annual tons, respectively. The total cost for the production of these nutrient levels was just under \$60 million, including processing, transportation, storage, marketing, application, etc. Although the total cost increased about \$12 million over that of constant nutrient demand, the same types of facilities were selected by the model to minimize the total cost of supplying fertilizer to Michigan. Thus, changing the demand to reflect a simple linear growth in nutrient consumption did not affect the long run industry organization, except for increased total cost and proportional increases in the level of operation of those facilities in Optimum.

The following section analyzes in detail the potential cost savings as well as the investment requirements of the transition outlined above.

Costs, Investment, and Potential Savings

Costs and Potential Savings

If that portion of the fertilizer industry serving Michigan were to be transformed as outlined above, then the total cost of supplying fertilizer to Michigan farmers would be substantially reduced. The 1970 Actual organization which is equivalent to Year 0 in the transition, resulted in a total cost of \$71,445,667 (Table IV-1). Evolving the industry to Year 1, which is equivalent to Constrained Optimum, would allow the industry to supply Michigan's 1970 levels of consumption for \$52,555,247. This is a reduction in total cost of 26.44 per cent. If the industry passed the cost reduction on to the farmers, the cost per nutrient ton would fall from \$163.11 to \$119.98, which would save Michigan farmers \$18,890,420 (Table IV-1) on the total nutrient tonnage of 438,023 (Appendix F, Table F-1).

A significantly larger cost reduction would be realized if the

Table IV-1. Cost data for the transition years

Year	Total Cost (dollars)	Reduction in Cost[a] (dollars)	% Reduction in Cost[b] (per cent)	Cost/Nutrient Ton[c] (dollars)
0[d]	71,445,667	-0-	-0-	163.11
1[e]	52,555,247	18,890,420	26.44	119.98
2	48,490,653	22,955,014	32.13	110.70
3	47,292,651	24,153,016	33.91	107.97
4	47,168,520	24,277,147	33.98	107.69
5	47,019,035	24,426,632	34.19	107.34
6	46,754,220	24,691,447	34.56	106.74

[a]Total cost of Year 0 less the total cost for the year in question.

[b]Reduction in cost for the year in question as a per cent of the total cost of Year 0.

[c]Total cost for the year in question divided by total nutrient tons (438,023).

[d]Equivalent to 1970 Actual.

[e]Equivalent to Constrained Optimum.

transition were made to Year 2. The total cost for this particular organization is $48,490,653, which is 32.13 per cent less than that of Year 0. The potential savings is $22,955,014 when compared to Year 0 and $4,064,594 when compared to Year 1.

The total cost continued to drop as additional years of transition are made. Total cost figures for Year's 3, 4, 5, and 6 are $47,292,651; $47,168,520; $47,019,035, and $46,754,220, respectively (Table IV-1). At the same time, the potential savings continues to climb until it reaches $24,691,447 in Year 6, which corresponds to a reduction in total cost of 34.56 per cent. Meanwhile, the cost per nutrient ton fell from $163.11 in Year 0 to $106.74 in Year 6. Consequently, transforming the industry such that it would be comparable to the long run optimal organization involves the creation of very significant potential cost reductions. However, to achieve those reductions, the industry would need to make rather large investments in new facilities.

Investments

The 1970 Actual (Year 0) organization of the industry involves $75,456,505 of capital investment. If the industry would switch to the Constrained Optimum (Year 1) organization, the investment figure drops to $41,546,854, all of which is old (existing) facilities. This implies a reduction of nearly 34 million dollars in needed investment, or equivalently, a reduction of nearly 45 per cent (Table IV-2), which would be a capital loss to the owners of these facilities.

Making the transition to Year 2 would involve $14,082,255 of new investment, which is 38.01 per cent of the $37,048,229 of total invest-

Table IV-2. Investment data for the transition years

Year	Old Investment (dollars)	New Investment (dollars)	Total Investment (dollars)	Per cent new investment[a] (per cent)	% Reduction in Total Investment (per cent)
0[b]	75,456,505	-0-	75,456,505	-0-	-0-
1[c]	41,546,854	-0-	41,546,854	-0-	44.94
2	22,965,974	14,082,255	37,048,229	38.01	50.90
3	29,209,945	7,717,540	36,927,485	20.80	51.06
4	28,316,817	8,489,941	36,806,758	23.07	51.22
5	27,681,253	9,177,625	36,858,878	24.80	51.15
6	28,903,472	8,029,326	36,932,798	21.74	51.05

[a]New investment as a per cent of total investment.

[b]Equivalent to 1970 Actual.

[c]Equivalent to Constrained Optimum.

ment used that year. This total is 50.90 per cent less than that of Year 0 (Table IV-2). After Year 2, the first year new investment purchases were allowed, the amount of new investment levels off to average about 8.4 million dollars annually throughout the remainder of the transition. Similarly, the total investment during the last four years of transition levels off to average about 36.9 million dollars per year, or about 51 per cent less than the total investment of Year 0. As a per cent of total investment, the new investment of the last four years averages about 22.6 per cent.

Summary

We have seen that a complete transformation of the organization of the fertilizer industry could result in almost a 25 million dollar reduction in the total cost of supplying Michigan farmers with the levels of N, P_2O_5, and K_2O they purchased in 1970.

At the end of the six-year transition, the total cost of supplying N, P_2O_5, and K_2O to Michigan would be $46,754,220 annually, or about 34.56 per cent less than the current total cost. During the six-year transition, about 47.5 million dollars of new investment would be required, while the total cost savings would amount to nearly 139.4 million dollars, as compared with maintaining the current total cost throughout the transition.

Anhydrous ammonia production in Central Michigan, green potassium chloride facilities in Saskatoon, and dry blended fertilizer production facilities in outstate Michigan are the major new investment items. On the other hand, facilities such as the piston compressor technology for producing NH_3, the production of urea, ammoniated phosphate liquids and granular triple superphosphate are among the facilities that first become idle.

Changing the "demand" to approximate a five year growth in nutrient consumption, similar to that of the last five years (1965 to 1970), did not result in any changes in the mix of facilities selected to minimize total cost.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The fertilizer industry has been plagued with very low returns on investment in recent years. Total productive capacity was about 61 per cent greater than estimated domestic consumption in 1970, which is largely the cause of the low returns. Not only is productive capacity greater than consumption, but the growth rates of these two in recent years have added to the disparity. That is, growth of capacity has exceeded growth in consumption such that the amount of excess capacity has continued to grow.

In 1970, over 645 thousand man-hours of labor were used to manufacture and process Michigan's fertilizer consumption. With labor priced near \$4.00 per man-hour, the total expenditure for labor exceeds 2.5 million dollars. In 1967, the value added per man-hour in manufacturing fertilizers in the U.S. was \$13.49, while that of all manufacturing was \$9.41. Thus, labor is an important factor in the production of fertilizer.

Information as to how the optimal short and long run organizations of the industry are affected by changes in the wage rate and return on investment can be used to help the industry evolve to an organization utilizing less labor and investment, and resulting in lower total cost, yet supplying the same levels of N, P_2O_5, and K_2O

to the Michigan farms. In addition, information concerning the required levels of new investment needed each year to transform the industry into a more efficient (same output of nutrients for less cost) organization is useful in determining whether internal and external capital rationing will affect the transformation.

This study analyzed the effects of wage rates and return on investment on the short run and long run least cost organizations of the industry. To analyze these effects, a large linear programming model was used that had been constructed for a more encompassing study of the fertilizer industry. Within the framework of this model, the industry as it serves Michigan was simulated. A short run optimal organization (Constrained Optimum) that utilized only existing facilities was determined. Similarly, a long run optimal organization (Optimum) was determined that was constrained only by existing feasible technology and nutrient demands.

The simulation of the industry was used as a benchmark for comparison with the two optimal organizations. Wage rates and return on investment were parameterized separately to determine what effects they had on the Optimum and Constrained Optimum (from the standpoint of minimum cost) organizations.

Finally, the transition of the industry from its current organization to the long run optimal organization was mapped out to ascertain the intermediate optimal structure of the industry and the needed annual investment to complete the transformation.

The short run optimal organization of the fertilizer industry is insensitive to changes in the wage rate over the range from \$3.00 to \$6.50 per man-hour. Despite the fact that within this range the total cost of labor changed by nearly 1.6 million dollars and the wage bill approached 5.5 per cent of the total cost, the minimum cost organization did not change.

In the long run, however, changes in the wage rate did affect the optimal industry organization, but only to a minor extent. The effects of changes in the wage rate in the long run are felt primarily by the dry blended fertilizer producers. When the wage rate changed from \$3.50 to \$3.75 per man-hour, there was a decrease of 18,557 man-hours. Offsetting this decreased production of dry blended fertilizers, direct application of granular potassium chloride increased by nearly 60,000 tons per year.

The long run optimal organization of the industry remained stable as the wage rate was ranged from \$3.75 to \$4.75 per man-hour, inclusive. However, when the rate was raised to \$5.00, a change similar to that noted above occurred. This time, however, the decrease in labor utilization by dry blended fertilizer producers was 21,785 man-hours. At the same time, direct application of monoammonium phosphate was initiated at an annual level of 68,965 tons. No other changes occurred when the wage rate was raised to the maximum examined level of \$6.50 per man-hour.

More important implications than those resulting from wage rate changes are evident for the fertilizer industry laborer when investigating a change in the industry organization from that of the current structure to the long run optimal organization. Such a shift in industry organization would eliminate nearly 42 per cent of the fertilizer industry employees engaged in supplying Michigan with fertilizer. This sounds rather drastic; however, only 135 fewer employees would be needed, which is only about one-half of one per cent of the total employees in the U.S. fertilizer industry. On the other hand, reorganization of the entire industry could have a substantial impact on national unemployment.

The Constrained Optimum and Optimum organizations were very nearly optimal throughout the range of rates of return on investment examined. For rates of return less than 12.0 per cent, Constrained Optimum is suboptimal by less than one-tenth of one per cent of the total cost of the optimal organization; moreover, it is the optimal short run organization for rates of return between 6.0 and 12.0 per cent. Despite a considerably large number of changes in the optimal organization for returns less than 6.0 per cent, Constrained Optimum was just barely suboptimal in terms of total cost.

Similarly, Optimum was quite close in terms of total cost to the optimal long run organizations for the range of rates of return on investment examined. Maintaining the Optimum organization in the long run regardless of the return on investment would mean that, at the very worst, less than $0.13 per nutrient ton in potential cost savings would be foregone. This is very insignificant when compared with the potential $57.66 per nutrient ton that Optimum could save Michigan farmers when compared with the 1970 Actual organization.

A transformation from the current industry organization to the Optimum solution of industry organization would save Michigan farmers over 23 million dollars or about 32 per cent of the current total cost of N, P_2O_5, and K_2O consumed in Michigan. Among the new facilities needed to complete the transition are centrifugal compressor type anhydrous ammonia production facilities in central Michigan and additional dry blended fertilizer processing facilities in outstate Michigan.

Conclusions

The overall objective of this study has been to analyze the Constrained Optimum and Optimum industry organizations and to determine an optimal transition from the current industry organization to Optimum. Prior to and during the transition, assuming it is to be implemented, two important concepts should be kept in mind. These two concepts will be briefly discussed, after which specific conclusions will be listed.

There are many aspects of the transition that will need to be explained to all industry participants in educational programs before it will be readily accepted. Agricultural extension personnel will need to explain the cost saving advantages of the optimal products to farmers and farm managers. As mentioned previously, farmer acceptance of these optimal products is very crucial to successfully realizing the transition. In addition, extension personnel will need to help farmers currently using liquid products to make the conversion to dry product handling and application equipment.

Further educational efforts will be needed to insure proper coordination of the new marketing and merchandizing plans that will be used under the Optimum organization. Additional educational programs will be necessary to inform fertilizer producers of the advantages to them that the new industry arrangement affords; moreover, the producers and processors will need information on how and when they should make new investments and/or scrap old technology or facilities. Thus, there is a large educational effort that is a necessary part of the transition.

The second concept is that of farm policy. The decreased cost of fertilizer to farmers will likely mean that they will use more of it, thereby increasing total production. Given the inelastic demand for farm production, Michigan farmers would likely receive a lower total income. This assumes that the increased production does in fact have a downward influence on prices farmers receive. It's possible that the increased production in Michigan would have a negligible effect on price. Those persons involved in making farm policy should, however, be made aware of the potential effect of increased output.

The following specific conclusions can be drawn from this study:

1. The Constrained Optimum organization of the fertilizer industry can be used as a short run target towards which industry participants can set their sights. Its stability when confronted with fluctuations in the wage rate, its proximity to optimality throughout a wide range of returns on investment and its significant cost reduction over 1970 actual suggests that it is a desirable short term goal.

2. Changes in the wage rate in the short run, within the limits studied, should not be the sole impetus for changing to a technology not represented in Constrained Optimum. The fact that labor utilization was constant for wage rates from \$3.00 to \$6.50 per man-hour suggests that those technologies utilized in the Constrained Optimum organization use labor efficiently.

3. The Constrained Optimum organization can be considered as the short run optimal organization for returns on investment from -2.0

to 12.0 per cent, inclusive; actually, it is suboptimal for returns between -2.0 and 5.9 per cent, inclusive, but the difference is less than one-tenth of one per cent of the total cost of the optimal organization. Therefore, if management received an equitable return on investment there would be essentially no effect on the short run optimal organization of the industry, given returns on investment below 12.0 per cent.

4. The nitrogen segment of the industry is the most sensitive to changes in the variables studied. In particular, anhydrous ammonia is nearly always affected in one way or another; this is largely due to the fact that it is the primary source of nitrogen and is used in several production processes of fertilizers that are not predominately nitrogen.

5. Investment in anhydrous ammonia facilities in Central Michigan appears to be a desirable long run venture. All of the long run analyses had a considerable amount of the total anhydrous ammonia production manufactured in Michigan.

6. Granular mixed fertilizer producers could be phased out and replaced to a large extent by lower cost dry blended fertilizer producers located in outstate Michigan. The granulators were never part of any of the long run analyses; whereas, the blenders were selected in every long run analysis to help achieve minimum cost.

7. Monoammonium phosphate appears to be slightly superior to diammonium phosphate from an economic standpoint of minimizing cost. However, it is quite possible that, given a different ratio of nitrogen to phosphate in the total demand, diammonium phosphate would appear to be superior.

8. The relative stability of Optimum, given the ranges of the variables analyzed, and the nearly 23 million dollars it could subtract from total cost suggest it should be the long term goal of the industry, if cost minimization is the objective. Moreover, Optimum's stability implies that the investments associated with it would not be made uneconomical by changes in either the wage rate or the return on investment, given the ranges examined. Therefore, there would be less risk involved in investment made in the optimum facilities. However, they could be made uneconomical by new technology.

Recommendations

The need for additional research became evident as this study progressed.

The most obvious area that needs additional research is that of the "demands" for N, P_2O_5, and K_2O. Somehow, these demands need to be better specified than the aggregations utilized in this study. The high degree of aggregation used in the long run optimal organization resulted in only three products being produced. Since all P_2O_5 was made into a 7-28-28 dry blended fertilizer, any crop requiring only P_2O_5 would necessarily get N and K_2O, given the long run minimum cost industry organization. Therefore, I would recommend specifying the N, P_2O_5, and K_2O demands in accordance with the major crops produced in Michigan. Perhaps this could be best utilized by including crop production activities with each crop represented in the model by numerous levels of fertilization. The model could then be converted such that it would maximize farm profit.

Secondly, the ever increasing excess capacity and extremely low returns on investment suggest that some in-depth research needs to be done to analyze the investment decision-making procedures utilized within the industry. It appears that the current procedures are either poor or are not used appropriately.

Thirdly, the assumptions made for the transition from 1970 Actual to Optimum concerning the rate of deterioration of existing facilities directly affects the length of time required to complete the transition. In addition, the existance of non-zero salvage values could possibly change the transition to a considerable degree. The inter-relationships of these two assumptions point out the need for basic research in these two areas. After completing such research, the transition analysis could be reconsidered.

Finally, since anhydrous ammonia is made from natural gas and since NH_3 is so important throughout the industry, fluctuations in the price of natural gas could result in changes in the optimal industry organization. In particular, variations in the price of natural gas among the three production sites embodied in the model could yield some very useful results.

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APPENDIX A

1970 Actual, Constrained Optimum, and Optimum: Data

Table A-1. Product use summary for 1970 actual, constrained optimum, and optimum (in tons)

Product	1970 actual	Constrained optimum	Optimum
Total cost (in dollars)	71,445,667	52,555,247	48,297,763
Anhydrous ammonia	164,309	171,894	172,828
Aqueous ammonia	3,897	-0-	-0-
Nitric acid	59,832	10,539	-0-
Ammonium nitrate	78,210	13,777	-0-
Nonpressure nitrogen solution	40,912	-0-	-0-
Low pressure nitrogen solution	28,171	-0-	-0-
Nitrogen manufacturing solution	16,067	19,737	-0-
Urea	52,006	-0-	-0-
Granular ammonium sulfate	35,628	-0-	-0-
Elemental phosphorous	4,004	-0-	-0-
White phosphoric acid	16,866	-0-	-0-
Green phosphoric acid	195,455	236,748	260,565
Superphosphoric acid	207	-0-	-0-
Ammonium polyphosphate liquid (10-34-0)	4,832	-0-	-0-
Ammonium polyphosphate liquid (11-37-0)	402	-0-	-0-
Normal superphosphate	53,791	-0-	-0-
Run-of-pile triple superphosphate	138,945	115,303	-0-
Granular triple superphosphate	26,598	5,274	-0-
Diammonium phosphate	105,205	77,810	-0-
Monoammonium phosphate	26,244	99,910	270,576
Rock phosphate	277	-0-	-0-
Run-of-mine potassium chloride	111,166	121,462	-0-
Standard potassium chloride	1,877	-0-	-0-
Granular potassium chloride	95,919	137,590	259,032
Coarse potassium chloride	50,000	-0-	-0-
Granulated mixed fertilizers	388,555	303,655	-0-
Bulk blended fertilizers	203,213	185,535	329,689
Custom blended fertilizers	27,785	86,465	113,600
Hot process clear mixed liquids	11,450	-0-	-0-
Cold process clear mixed liquids	7,633	-0-	-0-
Suspension liquids	-0-	-0-	-0-
N supplied	141,932	141,932	141,932
P_2O_5 supplied	140,650	140,650	140,650
K_2O supplies	155,441	155,441	155,441

Table A-2. Anhydrous ammonia product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Gulf Coast	Production	Centrifugal	---	73,033	80,308	42,886
Gulf Coast	Production	Piston	---	10,363	-0-	-0-
Midwest	Production	Centrifugal	---	46,913	45,175	-0-
Central Michigan	Production	Centrifugal	---	-0-	-0-	129,942
Central Michigan	Production	Piston	---	34,000	46,411	-0-
Gulf Coast	Mfr's. storage	Cyrogenic	---	13,189	45,540	-0-
Midwest	Mfr's. storage	Cyrogenic	---	-0-	7,647	-0-
Central Michigan	Mfr's storage	Cyrogenic	---	-0-	-0-	54,239
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	50,763	7,448	-0-
Gulf Coast	TRansportation	Barge	Florida producers[2]	19,012	27,320	42,886

Table A-2. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year 1970 actual	Constrained optimum	Optimum
Gulf Coast	Transportation	Rail	Outstate retailers	13,622	45,540	-0-
Midwest	Product transfer	On-site	Midwest producers[3]	25,946	8,788	-0-
Midwest	Transportation	Rail	Outstate processors[4]	2,157	-0-	-0-
Midwest	Transportation	Rail	Outstate retailers	18,810	-0-	-0-
Midwest	Transportation	Truck	Farms	-0-	36,387	-0-
Central Michigan	Product transfer	On-site	Michigan producers[5]	4,350	-0-	-0-
Central Michigan	Transportation	Truck	Outstate retailers	29,642	-0-	-0-
Central Michigan	Transportation	Truck	Farms	8	46,411	129,942

Table A-2. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Outstate Michigan	Retailing	---	---	62,074	45,540	-0-
Outstate retailers	Transportation	Applicator	Farms	62,074	45,540	-0-
Farms	Application	---	---	62,082	128,338	129,942

[1]Nitric acid, ammonium nitrate, nitrogen manufacturing solutions, and urea producers.

[2]Diammonium phosphate and monoammonium phosphate producers.

[3]Nitric acid, ammonium nitrate, nonpressure and low pressure nitrogen solutions, nitrogen manufacturing solutions, urea, ammoniated polyphosphates, diammonium phosphate, and monoammonium phosphate producers.

[4]Aqueous ammonia, granular mixed and liquid mixed fertilizer producers.

[5]Diammonium phosphate and granular mixed fertilizer producers.

Table A-3. Aqueous ammonia product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Outstate Michigan	Production	Ammonia converter	---	3,897	-0-	-0-
Outstate Michigan	Transportation	Rail	Outstate retailer	3,897	-0-	-0-
Outstate Michigan	Retailing	---	---	3,897	-0-	-0-
Outstage retailers	Transportation	Applicator	Farms	3,897	-0-	-0-
Farms	Application	---	---	3,897	-0-	-0-

Table A-4. Nitric acid product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Gulf Coast	Production	Medium pressure	---	41,882	7,377	-0-
Midwest	Production	Medium pressure	---	17,950	3,162	-0-
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	41,882	7,377	-0-
Midwest	Product transfer	On-site	Midwest producers[1]	17,950	3,162	-0-

[1]Ammonium nitrate producers.

Table A-5. Ammonium nitrate product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Gulf Coast	Production	Neutralization-evaporation	---	54,747	9,644	-0-
Midwest	Production	Neutralization-evaporation	---	23,463	4,133	-0-
Gulf Coast	Mfr's. storage	Bulk	---	4,879	-0-	-0-
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	-0-	9,644	-0-
Gulf Coast	Transportation	Barge	Midwest producers[2]	20,105	-0-	-0-
Gulf Coast	Transportation	Rail	Michigan producers[3]	1,027	-0-	-0-
Gulf Coast	Transportation	Rail	Outstate processors[3]	5,912	-0-	-0-
Gulf Coast	Transportation	Rail	Outstate retailers	27,704	-0-	-0-

Table A-5. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Midwest	Product transfer	On-site	Midwest producers[2]	23,463	4,133	-0-
Outstate Michigan	Retailing	---	---	27,704	-0-	-0-
Outstage retailers	Transportation	Applicators	Farms	27,704	-0-	-0-
Farms	Application	---	---	27,704	-0-	-0-

[1]Nitrogen manufacturing solutions producers.

[2]Nonpressure and low pressure nitrogen solutions and nitrogen manufacturing solutions producers.

[3]Granulated mixed and dry blended fertilizer producers.

Table A-6. Nonpressure nitrogen solutions product flow

Originating location	Activity	Type	Terminating location	Product tons per year 1970 actual	Constrained optimum	Optimum
Midwest	Production	Blending	---	40,912	-0-	-0-
Midwest	Mfr's. storage	Tank	---	40,635	-0-	-0-
Midwest	Transportation	Rail	Outstate processors[1]	1,109	-0-	-0-
Midwest	Transportation	Rail	Outstate retailers	39,803	-0-	-0-
Outstate Michigan	Retailing	---	---	39,803	-0-	-0-
Outstage retailers	Transportation	Applicators	Farms	39,803	-0-	-0-
Farms	Application	---	---	39,803	-0-	-0-

[1]Cold process liquid mixed fertilizer producers.

Table A-7. Low pressure nitrogen solutions product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Midwest	Production	Blending	---	28,171	-0-	-0-
Midwest	Mfr's. storage	Tank	---	9,472	-0-	-0-
Midwest	Transportation	Rail	Michigan producers[1]	16,260	-0-	-0-
Midwest	Transportation	Rail	Outstate processors[1]	9,756	-0-	-0-
Midwest	Transportation	Rail	Outstate retailers	2,155	-0-	-0-
Outstate Michigan	Retailing	---	---	2,155	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	2,155	-0-	-0-
Farms	Application	---	---	2,155	-0-	-0-

[1]Granulated mixed fertilizer producers.

Table A-8. Nitrogen manufacturing solutions product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Gulf Coast	Production	Blending	---	-0-	13,816	-0-
Midwest	Production	Blending	---	16,067	5,921	-0-
Gulf Coast	Mfr's. storage	Tank	---	-0-	2,616	-0-
Midwest	Mfr's. storage	Tank	---	4,519	-0-	-0-
Gulf Coast	Transportation	Rail	Michigan producers[1]	-0-	10,329	-0-
Gulf Coast	Transportation	Rail	Outstate processors[1]	-0-	3,488	-0-
Midwest	Transportation	Rail	Michigan producers[1]	10,042	5,921	-0-
Midwest	Transportation	Rail	Outstate processors[1]	6,025	-0-	-0-

[1]Granulated mixed fertilizer producers.

Table A-9. Urea product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Gulf Coast	Production	Gas separation	---	29,470	-0-	-0-
Gulf Coast	Production	Ammonium carbamate slurry	---	6,934	-0-	-0-
Gulf Coast	Production	Water absorption	---	10,401	-0-	-0-
Midwest	Production	Gas separation	---	5,201	-0-	-0-
Gulf Coast	Mfr's. storage	Bulk	---	33,878	-0-	-0-
Gulf Coast	Transportation	Barge	Midwest producers[1]	9,651	-0-	-0-
Gulf Coast	Transportation	Rail	Michigan processors[2]	1,247	-0-	-0-
Gulf Coast	Transportation	Rail	Outstate processors[2]	11,861	-0-	-0-

Table A-9. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Gulf Coast	Transportation	Rail	Outstate retailers	24,047	-0-	-0-
Midwest	Product transfer	On-site	Midwest producers[1]	5,201	-0-	-0-
Outstate Michigan	Retailing	---	---	24,047	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	24,047	-0-	-0-
Farms	Application	---	---	24,047	-0-	-0-

[1] Nonpressure nitrogen solutions producers.

[2] Granulated mixed and dry blended fertilizer producers.

Table A-10. Ammonium sulfate product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Central Michigan	Purchase	---	---	11,174	-0-	-0-
Outstate processors	Purchase	---	---	21,984	-0-	-0-
Outstate retailers	Purchase	---	---	2,470	-0-	-0-
Outstate Michigan	Retailing	---	---	2,470	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	2,470	-0-	-0-
Farms	Application	---	---	2,470	-0-	-0-

Table A-11. Elemental phosphorus product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Florida	Production	Electric furnace	---	4,004	-0-	-0-
Florida	Transportation	Barge	Midwest producers[1]	27	-0-	-0-
Florida	Transportation	Rail	Michigan producers[1]	3,977	-0-	-0-

[1]White phosphoric and superphosphoric acid producers.

Table A-12. White phosphoric acid product flow

				Product tons per year		
Originating location	Activity	Type	Terminating location	1970 actual	Constrained optimum	Optimum
Central Michigan	Production	Furnace process	---	16,866	-0-	-0-
Central Michigan	Product	On-site	Michigan producer[1]	16,866	-0-	-0-

[1]Diammonium phosphate producer.

Table A-13. Green phosphoric acid product flow

Originating location	Activity	Type	Terminating location	Product tons per year 1970 actual	Constrained optimum	Optimum
Florida	Production	Wet process	---	134,864	163,356	260,565
Midwest	Production	Wet process	---	60,591	73,392	-0-
Florida	Mfr's. storage	Rubber-lined	---	3,561	-0-	-0-
Florida	Product transfer	On-site	Florida producers[1]	134,864	163,356	260,565
Midwest	Product transfer	On-site	Midwest producers[1]	55,843	73,392	-0-
Midwest	Transportation	Rail	Outstate processors[2]	4,748	-0-	-0-

[1]Ammoniated polyphosphates, triple superphosphate, diammonium phosphate and monoammonium phosphate producers.

[2]Hot process clear mixed liquid fertilizer producers.

Table A-14. Superphosphoric acid product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Midwest	Production	Thermal	---	207	-0-	-0-
Midwest	Product transfer	On-site	Midwest producers[1]	207	-0-	-0-

[1]Ammoniated polyphosphates producers.

Table A-15. Ammoniated polyphosphate (10-34-0) product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Midwest	Production	Ammoniation	---	4,832	-0-	-0-
Midwest	Mfr's. storage	Tank	---	3,624	-0-	-0-
Midwest	Transportation	Rail	Outstate processors[1]	4,832	-0-	-0-

[1]Cold process clear mixed liquid fertilizer producers.

Table A-16. Ammoniated polyphosphate (11-37-0) product flow

Originating location	Activity	Type	Terminating location	Product tons per year 1970 actual	Constrained optimum	Optimum
Midwest	Production	Ammoniation	---	402	-0-	-0-
Midwest	Mfr's. storage	Tank	---	302	-0-	-0-
Midwest	Transportation	Rail	Outstate processors[1]	402	-0-	-0-

[1]Cold process clear mixed liquid fertilizer producers.

Table A-17. Normal superphosphate product flow

Originating location	Activity	Type	Terminating location	Product tons per year		
				1970 actual	Constrained optimum	Optimum
Florida	Production	Cone mixer	---	21,791	-0-	-0-
Central Michigan	Production	Cone mixer	---	32,000	-0-	-0-
Florida	Mfr's. storage	Bulk	---	16,660	-0-	-0-
Florida	Transportation	Rail	Outstate processors[1]	21,791	-0-	-0-
Central Michigan	Product transfer	On-site	Michigan producers[1]	31,540	-0-	-0-
Central Michigan	Transportation	Rail	Outstate processors[1]	89	-0-	-0-
Central Michigan	Transportation	Rail	Outstate retailers	371	-0-	-0-
Outstate Michigan	Retailing	---	---	371	-0-	-0-

Table A-17. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Outstate retailers	Transportation	Applicators	Farms	371	-0-	-0-
Farms	Application	---	---	371	-0-	-0-

[1]Granulated mixed and dry blended fertilizer producers.

Table A-18. Run-of-pile triple superphosphate product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Florida	Production	Cone mixer	---	83,085	44,234	-0-
Midwest	Production	Cone mixer	---	55,860	71,069	-0-
Florida	Mfr's. storage	Bulk	---	55,907	25,897	-0-
Florida	Product transfer	On-site	Florida producers[1]	27,130	5,380	-0-
Florida	Transportation	Rail	Michigan producers[2]	14,024	38,854	-0-
Florida	Transportation	Rail	Outstate processors[2]	41,930	-0-	-0-
Midwest	Transportation	Rail	Michigan producers[2]	55,860	51,646	-0-
Midwest	Transportation	Rail	Outstate processors[2]	-0-	19,423	-0-

[1]Granulated triple superphosphate producers.

[2]Granulated mixed fertilizers producers.

Table A-19. Granular triple superphosphate product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Florida	Production	Rotary drum granulator	---	26,598	5,274	-0-
Florida	Mfr's. storage	Bulk	---	17,242	3,956	-0-
Florida	Transportation	Rail	Michigan processors[1]	1,831	-0-	-0-
Florida	Transportation	Rail	Outstate processors[1]	21,159	5,274	-0-
Florida	Transportation	Rail	Outstate retailers	3,608	-0-	-0-
Outstate Michigan	Retailing	---	---	3,608	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	3,608	-0-	-0-
Farms	Application	---	---	3,608	-0-	-0-

[1]Dry blended fertilizer producers.

Table A-20. Diammonium phosphate product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Florida	Production	Slurry ammoniation	---	70,886	64,582	-0-
Midwest	Production	Slurry ammoniation	---	14,519	13,228	-0-
Central Michigan	Production	Slurry ammoniation	---	19,800	-0-	-0-
Florida	Mfr's. storage	Bulk	---	51,194	28,358	-0-
Florida	Transportation	Rail	Michigan producers[1]	-0-	26,772	-0-
Florida	Transportation	Rail	Outstate processors[1]	64,048	37,810	-0-
Florida	Transportation	Rail	Outstate retailers	6,838	-0-	-0-
Midwest	Transportation	Rail	Michigan producers[1]	14,478	13,228	-0-

Table A-20. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Midwest	Transportation	Rail	Outstate processors[1]	40	-0-	-0-
Central Michigan	Product transfer	On-site	Michigan producers[1]	19,800	-0-	-0-
Outstate Michigan	Retailing	---	---	6,838	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	6,838	-0-	-0-
Farms	Application	---	---	6,838	-0-	-0-

[1]Granulated mixed and dry blended fertilizer producers.

Table A-21. Monoammonium phosphate product flow

Originating location	Activity	Type	Terminating location	Product tons per year		
				1970 actual	Constrained optimum	Optimum
Florida	Production	Slurry ammoniation	---	21,783	82,926	270,576
Midwest	Production	Slurry ammoniation	---	4,461	16,985	-0-
Florida	Mfr's. storage	Bulk	---	17,231	74,933	202,932
Florida	Transportation	Rail	Outstate processors[1]	18,514	72,156	270,576
Florida	Transportation	Rail	Outstate retailers	3,269	-0-	-0-
Florida	Transportation	Rail	Michigan processors[1]	-0-	10,770	-0-
Midwest	Transportation	Rail	Michigan processors[1]	2,180	-0-	-0-
Midwest	Transportation	Rail	Outstate processors[1]	2,281	16,985	-0-

Table A-21. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Outstate Michigan	Retailing	---	---	3,269	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	3,269	-0-	-0-
Farms	Application	---	---	3,269	-0-	-0-

[1]Dry blended fertilizer producers.

Table A-22. Rock phosphate product flow

Originating Location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Florida	Production	Grinding	---	277	-0-	-0-
Florida	Transportation	Rail	Outstate retailers	277	-0-	-0-
Outstate Michigan	Retailing	---	---	277	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	277	-0-	-0-
Farms	Application	---	---	277	-0-	-0-

Table A-23. Run-of-mine potassium chloride product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Saskatoon	Production	Flotation	---	111,116	121,462	-0-
Saskatoon	Mfr's. storage	Bulk	---	31,265	16,096	-0-
Saskatoon	Transportation	Rail	Michigan producers[1]	69,479	100,000	-0-
Saskatoon	Transportation	Rail	Outstate processors[1]	41,687	21,462	-0-

[1]Granulated mixed fertilizer producers.

Table A-24. Standard potassium chloride product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Saskatoon	Production	Flotation	---	1,877	-0-	-0-
Saskatoon	Mfr's. storage	Bulk	---	1,407	-0-	-0-
Saskatoon	Transportation	Rail	Outstate processors[1]	1,877	-0-	-0-

[1]Hot and cold process clear mixed liquid fertilizer producers.

Table A-25. Granular potassium chloride product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Saskatoon	Production	Flotation	---	95,919	137,590	259,032
Saskatoon	Mfr's. storage	Bulk	---	62,943	103,192	129,535
Saskatoon	Transportation	Rail	Michigan terminal	-0-	-0-	86,319
Saskatoon	Transportation	Rail	Michigan processors[1]	6,321	9,230	-0-
Saskatoon	Transportation	Rail	Outstate processors[1]	77,602	128,360	172,713
Saskatoon	Transportation	Rail	Outstate retailers	11,996	-0-	-0-
Michigan terminal	Transportation	Truck	Farms	-0-	-0-	86,319
Outstate Michigan	Retailing	---	---	11,996	-0-	-0-

Table A-25. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Outstate retailers	Transportation	Applicators	Farms	11,996	-0-	-0-
Farms	Application	---	---	11,996	-0-	86,319

[1]Dry blended fertilizer producers.

Table A-26. Coarse potassium chloride product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Saskatoon	Production	Flotation	---	50,000	-0-	-0-
Saskatoon	Transportation	Rail	Outstate retailers	50,000	-0-	-0-
Outstate Michigan	Retailing	---	---	50.000	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	50,000	-0-	-0-
Farms	Application	---	---	50,000	-0-	-0-

Table A-27. Bagged granulated mixed fertilizers product flow

Originating location	Activity	Type	Terminating location	Product tons per year		
				1970 actual	Constrained optimum	Optimum
Central Michigan	Production	TVA continuous	---	97,139	-0-	-0-
Outstate Michigan	Production	TVA (30,000 TPY)	---	58,283	-0-	-0-
Central Michigan	Mfr's. storage	Bagged	---	36,427	-0-	-0-
Central Michigan	Transportation	Truck	Outstate retailers	97,117	-0-	-0-
Central Michigan	Transportation	Truck	Farms	22	-0-	-0-
Outstate producer	Transportation	Truck	Outstate retailers	58,283	-0-	-0-
Outstate Michigan	Retailing	---	---	155,400	-0-	-0-
Outstate retailers	Transportation	Wagons	Farms	155,400	-0-	-0-
Farms	Application	---	---	155,400	-0-	-0-

Table A-28. Bulk granulated mixed fertilizer product flow

				Product tons per year		
Originating location	Activity	Type	Terminating location	1970 actual	Constrained optimum	Optimum
Central Michigan	Production	TVA continuous	---	145,708	250,000	-0-
Outstate Michigan	Production	TVA continuous	---	87,425	53,655	-0-
Central Michigan	Mfr's. storage	Bulk	---	-0-	187,500	-0-
Central Michigan	Transportation	Rail	Outstate retailers	145,708	-0-	-0-
Central Michigan	Transportation	Truck	Farms	-0-	250,000	-0-
Outstate producer	Transportation	Truck	Outstate retailers	87,425	-0-	-0-
Outstate producer	Transportation	Truck	Farms	-0-	53,655	-0-
Outstate Michigan	Retailing	--	---	233,133	-0-	-0-

Table A-28. (cont'd.)

				Product tons per year		
Originating location	Activity	Type	Terminating location	1970 actual	Constrained optimum	Optimum
Outstate retailers	Transportation	Applicators	Farms	233,133	-0-	-0-
Farms	Application	---	---	233,133	3-3,655	-0-

Table A-29. Bagged blended fertilizer product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Central Michigan	Production	Horizontal w/ rotary drum	---	16,444	-0-	-0-
Outstate Michigan	Production	Horizontal (1000 TPY)	---	6,986	-0-	-0-
Outstate Michigan	Production	Horizontal (2500 TPY)	---	29,787	-0-	-0-
Central Michigan	Transportation	Truck	Outstate retailer	16,444	-0-	-0-
Outstate processors	Transportation	Wagon	Farms	36,773	-0-	-0-
Outstate Michigan	Retailing	---	---	16,444	-0-	-0-
Outstate retailer	Transportation	Wagon	Farms	16,444	-0-	-0-
Farms	Application	---	---	53,217	-0-	-0-

Table A-30. Bulk blended fertilizers product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Constrained optimum	Optimum
Central Michigan	Production	Horizontal w/ rotary drum	---	2,902	20,000	-0-
Outstate Michigan	Production	Horizontal (9000 TPY)	---	-0-	252,000	-0-
Outstate Michigan	Production	Vertical (9000 TPY)	---	-0-	-0-	443,290
Outstate Michigan	Production	Horizontal (2500 TPY)	---	141,653	-0-	-0-
Outstate Michigan	Production	Horizontal (1000 TPY)	---	33,226	-0-	-0-
Central Michigan	Transportation	Rail	Outstate retailers	2,902	-0-	-0-
Central Michigan	Transportation	Truck	Farms	-0-	20,000	-0-

Table A-30. (cont'd.)

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Outstate processors	Transportation	Truck	Satellite outlets	-0-	126,000	221,645
Outstate processors	Transportation	Applicators	Farms	178,879	126,000	221,645
Outstate Michigan	Retailing	---	---	2,902	-0-	-0-
Outstate retailers	Transportation	Applicators	Farms	2,902	-0-	-0-
Satellite outlets	Product handling	---	---	-0-	126,000	221,645
Satellite outlets	Transportation	Applicators	Farms	-0-	126,000	221,645
Farms	Application	---	---	177,781	272,000	443,290

Table A-31. Clear mixed liquid fertilizer product flow

Originating location	Activity	Type	Terminating location	Product tons per year: 1970 actual	Product tons per year: Constrained optimum	Product tons per year: Optimum
Outstate Michigan	Production	Hot process (3000 TPY)	---	11,450	-0-	-0-
Outstate Michigan	Production	Cold blend (1000 TPY)	---	7,633	-0-	-0-
Outstate processors	Transportation	Applicators	Farms	19,083	-0-	-0-
Farms	Application	---	---	19,083	-0-	-0-

Table A-32. Miscellaneous items and factor usage

Item	1970 Actual	Constrained Optimum	Optimum
Labor (man-hours)	645,405	452,182	397,545
Wage bill @ $4.00/man-hour	2,581,620	1,808,728	1,590,180
Investment capital (dollars)	75,456,505	41,546,854	37,601,696
Operating capital (dollars)	28,535,706	17,212,759	16,087,234
Interest on investment @ 7.5%	5,659,238	3,116,014	2,820,127
Limestone filler (tons)	15,482	-0-	-0-
Total fertilizer material (tons)	877,131	703,993	659,551
Average content (per cent)			
All nutrients	49.9	62.2	66.4
N	16.2	20.2	21.5
P_2O_5	16.0	20.0	21.3
K_2O	17.7	22.1	23.6
Limestone filler	1.77	-0-	-0-

APPENDIX B

Returns on Investment in the Short Run

Table B-1. Product use summary for returns on investment in the short run (in tons)

Product	Rate of return						
	20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%	4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
Anhydrous ammonia	171,894	171,894	171,894	171,894	171,894	171,974	171,974
Nitric acid	10,539	10,539	10,539	10,539	10,539	9,930	9,930
Ammonium nitrate	13,777	13,777	13,777	13,777	13,777	12,980	12,980
Nitrogen manufacturing solution	19,737	19,737	19,737	19,738	19,738	18,596	18,596
Elemental phosphorous	-0-	-0-	-0-	-0-	-0-	3,977	3,977
Green phosphoric acid	236,748	236,748	236,748	236,748	236,748	220,645	220,645
White phosphoric acid	-0-	-0-	-0-	-0-	-0-	16,866	16,866
Run-of-pile triple superphosphate	115,303	115,303	115,303	115,303	115,303	112,087	112,087
Granular triple superphosphate	5,274	5,274	5,274	5,274	5,274	8,352	8,352
Diammonium phosphate	77,810	77,810	77,810	77,810	77,810	111,857	111,857
Monoammonium phosphate	99,911	99,911	99,911	99,911	99,911	72,737	72,737
Run-of-mine potassium chloride	121,462	121,462	121,462	121,462	121,462	114,440	114,440

Table B-1. (cont'd.)

Product	Rate of return						
	20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%	4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
Granular potassium chloride	137,590	137,590	137,590	137,590	137,590	144,629	144,629
Granulated mixed fertilizers	303,655	303,655	303,655	303,655	303,655	286,099	286,099
Bulk blended fertilizers	185,535	185,535	185,535	185,535	185,535	135,075	135,075
Custom blended fertilizers	86,465	86,465	86,465	86,465	86,465	136,925	136,925
N supplied	141,932	141,932	141,932	141,932	141,932	141,932	141,932
P_2O_5 supplied	140,650	140,650	140,650	140,650	140,650	140,650	140,650
K_2O supplies	155,441	155,441	155,441	155,441	155,441	155,441	155,441

Table B-2. Anhydrous ammonia product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Gulf Coast	Production	Centrifugal	---	80,308	80,308	80,308	80,308
Midwest	Production	Centrifugal	---	45,175	45,175	45,175	45,175
Central Michigan	Production	Piston	---	46,411	46,411	46,411	46,411
Gulf Coast	Mfr's. storage	Cyrogenic	---	36,752	36,752	45,540	48,205
Midwest	Mfr's. storage	Cyrogenic	---	16,435	16,435	7,647	4,981
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	7,448	7,448	7,448	4,783
Gulf Coast	Transportation	Barge	Florida producers[2]	27,320	27,320	27,320	27,320
Gulf Coast	Transportation	Rail	Outstate retailers	-0-	-0-	45,540	48,205
Midwest	Product transfer	On-site	Midwest producers[3]	-0-	-0-	8,788	11,454
Midwest	Transportation	Truck	Farms	45,175	45,175	36,387	33,721

Table B-2. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Central Michigan	Transportation	Truck	Farms	46,411	46,411	46,411	46,411
Outstate retailers	Transportation	Applicator	Farms	-0-	-0-	45,540	48,205
Farms	Application	---	128,338	128,338	128,338	128,338	128,338
Gulf Coast	Transportation	Barge	Midwest producers[3]	8,788	8,788	-0-	-0-
Gulf Coast	Transportation	Barge	Midwest terminal	36,752	36,752	-0-	-0-
Midwest terminal	Transportation	Truck	Farms	36,752	36,752	-0-	-0-
Gulf Coast	Transportation	Rail	Michigan processors[4]	-0-	-0-	-0-	-0-

Table B-2. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Midwest	Transportation	Rail	Michigan processors[4]	-0-	-0-	-0-	-0-

Table B-2. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Gulf Coast	Production	Centrifugal	---	80,308	80,345	80,345
Midwest	Production	Centrifugal	---	45,175	45,196	45,196
Central Michigan	Production	Piston	---	46,411	46,433	46,433
Gulf Coast	Mfr's. storage	Cyrogenic	---	48,828	45,739	50,085
Midwest	Mfr's. storage	Cyrogenic	---	4,359	8,789	4,443
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	4,160	3,920	3,920
Gulf Coast	Transportation	Barge	Florida producers[2]	27,320	26,340	26,340
Gulf Coast	Transportation	Rail	Outstate retailers	48,828	45,739	50,085
Midwest	Product transfer	On-site	Midwest producers[3]	12,076	11,501	11,501
Midwest	Transportation	Truck	Farms	33,099	33,695	29,349

Table B-2. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	Rate of return: 4.1% to 2.1%	Rate of return: 2.0% to -2.0%
				Product tons per year		
Central Michigan	Transportation	Truck	Farms	46,411	46,433	46,433
Outstate retailers	Transportation	Applicator	Farms	48,828	45,739	50,085
Farms	Application	---	---	128,338	125,867	125,867
Gulf Coast	Transportation	Barge	Midwest producers[3]	-0-	-0-	-0-
Gulf Coast	Transportation	Barge	Midwest terminal	-0-	-0-	-0-
Midwest terminal	Transportation	Truck	Farms	-0-	-0-	-0-
Gulf Coast	Transportation	Rail	Michigan processors[4]	-0-	4,346	-0-
Midwest	Transportation	Rail	Michigan processors[4]	-0-	-0-	4,346

Table B-2. (cont'd.)

[1]Nitric acid, ammonium nitrate, and nitrogen manufacutring solutions producers.

[2]Diammonium and monoammonium phosphate producers.

[3]Nitric acid, ammonium nitrate, nitrogen manufacturing solutions, and diammonium and monoammonium phosphate producers.

[4]Granular mixed fertilizer producers.

Table B-3. Nitric acid product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Gulf Coast	Production	Medium pressure	---	7,377	7,377	7,377	7,377
Midwest	Production	Medium pressure	---	3,162	3,162	3,162	3,162
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	7,377	7,377	7,377	7,377
Midwest	Product transfer	On-site	Midwest producers[1]	3,162	3,162	3,162	3,162

Table B-3. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	Rate of return: 4.1% to 2.1%	Rate of return: 2.0% to -2.0%
				Product tons per year		
Gulf Coast	Production	Medium pressure	---	7,377	6,951	6,951
Midwest	Production	Medium pressure	---	3,162	2,979	2,979
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	7,377	6,951	6,951
Midwest	Product transfer	On-site	Midwest producers[1]	3,162	2,979	2,979

[1]Ammonium nitrate producers.

Table B-4. Ammonium nitrate product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Gulf Coast	Production	Neutralization evaporation	---	9,644	9,644	9,644	9,644
Midwest	Production	Neutralization evaporation	---	4,133	4,133	4,133	4,133
Gulf Coast	Product transfer	On-site	Gulf Coast producers[1]	9,644	9,644	9,644	1,826
Gulf Coast	Transportation	Barge	Midwest producers[1]	-0-	-0-	-0-	7,818
Midwest	Product transfer	On-site	Midwest producers[1]	4,133	4,133	4,133	4,133

Table B-4. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Gulf Coast	Production	Neutralization evaporation	---	9,644	9,086	9,086
Midwest	Production	Neutralization evaporation	---	4,133	3,894	3,894
Gulf Coast	Product transfer	On-site	Gulf Coast Producers[1]	-0-	-0-	-0-
Gulf Coast	Transportation	Barge	Midwest producers[1]	9,644	9,086	9,086
Midwest	Product transfer	On-site	Midwest producers[1]	4,133	3,894	3,894

[1]Nitrogen manufacturing solutions producers.

Table B-5. Nitrogen manufacturing solutions product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Gulf Coast	Production	Blending	---	13,816	13,816	13,816	2,616
Midwest	Production	Blending	---	5,921	5,921	5,921	17,122
Gulf Coast	Mfr's. storage	Tank	---	2,616	2,616	2,616	2,616
Midwest	Mfr's. storage	Tank	---	-0-	-0-	-0-	-0-
Gulf Coast	Transportation	Rail	Michigan producers[1]	10,329	10,329	10,329	-0-
Gulf Coast	Transportation	Rail	Outstate processors[1]	3,488	3,488	3,488	2,616
Midwest	Transportation	Rail	Michigan producers[1]	5,921	5,921	5,921	16,250
Midwest	Transportation	Rail	Outstate processors[1]	-0-	-0-	-0-	872

Table B-5. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.0% to 2.1%	2.0% to -2.0%
				Product tons per year		
Gulf Coast	Production	Blending	---	-0-	-0-	-0-
Midwest	Production	Blending	---	19,738	18,596	18,596
Gulf Coast	Mfr's. storage	Tank	---	-0-	-0-	-0-
Midwest	Mfr's. storage	Tank	---	2,616	1,760	1,760
Gulf Coast	Transportation	Rail	Michigan producers[1]	-0-	-0-	-0-
Gulf Coast	Transportation	Rail	Outstate processors[1]	-0-	-0-	-0-
Midwest	Transportation	Rail	Michigan producers[1]	16,250	16,250	16,250
Midwest	Transportation	Rail	Outstate processors[1]	3,488	2,346	2,346

[1]Granulated mixed fertilizer producers.

Table B-6. Elemental phosphorous product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%	4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year						
Florida	Production	Electric furnace	--	-0-	-0-	-0-	-0-	-0-	3,977	3,977
Florida	Transportation	Rail	Michigan producers[1]	-0-	-0-	-0-	-0-	-0-	3,977	3,977

[1]White phosphoric acid producers.

Table B-7. White phosphoric acid product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1% (Product tons per year)	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%	4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
Central Michigan	Production	Furnace process	---	-0-	-0-	-0-	-0-	-0-	16,866	16,866
Central Michigan	Product transfer	On-site	Michigan producers[1]	-0-	-0-	-0-	-0-	-0-	16,866	16,866

[1]Diammonium phosphate producers.

Table B-8. Green phosphoric acid product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Florida	Production	Wet process	---	163,356	163,356	163,356	163,356
Midwest	Production	Wet process	---	73,392	73,392	73,392	73,392
Florida	Product transfer	On-site	Florida producers[1]	163,356	163,356	163,356	163,356
Midwest	Product transfer	On-site	Midwest producers[1]	73,392	73,392	73,392	73,392

Table B-8. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	Rate of return: 4.1% to 2.1%	Rate of return: 2.0% to -2.0%
				Product tons per year		
Florida	Production	Wet process	---	163,356	152,245	152,245
Midwest	Production	Wet process	---	73,392	68,400	68,400
Florida	Product transfer	On-site	Florida producers[1]	163,356	152,245	152,245
Midwest	Product transfer	On-site	Midwest producers[1]	73,392	68,400	68,400

[1]Triple superphosphate, and diammonium and monoammonium phosphate producers.

Table B-9. Run-of-pile triple superphosphate product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Florida	Production	Cone mixer	---	44,234	44,234	44,234	44,234
Midwest	Production	Cone mixer	---	71,069	71,069	71,069	71,069
Florida	Mfr's. storage	Bulk	---	25,897	25,897	25,897	25,897
Florida	Product transfer	On-site	Florida producers[1]	5,380	5,380	5,380	5,380
Florida	Transportation	Rail	Michigan producers[2]	38,854	38,854	38,854	38,854
Midwest	Transportation	Rail	Michigan producers[2]	51,646	51,646	51,646	51,646
Midwest	Transportation	Rail	Outstate processors[2]	19,423	19,423	19,423	19,423

Table B-9. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Florida	Production	Cone mixer	---	44,234	45,066	45,066
Midwest	Production	Cone mixer	---	71,069	67,021	67,021
Florida	Mfr's. storage	Bulk	---	25,897	17,424	17,424
Florida	Product transfer	On-site	Florida producers[1]	5,380	8,519	8,519
Florida	Transportation	Rail	Michigan producers[2]	38,854	36,547	36,547
Midwest	Transportation	Rail	Michigan producers[2]	51,646	53,953	53,953
Midwest	Transportation	Rail	Outstate processors[2]	19,423	13,068	13,068

[1]Granulated triple superphosphate producers.

[2]Granulated mixed fertilizer producers.

Table B-10. Granular triple superphosphate product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Florida	Production	Rotary drum granulator	---	5,274	5,274	5,274	5,274
Florida	Mfr's. storage	Bulk	---	3,956	3,956	3,956	3,956
Florida	Transportation	Rail	Outstate processors[1]	5,274	5,274	5,274	5,274

Table B-10. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Florida	Production	Rotary drum granulator	---	5,274	8,352	8,352
Florida	Mfr's. storage	Bulk	---	3,956	6,264	6,264
Florida	Transportation	Rail	Outstate processors[1]	5,274	8,352	8,352

[1]Dry blended fertilizer producers.

Table B-11. Diammonium phosphate product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	Rate of return: 14.0% to 12.1%	Rate of return: 12.0% to 6.0%	Rate of return: 5.9% to 4.4%
				Product tons per year			
Florida	Production	Slurry ammoniation	---	-0-	64,582	64,582	64,582
Midwest	Production	Slurry ammoniation	---	-0-	13,228	13,228	13,228
Central Michigan	Production	Slurry ammoniation	---	-0-	-0-	-0-	-0-
Florida	Mfr's. storage	Bulk	---	28,358	28,358	28,358	28,358
Florida	Transportation	Rail	Michigan producers[1]	26,772	26,772	26,772	26,772
Florida	Transportation	Rail	Outstate processors[1]	37,810	37,810	37,810	37,810
Midwest	Transportation	Rail	Michigan producers[1]	13,228	13,228	13,228	13,228
Florida	Production	TVA process	---	64,582	-0-	-0-	-0-
Midwest	Production	TVA process	---	13,228	-0-	-0-	-0-

Table B-11. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Michigan	Transportation	Truck	Farms	-0-	-0-	-0-	-0-
Farms	Application	---	---	-0-	-0-	-0-	-0-

Table B-11. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Florida	Production	Slurry ammoniation	---	64,582	76,407	76,407
Midwest	Production	Slurry ammoniation	---	13,228	15,650	15,650
Central Michigan	Production	Slurry ammoniation	---	-0-	19,800	19,800
Florida	Mfr's. storage	Bulk	---	28,358	39,042	39,042
Florida	Transportation	Rail	Michigan producers[1]	26,772	24,350	24,350
Florida	Transportation	Rail	Outstate processors[1]	37,810	52,057	52,057
Midwest	Transportation	Rail	Michigan producers[1]	13,228	15,650	15,650
Florida	Production	TVA process	---	-0-	-0-	-0-
Midwest	Production	TVA process	---	-0-	-0-	-0-

Table B-11. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Michigan	Transportation	Truck	Farms	-0-	19,800	19,800
Farms	Application	---	---	-0-	19,800	19,800

[1]Granulated mixed and dry blended fertilizer producers.

Table B-12. Monoammonium phosphate product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Florida	Production	Slurry ammoniation	---	82,926	82,926	82,926	82,926
Midwest	Production	Slurry ammoniation	---	16,985	16,985	16,985	16,985
Florida	Mfr's. storage	Bulk	---	74,933	74,933	74,933	74,933
Florida	Transportation	Rail	Outstate processors[1]	72,156	72,156	72,156	72,156
Midwest	Transportation	Rail	Outstate processors[1]	16,985	16,985	16,985	16,985
Florida	Transportation	Rail	Michigan processors	10,770	10,770	10,770	10,770

Table B-12. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Florida	Production	Slurry ammoniation	---	82,926	60,372	60,372
Midwest	Production	Slurry ammoniation	---	16,985	12,365	12,365
Florida	Mfr's. storage	Bulk	---	74,933	54,553	54,553
Florida	Transportation	Rail	Outstate processors[1]	72,156	49,602	49,602
Midwest	Transportation	Rail	Outstate processors[1]	16,985	12,365	12,365
Florida	Transportation	Rail	Michigan processors	10,770	10,770	10,770

[1]Dry blended fertilizer producers.

Table B-13. Run-of-mine potassium chloride product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	Rate of return: 14.0% to 12.1%	Rate of return: 12.0% to 6.0%	Rate of return: 5.9% to 4.4%
				Product tons per year			
Saskatoon	Production	Flotation	---	121,462	121,462	121,462	121,462
Saskatoon	Mfr's. storage	Bulk	---	16,096	16,096	16,096	16,096
Saskatoon	Transportation	Rail	Michigan producers[1]	100,000	100,000	100,000	100,000
Saskatoon	Transportation	Rail	Outstate processors[1]	21,462	21,462	21,462	21,462

Table B-13. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Saskatoon	Production	Flotation	--	121,462	114,440	114,440
Saskatoon	Mfr's. storage	Bulk	--	16,096	10,830	10,830
Saskatoon	Transportation	Rail	Michigan producers[1]	100,000	100,000	100,000
Saskatoon	Transportation	Rail	Outstate processors[1]	21,462	14,440	14,440

[1]Granulated mixed fertilizer producers.

Table B-14. Granular potassium chloride product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Saskatoon	Production	Flotation	---	137,590	137,590	137,590	137,590
Saskatoon	Mfr's. storage	Bulk	---	103,192	103,192	103,192	103,192
Saskatoon	Transportation	Rail	Michigan processors[1]	9,230	9,230	9,230	9,230
Saskatoon	Transportation	Rail	Outstate processors[1]	128,360	128,360	128,360	128,360

Table B-14. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Saskatoon	Production	Flotation	---	137,590	144,629	144,629
Saskatoon	Mfr's. storage	Bulk	---	103,192	108,472	108,472
Saskatoon	Transportation	Rail	Michigan processors[1]	9,230	9,230	9,230
Saskatoon	Transportation	Rail	Outstate processors[1]	128,360	135,399	135,399

[1]Dry blended fertilizer producers.

Table B-15. Bulk granulated mixed fertilizer product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Central Michigan	Production	TVA continuous	---	250,000	250,000	250,000	250,000
Outstate Michigan	Production	TVA continuous	---	53,655	53,655	53,655	53,655
Central Michigan	Mfr's. storage	Bulk	---	187,500	187,500	187,500	187,500
Central Michigan	Transportation	Truck	Farms	250,000	250,000	250,000	250,000
Outstate producer	Transportation	Truck	Farms	53,655	53,655	53,655	53,655
Farms	Application	---	---	303,655	303,655	303,655	303,655

Table B-15. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return: 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Central Michigan	Production	TVA continuous	---	250,000	250,000	250,000
Outstate Michigan	Production	TVA continuous	---	53,655	36,099	36,099
Central Michigan	Mfr's. storage	Bulk	---	187,500	187,500	187,500
Central Michigan	Transportation	Truck	Farms	250,000	250,000	250,000
Outstate producer	Transportation	Truck	Farms	53,655	36,099	36,099
Farms	Application	---	---	303,655	286,099	286,099

Table B-16. Bulk blended fertilizers product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20% to 14.1%	14.0% to 12.1%	12.0% to 6.0%	5.9% to 4.4%
				Product tons per year			
Central Michigan	Production	Horizontal w/ rotary drum	---	20,000	20,000	20,000	20,000
Outstate Michigan	Production	Horizontal (9000 TPY)	---	252,000	252,000	252,000	252,000
Central Michigan	Transportation	Truck	Farms	20,000	20,000	20,000	20,000
Outstate processors	Transportation	Truck	Satellite outlets	126,000	126,000	126,000	126,000
Outstate processors	Transportation	Applicators	Farms	126,000	126,000	126,000	126,000
Satellite outlets	Product handling	---	---	126,000	126,000	126,000	126,000
Satellite outlets	Transportation	Applicators	Farms	126,000	126,000	126,000	126,000
Farms	Application	---	---	272,000	272,000	272,000	272,000

Table B-16. (cont'd.)

Originating location	Activity	Type	Terminating location	Rate of return 4.3% to 4.2%	4.1% to 2.1%	2.0% to -2.0%
				Product tons per year		
Central Michigan	Production	Horizontal w/ rotary drum	---	20,000	20,000	20,000
Outstate Michigan	Production	Horizontal (9000 TPY)	---	252,000	252,000	252,000
Central Michigan	Transportation	Truck	Farms	20,000	20,000	20,000
Outstate processors	Transportation	Truck	Satellite outlets	126,000	126,000	126,000
Outstate processors	Transportation	Applicators	Farms	126,000	126,000	126,000
Satellite outlets	Product handling	---	---	126,000	126,000	126,000
Satellite outlets	Transportation	Applicators	Farms	126,000	126,000	126,000
Farms	Application	---	---	272,000	272,000	272,000

APPENDIX C

The Labor Market and the Long Run

Table C-1. Product use summary for changes in the labor market in the long run (in tons)

Product	Wage rate $3.00 to $3.50	$3.75 to $4.75	$5.00 to $6.50
Anhydrous ammonia	172,764	172,828	172,763
Green phosphoric acid	260,492	260,565	260,487
Monoammonium phosphate	270,500	270,576	270,495
Granular potassium chloride	258,985	259,032	259,006
Bulk blended fertilizer	502,321	329,689	374,243
Custom blended fertilizer	-0-	113,601	-0-
N supplied	141,932	141,932	141,932
P_2O_5 supplied	140,650	140,650	140,650
K_2O supplied	155,441	155,441	155,441

Table C-2. Anhydrous ammonia product flow

Originating location	Activity	Type	Terminating location	Wage rate		
				$3.00 to $3.50	$3.75 to $4.75	$5.00 to $6.50
Gulf Coast	Production	Centrifugal	---	42,874	42,886	42,873
Central Michigan	Production	Centrifugal	---	129,890	129,942	129,890
Central Michigan	Mfr's. storage	Cyrogenic	---	54,248	54,239	62,429
Gulf Coast	Transportation	Barge	Florida producers[1]	42,874	42,886	42,873
Central Michigan	Transportation	Truck	Farms	129,890	129,942	129,890
Farms	Application	---	---	129,890	129,942	129,890

[1]Monoammonium phosphate producers.

Table C-3. Green phosphoric acid product flow

Originating location	Activity	Type	Terminating location	Wage rate: $3.00 to $3.50	$3.75 to $4.75	$5.00 to $6.50
Florida	Production	Wet process	---	260,492	260,565	260,487
Florida	Product transfer	On-site	Florida producers[1]	260,492	260,565	260,487

[1]Monoammonium phosphate producers.

Table C-4. Monoammonium phosphate product flow

Originating location	Activity	Type	Terminating location	Wage rate: \$3.00 to \$3.50	Wage rate: \$3.75 to \$4.75	Wage rate: \$5.00 to \$6.50
Florida	Production	Slurry ammoniation	---	270,500	270,576	270,495
Florida	Mfr's. storage	Bulk	---	202,875	202,932	151,148
Florida	Transportation	Rail	Outstate processors[1]	270,500	270,576	201,530
Farms	Application	---	---	-0-	-0-	68,965
Florida	Transportation	Rail	Michigan terminal	-0-	-0-	68,965
Michigan terminal	Transportation	Truck	Farm	-0-	-0-	68,965

[1]Dry-blended fertilizer producers.

Table C-5. Granular potassium chloride product flow

Originating location	Activity	Type	Terminating location	Wage rate $3.00 to $3.50	$3.75 to $4.75	$5.00 to $6.50
Saskatoon	Production	Flotation	---	258,985	259,032	259,006
Saskatoon	Mfr's. storage	Bulk	---	173,866	129,535	129,535
Saskatoon	Transportation	Rail	Michigan terminal	27,163	86,319	86,293
Saskatoon	Transportation	Rail	Outstate processors[1]	231,821	172,713	172,713
Michigan terminal	Transportation	Truck	Farms	27,163	86,319	86,293
Farms	Application	---	---	27,163	86,319	86,293

[1]Dry-blended fertilizer producers.

Table C-6. Bulk blended fertilizer product flow

Originating location	Activity	Type	Terminating location	Wage rate $3.00 to $3.50	Wage rate $3.75 to $4.75	Wage rate $5.00 to $6.50
Outstate Michigan	Production	Vertical (9000 TPY)	---	502,321	443,290	374,243
Outstate processors	Transportation	Truck	Satellite outlets	251,160	221,645	187,121
Outstate processors	Transportation	Applicators	Farms	251,160	221,645	187,121
Satellite outlets	Product handling	---	---	251,160	221,645	187,121
Satellite outlets	Transportation	Applicators	Farms	251,160	221,645	187,121
Farms	Application	---	---	502,321	443,290	374,243

APPENDIX D

Returns on Investment in the Long Run

Table D-1. Product use summary for returns on investment in the long run (in tons)

Product	Rate of return: 20.0% to 10.8%	10.7% to 8.0%	6.0% to -2.0%
Anhydrous ammonia	172,763	172,828	172,764
Green phosphoric acid	260,487	260,565	260,492
Monoammonium phosphate	270,495	270,576	270,500
Granular potassium chloride	259,006	259,032	258,985
Bulk blended fertilizer	374,243	329,689	502,321
Custom blended fertilizer	-0-	113,600	-0-
N supplied	141,932	141,932	141,932
P_2O_5 supplied	140,650	140,650	140,650
K_2O supplied	155,441	155,441	155,441

Table D-2. Anhydrous ammonia product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20.0% to 10.8%	Rate of return: 10.7% to 8.0%	Rate of return: 6.0% to -2.0%
				Product tons per year		
Gulf Coast	Production	Centrifugal	---	42,873	42,886	42,874
Central Michigan	Production	Centrifugal	---	129,890	129,942	129,890
Central Michigan	Mfr's. storage	Cyrogenic	---	62,429	54,239	54,248
Gulf Coast	Transportation	Barge	Florida producers[1]	42,873	42,886	42,874
Central Michigan	Transportation	Truck	Farms	129,890	129,942	129,890
Farms	Application	---	---	129,890	129,942	129,890

[1]Monoammonium phosphate producers.

Table D-3. Green phosphoric acid product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20.0% to 10.8%	Rate of return: 10.7% to 8.0%	Rate of return: 6.0% to -2.0%
				Product tons per year		
Florida	Production	Wet process	---	260,487	260,565	260,492
Florida	Product transfer	On-site	Florida producers[1]	260,487	260,565	260,492

[1]Monoammonium phosphate producers.

Table D-4. Monoammonium phosphate product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20.0% to 10.8%	10.7% to 8.0%	6.0% to -2.0%
				Product tons per year		
Florida	Production	Slurry ammoniation	---	270,495	270,576	270,500
Florida	Mfr's. storage	Bulk	---	151,148	202,932	202,875
Florida	Transportation	Rail	Outstate processors[1]	201,530	270,576	270,500
Farms	Application	---	---	68,965	-0-	-0-
Florida	Transportation	Rail	Michigan terminal	68,965	-0-	-0-
Michigan terminal	Transportation	Truck	Farms	68,965	-0-	-0-

[1]Dry blended fertilizer producers.

Table D-5. Granular potassium chloride product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20.0% to 10.8%	Rate of return: 10.7% to 8.0%	Rate of return: 6.0% to -2.0%
				Product tons per year		
Saskatoon	Production	Flotation	---	259,006	259,032	258,985
Saskatoon	Mfr's. storage	Bulk	---	129,535	129,535	173,866
Saskatoon	Transportation	Rail	Michigan terminal	86,293	86,319	27,163
Saskatoon	Transportation	Rail	Outstate processors[1]	172,713	172,713	231,821
Michigan terminal	Transportation	Truck	Farms	86,293	86,319	27,163
Farms	Application	---	---	86,293	86,319	27,163

[1]Dry blended fertilizer producers.

Table D-6. Bulk blended fertilizers product flow

Originating location	Activity	Type	Terminating location	Rate of return: 20.0% to 10.8%	Rate of return: 10.7% to 8.0%	Rate of return: 6.0% to -2.0%
				Product tons per year		
Outstate Michigan	Production	Vertical (9000 TPY)	---	374,243	443,290	502,321
Outstate processors	Transportation	Truck	Satellite outlets	187,122	221,645	251,161
Outstate processors	Transportation	Applicators	Farms	187,122	221,645	251,161
Satellite outlets	Product handling	---	---	187,122	221,645	251,161
Satellite outlets	Transportation	Applicators	Farms	187,121	221,645	251,161
Farms	Application	---	---	374,243	443,290	502,321

APPENDIX E

Transition Constraints

Table E-1. Transition constraints and levels of utilization for Year 1 (in tons)

Product	Location	Activity	Type	Constraint[a]	Level
Anhydrous ammonia	Gulf Coast	Production	Centrifugal	none	80,308
Anhydrous ammonia	Gulf Coast	Production	Piston	none	-0-
Anhydrous ammonia	Midwest	Production	Centrifugal	none	45,175
Anhydrous ammonia	Central Michigan	Production	Centrifugal	-0-	-0-
Anhydrous ammonia	Central Michigan	Production	Piston	68,000	46,411
Anhydrous ammonia	Gulf Coast	Mfr's. storage	Cyrogenic	none	45,540
Anhydrous ammonia	Midwest	Mfr's. storage	Cyrogenic	none	7,647
Anhydrous ammonia	Central Michigan	Mfr's. storage	Cyrogenic	-0-	-0-
Nitric acid	Gulf Coast	Production	Medium pressure	none	7,377
Nitric acid	Midwest	Production	Medium pressure	none	3,162

Table E-1. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Level
Ammonium nitrate	Gulf Coast	Production	Neutralization evaporation	none	9,644
Ammonium nitrate	Midwest	Production	Neutralization evaporation	none	4,133
Ammonium nitrate	Gulf Coast	Mfr's. storage	Bulk	none	-0-
Non-pressure N-solution	Midwest	Production	Blending	none	-0-
Non-pressure N-solution	Midwest	Mfr's. storage	Tank	none	-0-
Low-pressure N-solution	Midwest	Production	Blending	none	-0-
Low-pressure N-solution	Midwest	Mfr's. storage	Tank	none	-0-
N-mfg. solution	Gulf Coast	Production	Blending	none	13,816
N-mfg. solution	Midwest	Production	Blending	none	5,921

Table E-1. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Level
N-mfg. solution	Gulf Coast	Mfr's. storage	Tank	none	2,616
N-mfg. solution	Midwest	Mfr's. storage	Tank	none	-0-
Urea	Gulf Coast	Production	Gas separation	none	-0-
Urea	Gulf Coast	Production	Ammonium carbamate slurry	none	-0-
Urea	Gulf Coast	Production	Water absorption	none	-0-
Urea	Midwest	Production	Gas separation	none	-0-
Urea	Gulf Coast	Mfr's. storage	Bulk	none	-0-
Elemental phosphorus	Florida	Production	Electric furnace	none	-0-
White phosphoric acid	Central Michigan	Production	Furnace process	121,900	-0-
Green phosphoric acid	Florida	Production	Wet process	none	163,356

Table E-1. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Level
Green phosphoric acid	Midwest	Production	Wet process	none	73,392
Green phosphoric acid	Florida	Mfr's. storage	Rubber-lined	none	-0-
10-34-0[b]	Midwest	Production	Ammoniation	none	-0-
10-34-0[b]	Midwest	Mfr's. storage	Tank	none	-0-
11-37-0[c]	Midwest	Production	Ammoniation	none	-0-
11-37-0[c]	Midwest	Mfr's. storage	Tank	none	-0-
NSP[d]	Florida	Production	Cone mixer	none	-0-
NSP[d]	Central Michigan	Production	Cone mixer	32,000	-0-
NSP[d]	Florida	Mfr's. storage	Bulk	none	-0-
R-O-P TSP[e]	Florida	Production	Cone mixer	none	44,234
R-O-P TSP[e]	Midwest	Production	Cone mixer	none	71,069

Table E-1. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Level
R-O-P TSP[e]	Florida	Mfr's. storage	Bulk	none	25,897
Granular TSP[f]	Florida	Production	Rotary drum granulator	none	5,274
Granular TSP[f]	Florida	Mfr's. storage	Bulk	none	3,956
Diammonium phosphate	Florida	Production	Slurry ammoniation	none	64,582
Diammonium phosphate	Midwest	Production	Slurry ammoniation	none	13,228
Diammonium phosphate	Central Michigan	Production	Slurry ammoniation	19,800	-0-
Diammonium phosphate	Florida	Mfr's. storage	Bulk	none	28,358
Monoammonium phosphate	Florida	Production	Slurry ammoniation	none	82,926
Monoammonium phosphate	Midwest	Production	Slurry ammoniation	none	16,985

Table E-1. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Level
Monoammonium phosphate	Florida	Mfr's. storage	Bulk	none	74,933
Rock phosphate	Florida	Production	Grinding	none	-0-
Super phosphoric acid	Midwest	Production	Thermal	none	-0-
R-O-M KCL[g]	Saskatoon	Production	Flotation	none	121,462
R-O-M KCL[g]	Saskatoon	Mfr's. storage	Bulk	none	16,096
STD. KCL[h]	Saskatoon	Production	Flotation	none	-0-
STD. KCL[h]	Saskatoon	Mfr's.	Bulk	none	-0-
Gran. KCL[i]	Saskatoon	Production	Flotation	none	137,590
Gran. KCL[i]	Saskatoon	Mfr's. storage	Bulk	none	103,192
Coarse KCL[j]	Saskatoon	Production	Flotation	none	-0-
Granulated mixed fert.	Central Michigan	Production	TVA continuous	250,000	250,000

Table E-1. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Level
Granulated mixed fert.	Outstate Michigan	Production	TVA continuous	250,000	53,655
Granulated mixed fert.	Central Michigan	Mfr's. storage	Bulk	none	187,500
Bulk blended fert.	Central Michigan	Production	Horizontal w/ rotary drum	20,000	20,000
Bulk blended fert.	Outstate Michigan	Production	Horizontal (9000 TPY)	252,000	252,000
Bulk blended fert.	Outstate Michigan	Production	Vertical (9000 TPY)	-0-	-0-
Bulk blended fert.	Outstate Michigan	Production	Horizontal (2500 TPY)	210,000	-0-
Bulk blended fert.	Outstate Michigan	Retailing	---	none	126,000
Dry products	Michigan	Retailing	---	687,300	-0-
Anhydrous ammonia	Michigan	Retailing	---	74,800	45,540

Table E-1. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Level
Liquid products	Michigan	Retailing	---	55,100	-0-

[a]Limiting capacity for current facilities during this year.

[b]Ammonium polyphosphate liquid (10-34-0).

[c]Ammonium polyphosphate liquid (11-37-0).

[d]Normal superphosphate.

[e]Run-of-pile triple superphosphate.

[f]Granular triple superphosphate.

[g]Run-of-mine potassium chloride.

[h]Standard potassium chloride.

[i]Granular potassium chloride.

[j]Coarse potassium chloride.

Table E-2. Transition constraints and levels of utilization for Year 2 (in tons)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Anhydrous ammonia	Gulf Coast	Production	Centrifugal	64,246	64,246	10,522	74,768
Anhydrous ammonia	Gulf Coast	Production	Piston	4,145	-0-	NA[d]	-0-
Anhydrous ammonia	Midwest	Production	Centrifugal	36,140	11,315	NA[d]	11,315
Anhydrous ammonia	Central Michigan	Production	Centrifugal	-0-	-0-	86,244	86,244
Anhydrous ammonia	Central Michigan	Production	Piston	37,129	-0-	NA	-0-
Anhydrous ammonia	Gulf Coast	Mfr's. storage	Cyrogenic	36,431	36,431	NA	36,431
Anhydrous ammonia	Midwest	Mfr's. storage	Cyrogenic	6,118	6,118	NA	6,118
Anhydrous ammonia	Central Michigan	Mfr's. storage	Cyrogenic	-0-	-0-	19,972	19,972
Nitric acid	Gulf Coast	Production	Medium pressure	25,129	-0-	NA	-0-

Table E-2. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Nitric acid	Midwest	Production	Medium pressure	10,770	5,147	NA	5,147
Ammonium nitrate	Gulf Coast	Production	Neutralization evaporation	32,848	-0-	NA	-0-
Ammonium nitrate	Midwest	Production	Neutralization evaporation	14,078	6,729	NA	6,729
Ammonium nitrate	Gulf Coast	Mfr's. storage	Bulk	1,952	-0-	NA	-0-
Non-pressure N-solution	Midwest	Production	Blending	16,365	-0-	NA	-0-
Non-pressure N-solution	Midwest	Mfr's. storage	Tank	16,254	-0-	NA	-0-
Low-pressure N-solution	Midwest	Production	Blending	11,268	-0-	NA	-0-
Low-pressure N-solution	Midwest	Mfr's. storage	Tank	3,789	-0-	NA	-0-
N-mfg. solution	Gulf Coast	Production	Blending	11,053	-0-	NA	-0-

Table E-2. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
N-mfg. solution	Midwest	Production	Blending	9,640	9,640	NA	9,640
N-mfg. solution	Gulf Coast	Mfr's. storage	Tank	2,093	-0-	NA	-0-
N-mfg. solution	Midwest	Mfr's. storage	Tank	1,808	-0-	NA	-0-
Urea	Gulf Coast	Production	Gas separation	11,788	-0-	NA	-0-
Urea	Gulf Coast	Production	Ammonium carbamate slurry	2,774	-0-	NA	-0-
Urea	Gulf Coast	Production	Water absorption	4,160	-0-	NA	-0-
Urea	Midwest	Production	Gas separation	2,080	-0-	NA	-0-
Urea	Gulf Coast	Mfr's. storage	Bulk	11,788	-0-	NA	-0-
Elemental phosphorus	Florida	Production	Electric furnace	1,602	1,591	NA	1,591
White phosphoric acid	Central Michigan	Production	Furnace process	6,746	6,746	NA	6,746

Table E-2. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Green phosphoric acid	Florida	Production	Wet process	130,685	130,685	111,918	242,603
Green phosphoric acid	Midwest	Production	Wet process	58,714	-0-	NA	-0-
Green phosphoric acid	Florida	Mfr's. storage	Rubber-lined	1,424	-0-	-0-	-0-
10-34-0[e]	Midwest	Production	Ammoniation	1,933	-0-	NA	-0-
10-34-0[e]	Midwest	Mfr's. storage	Tank	1,450	-0-	NA	-0-
11-37-0[f]	Midwest	Production	Ammoniation	161	-0-	NA	-0-
11-37-0[f]	Midwest	Mfr's. storage	Tank	121	-0-	NA	-0-
NSP[g]	Florida	Production	Cone mixer	8,716	-0-	NA	-0-
NSP[g]	Central Michigan	Production	Cone mixer	12,800	-0-	NA	-0-
NSP[g]	Florida	Mfr's. storage	Bulk	6,664	-0-	NA	-0-

Table E-2. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
R-O-P TSP[h]	Florida	Production	Cone mixer	49,851	49,851	NA	49,851
R-O-P TSP[h]	Midwest	Production	Cone mixer	56,855	3,836	NA	3,836
R-O-P TSP[h]	Florida	Mfr's. storage	Bulk	33,058	-0-	NA	-0-
Granular TSP[i]	Florida	Production	Rotary drum granulator	15,959	-0-	NA	-0-
Granular TSP[i]	Florida	Mfr's. storage	Bulk	10,345	-0-	NA	-0-
Diammonium phosphate	Florida	Production	Slurry ammoniation	51,666	51,666	NA	51,666
Diammonium phosphate	Midwest	Production	Slurry ammoniation	10,582	-0-	NA	-0-
Diammonium phosphate	Central Michigan	Production	Slurry ammoniation	7,920	7,920	NA	7,920
Diammonium phosphate	Florida	Mfr's. storage	Bulk	30,716	-0-	NA	-0-
Monoammonium phosphate	Florida	Production	Slurry ammoniation	66,341	66,341	103,980	170,321

Table E-2. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Monoammonium phosphate	Midwest	Production	Slurry ammoniation	13,588	-0-	NA	-0-
Monoammonium phosphate	Florida	Mfr's. storage	Bulk	59,946	59,946	39,286	99,232
Rock phosphate	Florida	Production	Grinding	111	-0-	NA	-0-
Super phosphoric acid	Midwest	Production	Thermal	83	-0-	NA	-0-
R-O-M KCL[j]	Saskatoon	Production	Flotation	97,170	59,323	NA	59,323
R-O-M KCL[j]	Saskatoon	Mfr's. storage	Bulk	18,759	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Production	Flotation	751	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Mfr's. storage	Bulk	563	-0-	NA	-0-
Gran. KCL[l]	Saskatoon	Production	Flotation	110,072	110,072	69,632	179,704
Gran. KCL[l]	Saskatoon	Mfr's. storage	Bulk	82,554	82,554	2,489	85,043

Table E-2. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Coarse KCL[m]	Saskatoon	Production	Flotation	20,000	20,000	NA	20,000
Granulated mixed fert.	Central Michigan	Production	TVA continuous	200,000	148,308	NA	148,308
Granulated mixed fert.	Outstate Michigan	Production	TVA continuous	52,455	-0-	NA	-0-
Granulated mixed fert.	Central Michigan	Mfr's. storage	Bulk	150,000	111,231	NA	111,231
Bulk blended fert.	Central Michigan	Production	Horizontal w/ rotary drum	16,000	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Production	Horizontal (9000 TPY)	201,600	201,600	NA	201,600
Bulk blended fert.	Outstate Michigan	Production	Vertical (9000 TPY)	-0-	-0-	44,099	44,099
Bulk blended fert.	Outstate Michigan	Production	Horizontal (2500 TPY)	56,661	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Retailing	---	100,800	100,800	22,050	122,850
Dry products	Michigan	Retailing	---	215,383	-0-	NA	-0-

Table E-2. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Anhydrous ammonia	Michigan	Retailing	---	37,244	-0-	NA	-0-
Liquid products	Michigan	Retailing	---	18,342	-0-	NA	-0-

[a]Limiting quantity for OLD facilities during this year.

[b]Total capacity from previous years after adjustments for physical depreciation.

[c]Total capacity of facilities purchased during this year.

[d]Not allowed.

[e]Ammonium polyphosphate liquid (10-34-0).

[f]Ammonium polyphosphate liquid (11-37-0).

[g]Normal superphosphate.

[h]Run-of-pile triple superphosphate.

[i]Granular triple superphosphate.

[j]Run-of-mine potassium chloride.

Table E-2. (cont'd.)

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[k]Standard potassium chloride.

[l]Granular potassium chloride.

[m]Coarse potassium chloride.

Table E-3. Transition constraints and levels of utilization for Year 3 (in tons)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Anhydrous ammonia	Gulf Coast	Production	Centrifugal	57,655	57,655	10,044	67,699
Anhydrous ammonia	Gulf Coast	Production	Piston	-0-	-0-	NA[d]	-0-
Anhydrous ammonia	Midwest	Production	Centrifugal	27,105	8,053	NA	8,053
Anhydrous ammonia	Central Michigan	Production	Centrifugal	77,620	77,620	19,101	96,721
Anhydrous ammonia	Central Michigan	Production	Piston	18,564	-0-	NA	-0-
Anhydrous ammonia	Gulf Coast	Mfr's. storage	Cyrogenic	27,324	27,324	NA	27,324
Anhydrous ammonia	Midwest	Mfr's. storage	Cyrogenic	4,588	4,588	NA	4,588
Anhydrous ammonia	Central Michigan	Mfr's. storage	Cyrogenic	17,975	17,975	12,603	30,578
Nitric acid	Gulf Coast	Production	Medium pressure	8,376	-0-	NA	-0-
Nitric acid	Midwest	Production	Medium pressure	7,180	3,432	NA	3,432

Table E-3. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Ammonium nitrate	Gulf Coast	Production	Neutralization evaporation	10,949	-0-	NA	-0-
Ammonium nitrate	Midwest	Production	Neutralization evaporation	9,385	4,486	NA	4,486
Ammonium nitrate	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
N-mfg. solution	Gulf Coast	Production	Blending	5,526	-0-	NA	-0-
N-mfg. solution	Midwest	Production	Blending	6,427	6,427	NA	6,427

Table E-3. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
N-mfg. solution	Gulf Coast	Mfr's. storage	Tank	1,046	-0-	NA	-0-
N-mfg. solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Ammonium carbamate slurry	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Water absorption	-0-	-0-	NA	-0-
Urea	Midwest	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Elemental phosphorus	Florida	Production	Electric furnace	801	795	NA	795
White Phosphoric acid	Central Michigan	Production	Furnace process	3,373	3,373	NA	3,373

Table E-3. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Green phosphoric acid	Florida	Production	Wet process	198,740	198,740	50,948	249,688
Green phosphoric acid	Midwest	Production	Wet process	29,357	-0-	NA	-0-
Green phosphoric acid	Florida	Mfr's. storage	Rubber-lined	-0-	-0-	-0-	-0-
10-34-0[e]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
10-34-0[e]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
NSP[g]	Florida	Production	Cone mixer	-0-	-0-	NA	-0-
NSP[g]	Central Michigan	Production	Cone mixer	-0-	-0-	NA	-0-
NSP[g]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-

Table E-3. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
R-O-P TSP[h]	Florida	Production	Cone mixer	33,522	33,522	NA	33,522
R-O-P TSP[h]	Midwest	Production	Cone mixer	42,641	2,271	NA	2,271
R-O-P TSP[h]	Florida	Mfr's. storage	Bulk	11,181	-0-	NA	-0-
Granular TSP[i]	Florida	Production	Rotary drum granulator	5,320	-0-	NA	-0-
Granular TSP[i]	Florida	Mfr's. storage	Bulk	3,448	-0-	NA	-0-
Diammonium phosphate	Florida	Production	Slurry ammoniation	38,749	38,749	NA	38,749
Diammonium phosphate	Midwest	Production	Slurry ammoniation	5,291	-0-	NA	-0-
Diammonium phosphate	Central Michigan	Production	Slurry ammoniation	3,960	3,960	NA	3,960
Diammonium phosphate	Florida	Mfr's. storage	Bulk	10,239	-0-	NA	-0-

Table E-3. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Monoammonium phosphate	Florida	Production	Slurry ammoniation	143,338	143,338	57,732	201,070
Monoammonium phosphate	Midwest	Production	Slurry ammoniation	6,794	-0-	NA	-0-
Monoammonium phosphate	Florida	Mfr's. storage	Bulk	80,317	80,317	36,218	116,535
Rock phosphate	Florida	Production	Grinding	-0-	-0-	NA	-0-
Super phosphoric acid	Midwest	Production	Thermal	-0-	-0-	NA	-0-
R-O-M KCL[j]	Saskatoon	Production	Flotation	72,877	39,551	NA	39,551
R-O-M KCL[j]	Saskatoon	Mfr's. storage	Bulk	6,253	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Gran. KCL[l]	Saskatoon	Production	Flotation	145,223	145,223	64,246	209,469

Table E-3. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Gran. KCL[l]	Saskatoon	Mfr's. storage	Bulk	64,155	64,155	35,717	99,872
Coarse KCL[m]	Saskatoon	Production	Flotation	10,000	10,000	NA	10,000
Granulated mixed fert.	Central Michigan	Production	TVA continuous	150,000	98,877	NA	98,877
Granulated mixed fert.	Outstate Michigan	Production	TVA continuous	17,485	-0-	NA	-0-
Granulated mixed fert.	Central Michigan	Mfr's. storage	Bulk	112,500	74,158	NA	74,158
Bulk blended fert.	Central Michigan	Production	Horizontal w/ rotary drum	8,000	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Production	Horizontal (9000 TPY)	151,200	151,200	NA	151,200
Bulk blended fert.	Outstate Michigan	Production	Vertical (9000 TPY)	39,689	39,689	97,654	137,343
Bulk blended fert.	Outstate Michigan	Production	Horizontal (2500 TPY)	28,331	-0-	NA	-0-

Table E-3. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Bulk blended fert.	Outstate Michigan	Retailing	---	95,445	95,445	48,826	144,271
Dry products	Michigan	Retailing	---	-0-	-0-	NA	-0-
Anhydrous ammonia	Michigan	Retailing	---	12,415	-0-	NA	-0-
Liquid products	Michigan	Retailing	---	-0-	-0-	NA	-0-

[a]Limiting quantity for OLD facilities during this year.

[b]Total capacity from previous years after adjustments for physical depreciation.

[c]Total capacity of facilities purchased during this year.

[d]Not allowed.

[e]Ammonium polyphosphate liquid (10-34-0).

[f]Ammonium polyphosphate liquid (11-37-0).

[g]Normal superphosphate.

Table E-3. (cont'd.)

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[h]Run-of-pile triple superphosphate.

[i]Granular triple superphosphate.

[j]Run-of-mine potassium chloride.

[k]Standard potassium chloride.

[l]Granular potassium chloride.

[m]Coarse potassium chloride.

Table E-4. Transition Constraints and levels of utilization for Year 4 (in tons)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Anhydrous ammonia	Gulf Coast	Production	Centrifugal	49,580	49,580	11,050	60,630
Anhydrous ammonia	Gulf Coast	Production	Piston	-0-	-0-	NA[d]	-0-
Anhydrous ammonia	Midwest	Production	Centrifugal	18,070	4,791	NA	4,791
Anhydrous ammonia	Central Michigan	Production	Centrifugal	86,186	86,186	21,012	107,198
Anhydrous ammonia	Central Michigan	Production	Piston	-0-	-0-	NA	-0-
Anhydrous ammonia	Gulf Coast	Mfr's. storage	Cyrogenic	18,216	18,216	NA	18,216
Anhydrous ammonia	Midwest	Mfr's. storage	Cyrogenic	3,059	3,059	NA	3,059
Anhydrous ammonia	Central Michigan	Mfr's. storage	Cyrogenic	27,320	27,320	13,865	41,185
Nitric acid	Gulf Coast	Production	Medium pressure	-0-	-0-	NA	-0-

Table E-4. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Nitric acid	Midwest	Production	Medium pressure	3,590	1,716	NA	1,716
Ammonium nitrate	Gulf Coast	Production	Neutralization evaporation	-0-	-0-	NA	-0-
Ammonium nitrate	Midwest	Production	Neutralization evaporation	4,693	2,243	NA	2,243
Ammonium nitrate	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
N-mfg. solution	Gulf coast	Production	Blending	-0-	-0-	NA	-0-

Table E-4. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
N-mfg. solution	Midwest	Production	Blending	3,213	3,213	NA	3,213
N-mfg. solution	Gulf Coast	Mfr's. storage	Tank	-0-	-0-	NA	-0-
N-mfg. solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Ammonium carbamate slurry	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Water absorption	-0-	-0-	NA	-0-
Urea	Midwest	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Elemental phosphorus	Florida	Production	Electric furnace	-0-	-0-	NA	-0-

Table E-4. (Cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
White phosphoric acid	Central Michigan	Production	Furnace process	-0-	-0-	NA	-0-
Green phosphoric acid	Florida	Production	Wet process	200,730	200,730	56,044	256,774
Green phosphoric acid	Midwest	Production	Wet process	-0-	-0-	NA	-0-
Green phosphoric acid	Florida	Mfr's. storage	Rubber-lined	-0-	-0-	NA	-0-
10-34-0[e]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
10-34-0[e]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
NSP[g]	Florida	Production	Cone mixer	-0-	-0-	NA	-0-
NSP[g]	Central Michigan	Production	Cone mixer	-0-	-0-	NA	-0-

Table E-4. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
NSP[g]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
R-O-P TSP[h]	Florida	Production	Cone mixer	16,617	16,617	NA	16,617
R-O-P TSP[h]	Midwest	Production	Cone mixer	28,428	1,277	NA	1,277
R-O-P TSP[h]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Granular TSP[i]	Florida	Production	Rotary drum granulator	-0-	-0-	NA	-0-
Granular TSP[i]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Diammonium phosphate	Florida	Production	Slurry ammoniation	25,833	25,833	NA	25,833
Diammonium phosphate	Midwest	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Diammonium phosphate	Central Michigan	Production	Slurry ammoniation	-0-	-0-	NA	-0-

Table E-4. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Diammonium phosphate	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Monoammonium phosphate	Florida	Production	Slurry ammoniation	168,313	168,313	63,510	231,823
Monoammonium phosphate	Midwest	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Monoammonium phosphate	Florida	Mfr's. storage	Bulk	93,998	93,998	39,846	133,844
Rock phosphate	Florida	Production	Grinding	-0-	-0-	NA	-0-
Super phosphoric acid	Midwest	Production	Thermal	-0-	-0-	NA	-0-
R-O-M KCL[j]	Saskatoon	Production	Flotation	48,585	19,772	NA	19,772
R-O-M KCL[j]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-

Table E-4. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
STD. KCL[k]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Gran. KCL[l]	Saskatoon	Production	Flotation	168,563	168,563	70,678	239,241
Gran. KCL[l]	Saskatoon	Mfr's. storage	Bulk	75,413	75,413	39,293	114,706
Coarse KCL[m]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
Granulated mixed fert.	Central Michigan	Production	TVA continuous	100,000	49,431	NA	49,431
Granulated mixed fert.	Outstate Michigan	Production	TVA continuous	-0-	-0-	NA	-0-
Granulated mixed fert.	Central Michigan	Mfr's. storage	Bulk	75,000	37,073	NA	37,073
Bulk blended fert.	Central Michigan	Production	Horizontal w/ rotary drum	-0-	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Production	Horizontal (9000 TPY)	100,800	100,800	NA	100,800

Table E-4. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Bulk blended fert.	Outstate Michigan	Production	Vertical (9000 TPY)	123,168	123,168	107,432	230,600
Bulk blended fert.	Outstate Michigan	Production	Horizontal (2500 TPY)	-0-	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Retailing	---	111,983	111,983	53,717	165,700
Dry products	Michigan	Retailing	---	-0-	-0-	NA	-0-
Anhydrous ammonia	Michigan	Retailing	---	-0-	-0-	NA	-0-
Liquid products	Michigan	Retailing	---	-0-	-0-	NA	-0-

[a]Limiting quantity for OLD facilities during this year.

[b]Total capacity from previous years after adjustments for physical depreciation.

[c]Total capacity of facilities purchased during this year.

[d]Not allowed.

Table E-4. (cont'd.)

[e]Ammonium polyphosphate liquid (10-34-0).

[f]Ammonium polyphosphate liquid (11-37-0).

[g]Normal superphosphate.

[h]Run-of-pile triple superphosphate.

[i]Granular triple superphosphate.

[j]Run-of-mine potassium chloride.

[k]Standard potassium chloride.

[l]Granular potassium chloride.

[m]Coarse potassium chloride.

Table E-5. Transition constraints and levels of utilization for Year 5 (in tons)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Anhydrous ammonia	Gulf Coast	Production	Centrifugal	41,407	41,407	10,574	51,981
Anhydrous ammonia	Gulf Coast	Production	Piston	-0-	-0-	NA[d]	-0-
Anhydrous ammonia	Midwest	Production	Centrifugal	9,035	1,529	NA	1,529
Anhydrous ammonia	Central Michigan	Production	Centrifugal	94,562	94,562	24,691	119,253
Anhydrous ammonia	Central Michigan	Production	Piston	-0-	-0-	NA	-0-
Anhydrous ammonia	Gulf Coast	Mfr's. storage	Cyrogenic	9,108	9,108	NA	9,108
Anhydrous ammonia	Midwest	Mfr's. storage	Cyrogenic	1,529	1,529	NA	1,529
Anhydrous ammonia	Central Michigan	Mfr's. storage	Cyrogenic	36,541	36,541	15,251	51,792
Nitric acid	Gulf Coast	Production	Medium pressure	-0-	-0-	NA	-0-

Table E-5. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Nitric acid	Midwest	Production	Medium pressure	-0-	-0-	NA	-0-
Ammonium nitrate	Gulf Coast	Production	Neutralization evaporation	-0-	-0-	NA	-0-
Ammonium nitrate	Midwest	Production	Neutralization evaporation	-0-	-0-	NA	-0-
Ammonium nitrate	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
N-mfg. solution	Gulf Coast	Production	Blending	-0-	-0-	NA	-0-
N-mfg. solution	Midwest	Production	Blending	-0-	-0-	NA	-0-

Table E-5. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
N-mfg. solution	Gulf Coast	Mfr's. storage	Tank	-0-	-0-	NA	-0-
N-mfg. solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Ammonium carbamate slurry	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Water absorption	-0-	-0-	NA	-0-
Urea	Midwest	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Elemental phosphorus	Florida	Production	Electric furnace	-0-	-0-	NA	-0-
White phosphoric acid	Central Michigan	Production	Furnace process	-0-	-0-	NA	-0-
Green Phosphoric acid	Florida	Production	Wet process	202,212	202,212	58,275	260,487

Table E-5. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Green phosphoric acid	Midwest	Production	Wet process	-0-	-0-	NA	-0-
Green phosphoric acid	Florida	Mfr's. storage	Rubber-lined	-0-	-0-	NA	-0-
10-34-0[e]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
10-34-0[e]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
NSP[g]	Florida	Production	Cone mixer	-0-	-0-	NA	-0-
NSP[g]	Central Michigan	Production	Cone mixer	-0-	-0-	NA	-0-
NSP[g]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
R-O-P TSP[h]	Florida	Production	Cone mixer	-0-	-0-	NA	-0-
R-O-P TSP[h]	Midwest	Production	Cone mixer	14,214	-0-	NA	-0-

Table E-5. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
R-O-P TSP[h]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Granular TSP[i]	Florida	Production	Rotary drum granulator	-0-	-0-	NA	-0-
Granular TSP[i]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Diammonium phosphate	Florida	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Diammonium phosphate	Midwest	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Diammonium phosphate	Central Michigan	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Diammonium phosphate	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Monoammonium phosphate	Florida	Production	Slurry ammoniation	192,716	192,716	77,779	270,495
Monoammonium phosphate	Midwest	Production	Slurry ammoniation	-0-	-0-	NA	-0-

Table E-5. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Monoammonium phosphate	Florida	Mfr's. storage	Bulk	107,323	107,323	43,825	151,148
Rock phosphate	Florida	Production	Grinding	-0-	-0-	NA	-0-
Super phosphoric acid	Midwest	Production	Thermal	-0-	-0-	NA	-0-
R-O-M KCL[j]	Saskatoon	Production	Flotation	24,292	-0-	NA	-0-
R-O-M KCL[j]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Gran. KCL[l]	Saskatoon	Production	Flotation	191,267	191,267	67,739	259,006
Gran. KCL[l]	Saskatoon	Mfr's. storage	Bulk	86,318	86,318	43,217	129,535
Coarse KCL[m]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-

Table E-5. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Granulated mixed fert.	Central Michigan	Production	TVA continuous	50,000	-0-	NA	-0-
Granulated mixed fert.	Outstate Michigan	Production	TVA continuous	-0-	-0-	NA	-0-
Granulated mixed fert.	Central Michigan	Mfr's. storage	Bulk	37,500	-0-	NA	-0-
Bulk blended fert.	Central Michigan	Production	Horizontal w/ rotary drum	-0-	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Production	Horizontal (9000 TPY)	50,400	50,400	NA	50,400
Bulk blended fert.	Outstate Michigan	Production	Vertical (9000 TPY)	205,681	205,681	118,162	323,843
Bulk blended fert.	Outstate Michigan	Production	Horizontal (2500 TPY)	-0-	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Retailing	---	128,041	128,041	59,081	187,122
Dry products	Michigan	Retailing	---	-0-	-0-	NA	-0-

Table E-5. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Used
Anhydrous ammonia	Michigan	Retailing	---	-0-	-0-	NA	-0-
Liquid products	Michigan	Retailing	---	-0-	-0-	NA	-0-

[a]Limiting quantity for OLD facilities during this year.

[b]Total capacity from previous years after adjustments for physical depreciation.

[c]Total capacity of facilities purchased during this year.

[d]Not allowed.

[e]Ammonium polyphosphate liquid (10-34-0).

[f]Ammonium polyphosphate liquid (11-37-0).

[g]Normal superphosphate.

[h]Run-of-pile triple superphosphate.

[i]Granular triple superphosphate.

[j]Run-of-mine potassium chloride.

Table E-5. (cont'd.)

[k]Standard potassium chloride.

[l]Granular potassium chloride.

[m]Coarse potassium chloride.

Table E-6. Transition constraints and levels of utilization for Year 6 (in tons)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Anhydrous ammonia	Gulf Coast	Production	Centrifugal	31,701	31,701	11,172	42,873
Anhydrous ammonia	Gulf Coast	Production	Piston	-0-	-0-	NA	-0-
Anhydrous ammonia	Midwest	Production	Centrifugal	-0-	-0-	NA	-0-
Anhydrous ammonia	Central Michigan	Production	Centrifugal	104,149	104,149	25,741	129,890
Anhydrous ammonia	Central Michigan	Production	Piston	-0-	-0-	NA	-0-
Anhydrous ammonia	Gulf Coast	Mfr's. storage	Cyrogenic	-0-	-0-	NA	-0-
Anhydrous ammonia	Midwest	Mfr's. storage	Cyrogenic	-0-	-0-	NA	-0-
Anhydrous ammonia	Central Michigan	Mfr's. storage	Cyrogenic	45,623	45,623	16,806	62,429
Nitric acid	Gulf Coast	Production	Medium pressure	-0-	-0-	NA	-0-

Table E-6. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Nitric acid	Midwest	Production	Medium pressure	-0-	-0-	NA	-0-
Ammonium nitrate	Gulf Coast	Production	Neutralization evaporation	-0-	-0-	NA	-0-
Ammonium nitrate	Midwest	Production	Neutralization evaporation	-0-	-0-	NA	-0-
Ammonium nitrate	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Non-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
Low-pressure N-solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
N-mfg. solution	Gulf Coast	Production	Blending	-0-	-0-	NA	-0-

Table E-6. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
N-mfg. solution	Midwest	Production	Blending	-0-	-0-	NA	-0-
N-mfg. solution	Gulf Coast	Mfr's. storage	Tank	-0-	-0-	NA	-0-
N-mfg. solution	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Ammonium carbamate slurry	-0-	-0-	NA	-0-
Urea	Gulf Coast	Production	Water absorption	-0-	-0-	NA	-0-
Urea	Midwest	Production	Gas separation	-0-	-0-	NA	-0-
Urea	Gulf Coast	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Elemental phosphorus	Florida	Production	Electric furnace	-0-	-0-	NA	-0-

Table E-6. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
White phosphoric acid	Central Michigan	Production	Furnace process	-0-	-0-	NA	-0-
Green phosphoric acid	Florida	Production	Wet process	200,097	200,097	60,390	260,487
Green phosphoric acid	Midwest	Production	Wet process	-0-	-0-	NA	-0-
Green phosphoric acid	Florida	Mfr's. storage	Rubber-lined	-0-	-0-	-0-	-0-
10-34-0[e]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
10-34-0[e]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Production	Ammoniation	-0-	-0-	NA	-0-
11-37-0[f]	Midwest	Mfr's. storage	Tank	-0-	-0-	NA	-0-
NSP[g]	Florida	Production	Cone mixer	-0-	-0-	NA	-0-
NSP[g]	Central Michigan	Production	Cone mixer	-0-	-0-	NA	-0-

Table E-6. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
NSP[g]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
R-O-P TSP[h]	Florida	Production	Cone mixer	-0-	-0-	NA	-0-
R-O-P TSP[h]	Midwest	Production	Cone mixer	-0-	-0-	NA	-0-
R-O-P TSP[h]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Granular TSP[i]	Florida	Production	Rotary drum granulator	-0-	-0-	NA	-0-
Granular TSP[i]	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Diammonium phosphate	Florida	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Diammonium phosphate	Midwest	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Diammonium phosphate	Central Michigan	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Diammonium phosphate	Florida	Mfr's. storage	Bulk	-0-	-0-	NA	-0-

Table E-6. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Monoammonium phosphate	Florida	Production	Slurry ammoniation	223,610	223,610	46,885	270,495
Monoammonium phosphate	Midwest	Production	Slurry ammoniation	-0-	-0-	NA	-0-
Monoammonium phosphate	Florida	Mfr's. storage	Bulk	120,244	120,244	30,904	151,148
Rock phosphate	Florida	Production	Grinding	-0-	-0-	NA	-0-
Super phosphoric acid	Midwest	Production	Thermal	-0-	-0-	NA	-0-
R-O-M KCL[j]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
R-O-M KCL[j]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
STD. KCL[k]	Saskatoon	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Gran. KCL[l]	Saskatoon	Production	Flotation	204,259	204,259	54,747	259,006

Table E-6. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Gran. KCL[l]	Saskatoon	Mfr's. storage	Bulk	96,825	96,825	32,710	129,535
Coarse KCL[m]	Saskatoon	Production	Flotation	-0-	-0-	NA	-0-
Granulated mixed fert.	Central Michigan	Production	TVA continuous	-0-	-0-	NA	-0-
Granulated mixed fert.	Outstate Michigan	Production	TVA continuous	-0-	-0-	NA	-0-
Granulated mixed fert.	Central Michigan	Mfr's. storage	Bulk	-0-	-0-	NA	-0-
Bulk blended fert.	Central Michigan	Production	Horizontal w/ rotary drum	-0-	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Production	Horizontal (9000 TPY)	-0-	-0-	NA	-0-
Bulk blended fert.	Outstate Michigan	Production	Vertical (9000 TPY)	287,109	287,109	87,134	374,243
Bulk blended fert.	Outstate Michigan	Production	Horizontal (2500 TPY)	-0-	-0-	NA	-0-

Table E-6. (cont'd.)

Product	Location	Activity	Type	Constraint[a]	Old[b]	Purchased New[c]	Total Use
Bulk blended fert.	Outstate Michigan	Retailing	---	143,555	143,555	43,567	187,122
Dry products	Michigan	Retailing	---	-0-	-0-	NA	-0-
Anhydrous ammonia	Michigan	Retailing	---	-0-	-0-	NA	-0-
Liquid products	Michigan	Retailing	---	-0-	-0-	NA	-0-

[a]Limiting quantity for OLD facilities during this year.

[b]Total capacity from previous years after adjustments for physical depreciation.

[c]Total capacity of facilities purchased during this year.

[d]Not allowed.

[e]Ammonium polyphosphate liquid (10-34-0).

[f]Ammonium polyphosphate liquid (11-37-0).

[g]Normal superphosphate.

Table E-6. (cont'd.)

[h]Run-of-pile triple superphosphate.

[i]Granular triple superphosphate.

[j]Run-of-mine potassium chloride.

[k]Standard potassium chloride.

[l]Granular potassium chloride.

[m]Coarse potassium chloride.

APPENDIX F

The Transition Years

Table F-1. Product use summary for the transition years[1] (in tons)

Product	Year 2	Year 3	Year 4	Year 5	Year 6
Anhydrous ammonia	172,327	172,473	172,619	172,763	172,763
Nitric acid	5,147	3,432	1,716	-0-	-0-
Ammonium nitrate	6,729	4,486	2,243	-0-	-0-
Nitrogen manufacturing solution	9,640	6,427	3,213	-0-	-0-
Elemental phosphorous	1,591	795	-0-	-0-	-0-
Wet process phosphoric acid	242,603	249,688	256,774	260,487	260,487
Furnace process phosphoric acid	6,746	3,373	-0-	-0-	-0-
Run-of-pile triple superphosphate	53,687	35,793	17,894	-0-	-0-
Diammonium phosphate	59,586	42,709	25,833	-0-	-0-
Monoammonium phosphate	170,321	201,070	231,823	270,495	270,495
Run-of-mine potassium chloride	59,323	39,551	19,772	-0-	-0-
Granular potassium chloride	179,704	209,469	239,241	259,006	259,006
Coarse potassium chloride	20,000	10,000	-0-	-0-	-0-
Granulated mixed fertilizers	148,308	98,887	49,431	-0-	-0-
Bulk blended fertilizers	245,699	288,543	331,400	374,243	374,243

Table F-1. (cont'd.)

Product	Year 2	Year 3	Year 4	Year 5	Year 6
N supplied	141,932	141,932	141,932	141,932	141,932
P_2O_5 supplied	140,650	140,650	140,650	140,650	140,650
K_2O supplied	155,441	155,441	155,441	155,441	155,441

[1]For years 0 and 1, see Appendix A, 1970 Actual and Constrained Optimum, respectively.

Table F-2. Anhydrous ammonia product flow

Originating location	Activity	Type	Terminating location		Year 2	Year 3	Year 4	Year 5	Year 6
Gulf Coast	Production	Centrifugal[1]	---	(new)	10,522	10,044	11,050	10,574	11,172
Gulf Coast	Production	Centrifugal	---		64,246	57,655	49,580	41,407	31,701
Midwest	Production	Centrifugal	---		11,315	8.053	4,791	1,529	-0-
Central Michigan	Production	Centrifugal[1]	---	(new)	86,244	19,101	21,012	24,691	25,741
Central Michigan	Production	Centrifugal	---		-0-	77,620	86,186	94,562	104,149
Gulf Coast	Mfr's. storage	Cyrogenic	---		36,431	27,324	18,216	9,108	-0-
Midwest	Mfr's. storage	Cyrogenic	---		6,118	4,588	3,059	1,529	-0-
Central Michigan	Mfr's. storage	Cyrogenic[1]	---	(new)	19,972	12,603	13,865	15,251	16,806
Central Michigan	Mfr's. storage	Cyrogenic	---		-0-	17,975	27,320	36,541	45,623
Gulf Coast	Transportation	Barge	Florida producers[2]		38,337	40,375	42,414	42,873	42,873

Table F-2. (cont'd.)

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Midwest	Product transfer	On-site	Midwest producers[3]	5,197	3,465	1,732	-0-	-0-
Central Michigan	Product transfer	On-site	Michigan producers[4]	1,738	869	-0-	-0-	-0-
Central Michigan	Transportation	Truck	Farms	84,506	95,852	107,198	119,253	129,890
Farms	Application	---	---	127,055	127,764	128,473	129,890	129,890
Gulf Coast	Transportation	Rail	Michigan terminal	36,431	27,324	18,216	9,108	-0-
Midwest	Transportation	Rail	Michigan terminal	6,118	4,588	3,059	1,529	-0-
Michigan terminal	Transportation	Truck	Farms	42,549	31,912	21,275	10,637	-0-

[1] These facilities represent new investment.

[2] Diammonium and monoammonium phosphate producers.

[3] Nitric acid, ammonium nitrate, nitrogen manufacturing solutions, and diammonium and monoammonium phosphate producers.

[4] Diammonium phosphate and granular mixed fertilizer producers.

Table F-3. Nitric acid product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Midwest	Production	Medium pressure	---	5,147	3,432	1,716	-0-	-0-
Midwest	Product transfer	On-site	Midwest producers[1]	5,147	3,432	1,716	-0-	-0-

[1] Ammonium nitrate producers.

Table F-4. Ammonium nitrate product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Midwest	Production	Neutralization evaporation	---	6,729	4,486	2,243	-0-	-0-
Midwest	Product transfer	On-site	Midwest producers[1]	6,729	4,486	2,243	-0-	-0-

[1] Nitrogen manufacturing solutions producers.

Table F-5. Nitrogen manufacturing solutions product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Midwest	Production	Blending	---	9,640	6,427	3,213	-0-	-0-
Midwest	Transportation	Rail	Michigan producers[1]	9,640	6,427	3,213	-0-	-0-

[1]Granular mixed fertilizer producers.

Table F-6. Elemental phosphorous product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Florida	Production	Electric furnace	---	1,591	795	-0-	-0-	-0-
Florida	Transportation	Rail	Michigan producers[1]	1,591	795	-0-	-0-	-0-

[1]White phosphoric acid producers.

Table F-7. White phosphoric acid product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Central Michigan	Production	Furnace process	---	6,746	3,373	-0-	-0-	-0-
Central Michigan	Product	On-site	Michigan producers[1]	6,746	3,373	-0-	-0-	-0-

[1]Diammonium phosphate producers.

Table F-8. Green phosphoric acid product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Florida	Production	Wet process[1]	--- (new)	111,918	50,948	56,044	58,275	60,390
Florida	Production	Wet process	---	130,685	198,740	200,730	202,212	200,097
Florida	Product transfer	On-site	Florida producers[2]	240,133	248,225	255,952	260,487	260,487
Florida	Transportation	Barge	Midwest producers[2]	2,471	1,463	822	-0-	-0-

[1]These facilities represent new investment.

[2]Diammonium and monoammonium phosphate producers.

Table F-9. Run-of-pile triple superphosphate product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Florida	Production	Cone mixer	---	49,851	33,522	16,617	-0-	-0-
Midwest	Production	Cone mixer	---	3,836	2,271	1,277	-0-	-0-
Florida	Transportation	Rail	Michigan producers[1]	49,851	33,522	16,617	-0-	-0-
Midwest	Transportation	Rail	Michigan producers[1]	3,836	2,271	1,277	-0-	-0-

[1]Granular mixed fertilizer producers.

Table F-10. Diammonium phosphate products flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Florida	Production	Slurry ammoniation	---	51,666	38,749	25,833	-0-	-0-
Central Michigan	Production	Slurry ammoniation	---	7,920	3,960	-0-	-0-	-0-
Florida	Transportation	Rail	Michigan producers[1]	23,729	15,820	7,909	-0-	-0-
Farms	Application	---	---	35,856	26,889	17,924	-0-	-0-
Central Michigan	Transportation	Truck	Farms	7,920	3,960	-0-	-0-	-0-
Florida	Transportation	Rail	Michigan terminal	27,937	22,929	17,924	-0-	-0-
Michigan terminal	Transportation	Truck	Farms	27,937	22,929	17,924	-0-	-0-

[1]Granular mixed and dry blended fertilizer producers.

Table F-11. Monoammonium phosphate product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Florida	Production	Slurry ammoniation[1]	--- (new)	103,980	57,732	63,510	77,779	46,885
Florida	Production	Slurry ammoniation	---	66,341	143,338	168,313	192,716	223,610
Florida	Mfr's. storage	Bulk[1]	--- (new)	39,286	36,218	39,846	43,825	30,904
Florida	Mfr's. storage	Bulk	---	59,946	80,317	93,998	107,323	120,244
Florida	Transportation	Rail	Outstate processors[2]	132,309	155,380	178,459	201,530	201,530
Farms	Application	---	---	38,012	45,690	53,365	68,965	68,965
Florida	Transportation	Rail	Michigan terminal	38,012	45,690	53,365	68,965	68,965
Michigan terminal	Transportation	Truck	Farms	38,102	45,690	53,365	68,965	68,965

[1]These facilities represent new investment.

[2]Dry blended fertilizer producers.

Table F-12. Run-of-mine potassium chloride product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Saskatoon	Production	Flotation	---	59,323	39,551	19,772	-0-	-0-
Saskatoon	Transportation	Rail	Michigan producers[1]	59,323	39,551	19,772	-0-	-0-

[1]Granular mixed fertilizer producers.

Table F-13. Granular potassium chloride product flow

Originating location	Activity	Type	Terminating location		Year 2	Year 3	Year 4	Year 5	Year 6
Saskatoon	Production	Flotation[1]	---	(new)	69,632	64,246	70,678	67,739	54,747
Saskatoon	Production	Flotation	---		110,072	145,223	168,563	191,267	204,259
Saskatoon	Mfr's. storage	Bulk[1]	---	(new)	2,489	35,717	39,293	43,217	32,710
Saskatoon	Mfr's. storage	Bulk	---		82,554	64,155	75,413	86,318	96,825
Saskatoon	Transportation	Rail	Michigan terminal		66,314	76,307	86,300	86,293	86,293
Saskatoon	Transportation	Rail	Outstate processors[2]		113,390	133,163	152,941	172,713	172,713
Michigan terminal	Transportation	Truck	Farms		66,314	76,307	86,300	86,293	86,293
Farms	Application	--	---		66,314	76,307	86,300	86,293	86,293

[1]These facilities represent new investments.

[2]Dry blended fertilizer producers.

Table F-14. Coarse potassium chloride product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Saskatoon	Production	Flotation	---	20,000	10,000	-0-	-0-	-0-
Farms	Application	---	---	20,000	10,000	-0-	-0-	-0-
Saskatoon	Transportation	Rail	Michigan terminal	20,000	10,000	-0-	-0-	-0-
Michigan terminal	Transportation	Truck	Farms	20,000	10,000	-0-	-0-	-0-

Table F-15. Bulk granulated mixed fertilizer product flow

Originating location	Activity	Type	Terminating location	Year 2	Year 3	Year 4	Year 5	Year 6
Central Michigan	Production	TVA continuous	---	148,308	98,877	49,431	-0-	-0-
Central Michigan	Mfr's. storage	Bulk	---	111,231	74,158	37,073	-0-	-0-
Central Michigan	Transportation	Truck	Farms	148,308	98,877	49,431	-0-	-0-
Farms	Application	---	---	148,308	98,877	49,431	-0-	-0-

Table F-16. Bulk blended fertilizers product flow

Originating location	Activity	Type	Terminating location		Year 2	Year 3	Year 4	Year 5	Year 6
Outstate Michigan	Production	Horizontal (9000 TPY)	---		201,600	151,200	100,800	50,400	-0-
Outstate Michigan	Production	Vertical (9000 TPY)[1]	---	(new)	44,099	97,654	107,432	118,162	87,134
Outstate Michigan	Production	Vertical (9000 TPY)	---		-0-	39,689	123,168	205,681	287,109
Outstate processors	Transportation	Truck	Satellite outlets		122,850	144,271	165,700	187,122	187,122
Outstate processors	Transportation	Applicators	Farms		122,850	144,271	165,700	187,122	187,122
Satellite outlets	Product handling[1]	---	---	(new)	22,050	48,826	53,717	59,081	43,567
Satellite outlets	Product handling	---	---		100,800	95,445	111,983	128,041	143,555
Satellite outlets	Transportation	Applicators	Farms		122,850	144,271	165,700	187,122	187,122
Farms	Application	---	---		245,699	288,543	331,400	374,243	374,243

[1]These facilities represent new investment.