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# *THE OPTIMAL NUMBER AND SIZE OF FERTILIZER PLANTS UNDER HAZARDOUS MATERIALS REGULATIONS*

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## ABSTRACT

Public concern about hazardous materials, such as agricultural fertilizers, has steadily increased. Thus, North Dakota created Recommended Management Practices for The Primary and Secondary Containment of Fertilizers (RMP).

This study attempted to determine how compliance with RMP guidelines affects logistic, operating, and investment costs of fertilizer plants and evaluate the effect on plant size and industry market structure. This study will be important to fertilizer plant managers because the North Dakota Health and Consolidated Laboratories, which regulates the North Dakota fertilizer industry, has been approached about introducing legislation that would create and support consistency within the industry.

A cost-minimizing, mixed-integer linear programming model was employed in four different scenarios to analyze the effects of possible fertilizer legislation. Results show forced compliance with the RMP guidelines will (1) start a shake-out of excess capacity, (2) generate cost savings of 8 percent for the industry, and (3) discourage storage capacity expansion.

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## CHAPTER 1. INTRODUCTION

During the past 30 years, public concern and awareness about the transport and storage of hazardous materials have steadily increased. In rural areas, many of these concerns arose from safety issues involved in transporting, applying, and storing agricultural inputs, such as agricultural chemicals and fertilizers. For example, society wanted to protect the environment and human health from the dangers of surface water and groundwater contamination (Kammel et al., p.1). These concerns prompted an increase in federal and state hazardous materials and substances regulations. In turn, the changes in regulations affected the transportation and storage of many agricultural inputs.

In North Dakota, the fertilizer industry is regulated by the North Dakota State Department of Health and Consolidated Laboratories (NDDHCL) and the agricultural chemical industry is regulated by the North Dakota Department of Agriculture (NDDA). The supply chains of the agricultural fertilizer and chemical industries closely resemble each other. However, the fertilizer industry is not regulated to the extent of the agricultural chemical industry. Although North Dakota has not created laws specifically regulating fertilizer storage, the NDDHCL has issued recommended guidelines for the states fertilizer plants. The guidelines, published in November 1994, are referred to as Recommended Management Practices for The Primary and Secondary Containment of Fertilizers (RMP).

### Problem Statement

Fertilizer plants in North Dakota have barely begun to comply with the RMP guidelines which were published to help prevent their products from interfering with the environment. Environmental regulations have been "the strongest driving force behind the numerous sellouts and mergers of recent years" (Henley, p. 22). Future regulation of the fertilizer industry is uncertain at present, and it is difficult to foresee what additional regulations, if any, will be placed on the industry. However, given the increase in public concern over environmental issues and safeguarding resources for the future, continued regulation is likely. Concern for the environment and safety of resources are issues that are also promoted by private sector firms (Batie, p. 1). "Federal institutions are declining in importance, and international and local institutions are rising in importance" (Batie, p. 1). Furthermore, "private-public/quasi-public (i.e., nongovernmental organizations)" have begun to develop and present environmental programs (Batie, p. 1). Batie's view is also supported by a New York Times editorial which states, " . . . while people may have legitimate gripes about government regulation, they have no wish to dismantle a quarter-century of bipartisan legislation protecting the country's air, water, and public lands" ("Newt," p. E4).

The federal government has not adopted uniform nationwide regulations for regulating fertilizer storage and transportation. However, some state governments, such as Minnesota, Montana, and Indiana, adopted their own regulations for fertilizer storage and transportation. Although North Dakota has not created new regulations, it has created the RMP and has asked fertilizer plants to begin compliance with these guidelines. Some fertilizer plants brought their facilities into compliance with the RMP guidelines, but others have not. During the past year, representatives of the fertilizer industry in North Dakota approached the NDDHCL about introducing legislation that would create and support consistency within the industry (Vandel, 1996).

As the RMP measures were implemented, cost of operation, transportation, and storage of fertilizer changed. "While some severe tradeoffs between environmental protecting and profitable activities do exist, there is a growing suite of complementary technologies and information that provides opportunities to improve both the environment and profits" (Batie, p. 1). Therefore, fertilizer plants will need to evaluate their current operations and consider whether upgrading equipment and facilities, to comply with RMP guidelines, is profitable. If upgrading is not profitable, the firm may exit the industry. The economic consequences of fewer fertilizer plants are not clear. A potential problem with the exit of many fertilizer plants is the fertilizer industrys concentration could increase. A possible benefit of exit is that economies of size could lower operating costs for fertilizer plants and ultimately lower fertilizer purchase costs for farmers.

## Objectives

The objectives of this case study were to compare how compliance with the RMP guidelines affects the logistical, operating, and investment costs of fertilizer plants and evaluate the effect on fertilizer plant size and the market structure of the fertilizer industry. To accomplish these objectives, it was important to do the following:

1. Identify federal and state hazardous materials regulations affecting agricultural fertilizer storage and transportation;
2. Determine the number, location, and storage capacity of fertilizer plants in Cass County, N. D. and the townships immediately surrounding Cass County in North Dakota;[1]
3. Estimate the farm demand for fertilizer in Cass County, N. D. and the fringe;
4. Estimate the fixed costs of establishing and variable costs of operating the different sizes of liquid and dry fertilizer plants;
5. Estimate the costs of transporting fertilizer from distributor to plant to farm, and estimate the cost of fertilizer application.

## Research Method

It was assumed that fertilizer plants have limited, if any, alternative uses for invested capital because of the hazardous nature of materials they handle and store. It was also assumed that established fertilizer plant facilities were depreciated to zero in this case study. Therefore, the assumptions and observations about elevators in Lytle and Hill can also be applied to fertilizer plants because established

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[1]The townships immediately surrounding Cass County, N. D. within North Dakota are referred to as the "fringe."

fertilizer plants and country elevators will probably have similar reactions to new firms entering their respective markets (p. 205). Furthermore, established fertilizer plants in this case study should also be able to "ignore depreciation costs [sunk costs] except on purchases of new equipment [or facilities] . . ." (Lytle and Hill, p.205). Lytle and Hill concluded that the "inclusion of competitive techniques and managerial restrictions in the models adds realism to the solutions . . . And importantly, the approach of this study can handle the micro-market region conflict of recommending expansion to each individual firm while recommending contraction to the industry as a whole" (p. 207).

A cost-minimizing, mixed-integer linear programming model was created and used to determine optimum dry and liquid fertilizer plant sizes and locations. This model was employed in four scenarios to optimize fertilizer plant sizes and locations, and estimate transportation costs from manufacturer to fertilizer plant, fixed operating costs, variable operating costs, transportation costs from fertilizer plant to farm, and application costs.

Scenario 1 - Full Cost Baseline. This is a baseline model where plant capacities were forced to represent the 1994 structure of the fertilizer industry in Cass County, N. D., and liquid fertilizer plants were forced to bring their current facilities into compliance with the RMP guidelines. Full cost was defined to include the fixed and variable operating costs, transportation costs from manufacturer to plant, transportation costs from plant to farm, and fertilizer application cost.

Scenario 2 - Sunk Capital Hypothesis Baseline. The sunk costs of existing fertilizer plants were subtracted from the Scenario 1 model, and liquid fertilizer plants were forced to bring their current facilities into compliance with RMP guidelines. Existing plant fixed costs associated with construction, purchase, and depreciation were subtracted because accrued fixed costs do not affect firm decision making. Thus, this model provided a second baseline solution for sizes, locations, and types of fertilizer plants in Cass County, N. D.

Scenario 3 - Full Cost with Investment. In this scenario, all costs associated with upgrading the liquid fertilizer plants to meet RMP guidelines were included. In addition, the fertilizer plants were also allowed to expand their dry or liquid storage capacity, remain at the same capacity, or exit the industry. The model provided a preliminary solution for sizes, locations, and types of fertilizer plants in Cass County, N. D., when the industry is in compliance with RMP guidelines.

Scenario 4 - Sunk Capital Hypothesis with Investment. In this scenario, as in Scenario 2, the sunk costs of existing fertilizer plants were subtracted and all fixed costs associated with upgrading the liquid fertilizer plants to meet RMP guidelines were included. It is different from Scenario 2 in that the fertilizer plants were allowed to expand their dry or liquid fertilizer storage capacity, remain at the same capacity, or exit the industry. This model provided a solution for sizes, locations, and types of fertilizer plants when in compliance with RMP guidelines.

The market region model and solution from Lytle and Hills study resemble the model and solutions used and obtained in Scenarios 2 and 4 of this case study. In Scenario 2, the sunk capital hypothesis was implemented to obtain a second baseline scenario; and in Scenario 4, fertilizer plants were allowed to increase the size of their current facilities, if desired, or exit the market.[2]

Lytle and Hill found that the "cost of capital (or returns on investment) required for Firm A [the new firm] had a significant effect on its competitive role in the structural adjustments of the region" (p.206). In general, higher returns to capital helped existing firms retain their position in the industry,

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[2]In this case study, fertilizer plants are not allowed to decrease their fertilizer storage capacity.

and lower returns to capital helped the new firm establish itself (p. 206). Therefore, if the cost of building existing elevator facilities is not subtracted from fixed costs, the result is a competitive advantage for the new firm [a firm planning to increase its storage capacity] within the model.

The same effect resulted in Scenarios 1 and 3 of this case study because depreciation costs associated with existing fertilizer facilities were not subtracted from fixed operating cost. The inclusion of depreciation costs, in effect, raised the fixed costs for existing fertilizer plants by a comparable amount and may result in a competitive advantage for firms choosing to increase their storage capacity in the model. The advantage is that returns on capital investment for fertilizer plants that decide to increase storage capacity in the model may be represented by returns on capital proportionately higher than those of fertilizer plants that remain at the same storage capacity.

A comparison of Scenarios 3 and 4 in this case study illustrated how the sunk capital hypothesis affected fertilizer plant decisions regarding compliance with the RMP and increasing their fertilizer storage capacity. In Scenario 3, fertilizer plants choosing to increase their fertilizer storage capacity may have had an unfair competitive advantage because other firms had an unnecessarily high fixed operating cost. In Scenario 4, however, the fertilizer plants were "put on a level playing field" because construction, purchase, and depreciation costs already incurred by existing plants were subtracted from fixed operating cost.

## Thesis Organization

A description of federal and state hazardous materials regulations pertaining to agricultural fertilizers is presented in Chapter 2. The RMP written and distributed to North Dakota fertilizer plant managers by the NDDHCL isdiscussed, as it is North Dakotas most current statement on the transport and storage of agricultural fertilizers.

In Chapter 3, the construction of the empirical model is presented. A description of the variable and fixed costs, equipment costs, and transportation costs for both liquid and dry fertilizer plants will follow in Chapter 4, as well as a discussion of each component associated with upgrading and enlarging a liquid fertilizer plant. The empirical results of running the model are discussed in Chapter 5. A summary of the results, conclusions, implications, and limitations of this case study is presented in Chapter 6.

## CHAPTER 2. FERTILIZER INDUSTRY MARKET STRUCTURE

This chapter reviews literature related to the transportation or storage of fertilizer. Industry trends and competitive forces within the fertilizer industry will be analyzed using Porter's competitive forces (p. 4). A description of federal and state hazardous materials regulations pertaining to the transportation and storage of agricultural fertilizers also is presented.

### Literature Review

This literature review contains a summary of the limited number of articles related to the transportation or storage of fertilizer. In spite of national public concern about hazardous materials, such as fertilizers, few studies analyzing fertilizer transportation or storage have been published. While there may be additional studies that identify the type, volume, and number of fertilizer shipments, only one study combined that type of information with storage and handling regulations.[3]

The NDDHCL prepared the RMP for fertilizer plants in North Dakota "in response to environmental contamination incidents that have been detected at bulk fertilizer storage/handling facilities" (p. 1). The nine page document describes the NDDHCL's "recommended practices for the primary and secondary containment of fertilizer compounds with the intent to identify practices that can reduce the potential for soil, surface, or ground water contamination" (p. 1). The RMP briefly discusses six different topics related to fertilizer, four of which have more importance in this case study.[4] They are as follows: Section II. Liquid Fertilizer; Section III. Operational Containment of Liquid Fertilizer;

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[3]For more information about this study prepared for the state of Indiana, refer to Rogers, Duane S., and Jay T. Akridge. "The Economic Impact of Storage and Handling Regulations on Retail Fertilizer and Pesticide Plants." Accepted for Publication in Agribusiness: An International Journal. Purdue: Purdue University Agricultural Experiment Station, 1996.

[4]This listing is not meant to lessen the importance of Section I. Site Guidelines and Section VI. Accident Discharge Response Plan. The information in these two sections is an integral part of building and running a fertilizer plant. However, the fertilizer plant is assumed to already be located at an approved site, and the accident response plan is a managerial decision which is beyond the scope of this case study.

Section IV. Secondary Containment of Liquid Bulk Fertilizer; and Section V. Storage and Handling of Dry Fertilizer. Section II. Liquid Fertilizer, summarizes the basic guidelines for fertilizer storage tanks. In addition, the inspection and maintenance, security, and abandoning of fertilizer storage tanks are reviewed. Section III deals with primary containment at fertilizer facilities and includes recommendations for loading pads and protection of storage containers. Section IV contains general and specific recommendations for secondary containment facilities. Important aspects regarding dry fertilizer storage and handling are discussed in Section V.[5]

The RMP refers to Kammel et al. as a source of additional information and as the basis for its recommendations and guidelines. This report is "intended to be a desk reference that provides **recommendations** based on accepted engineering principles and practices. These recommendations are necessarily conservative because national circulation of this book precludes situation specific design" (Kammel et al., p. 1). Designing Facilities for Pesticide and Fertilizer Containment does not create standards for facility design and should be used as a point of reference that can be modified for individual circumstances (Kammel et al., p. 1). The book covers a wide array of topics including the following: laws regulating the fertilizer and pesticide industries, worker safety, pesticide and fertilizer storage, secondary containment, emergency response, maintenance of the facilities, as well as other topics related to fertilizer and pesticide management. This book is the basis for the RMP created by the NDDHCL, and thus is the basis for the design assumptions of primary and secondary liquid fertilizer storage facilities in this case study.

Dahl et al. examined the effect of sales area size, sales density, volume, and equipment configuration on the custom application cost of bulk fertilizer. This is the only known study regarding dry fertilizer in North Dakota that breaks down the investment and operation costs for dry fertilizer

[5]The recommended guidelines for dry fertilizer storage do not include any large investment costs.

plants. Data about construction and annual operation costs were gathered for six dry fertilizer storage facility sizes prevalent in North Dakota (Dahl et al., p. iv). Information about dry fertilizer plant sizes and fertilizer plant equipment gathered by Dahl et al. was adapted for this case study

Rogers and Akridge developed a budgeting model to approximate the "cost of retailing dry bulk fertilizer, liquid bulk fertilizer, anhydrous ammonia, and pesticides for three sizes of facilities" for plants in Indiana (p. i). Two objectives of their study were to assess the costs related to upgrading existing fertilizer plants to conform with regulations on containment of fertilizers and pesticides and to estimate the effect of an increase in investment costs on the profitability of these fertilizer plants (Rogers and Akridge, p. 1). Estimates of the cost to upgrade the three plant sizes to comply with Indianas fertilizer and pesticide regulations were gathered and used in their budgeting model. They also compared two strategies that could be used to offset the investment cost. They are increasing plant volume and increasing price (Rogers and Akridge, p. 2). The final objective was to "estimate the economic impact of the new regulations on the retail industry in Indiana" (Rogers and Akridge, p. 2). The fertilizer industry [in Rogers and Akridge] was described by using Porter's analysis, which views an industry in terms of five competitive forces: the threat of new entrants, rivalry among existing firms, threat of substitute products or services, bargaining power of buyers, and bargaining power of suppliers (p. 5). Rogers and Akridge found that significant economies of size are associated with compliance and that smaller plants generally have a harder time justifying the investment than larger plants (p. 17).

Tolliver et al. created an "inventory of hazardous commodities that originate in, terminate in, or pass through Region 8," which includes North Dakota (p. iii). Hazardous shipments are classified by originating and terminating business economic units (BEAs). Although BEAs normally do not conform to state boundaries, the four BEAs comprising North Dakota follow state boundaries fairly close. Therefore, the study reflects hazardous materials shipments by rail in North Dakota quite accurately. The project identifies the number and volume of hazardous materials shipments originating and terminating in North Dakota and also attempts to identify shipments passing through North Dakota. This study is strictly an inventory of all hazardous materials shipments by standard transportation commodity codes (STCC) and does not classify shipments for a specific industry or examine any regulatory changes with respect to the transport of hazardous materials.[6]

This case study does not consider the risk costs that may be involved with the transport and storage of agricultural fertilizers. Risk costs are associated with a hazardous materials release or spill. The majority of risk costs are legal settlement expenses, followed by environmental expenses, equipment damage, and lading loss (Dennis, p. 21).[7]

Dennis found that "the proportion of risk costs attributable to environmental expenses increased three-fold in the 1982-1992 period [as compared to the 1971-1981 period covered by a previous study] . . . The proportion of risk costs attributable to legal settlement expenses declined by 14 percentage points to a little over half of total risk costs, and the proportion of risk costs attributable to equipment damage also fell [when compared to the 1971-1981 period]" (p. 21). Dennis concludes that the change in "risk costs between the two periods reflects a variety of trends" (p. 23). Those trends include expanding liability under environmental laws, "the added expense of increasingly stringent remediation requirements," fewer injuries and deaths associated with hazardous materials releases, and changes in the type of major hazardous material release (p.23). Dennis' study considered only major releases of hazardous materials and should be considered a "minimum estimate of total risk cost incurred . . . because it was not possible to obtain complete coverage of all major releases and expenses" (p. 25). An

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[6]Standard transportation commodity codes (STCC) are five- or seven-digit numbers assigned to every commodity. Each digit in the STCC represents a characteristic of the commodity. For instance, all hazardous material STCC begin with 49 in the first two digits of their seven digit code. The 49 means the commodity is a hazardous material.

[7]Lading loss is a spill that occurs during loading or unloading.

analysis of risk costs in this case study would have been difficult. A risk cost analysis also would have been time and resource consuming, as well as beyond the scope of this case study.

**Fertilizer Plants**

A listing of the names and addresses of all fertilizer plants operating in North Dakota in 1994 was obtained from the NDDHCL and the Directory of Fertilizer Plants - 1992. The NDDHCL listing and fertilizer directory identified 32 possible dry and liquid fertilizer plants in Cass County, N. D. and the surrounding fringe area. Inclusion in the data collection process for this case study meant that the fertilizer plant operated in Cass County, N. D. (minus Reed and Barnes townships, which are the residential areas of Fargo and West Fargo) or one of the 23 surrounding fringe townships. Due to time, resource, and computing power constraints, this case study was limited to an analysis of fertilizer plants operating in Cass County and the surrounding fringe.

Cass County and the surrounding fringe are shown in Figure 2.1. The Cass County border was indicated by the heavy black lines, and township borders are represented by the thinner black lines. The townships were numbered for identification. Fertilizer plants, though only identified by number in the text and tables, were located as close to their "real world" location as possible within the model. The area was split into four quadrants in this study. The quadrant division lines are I-94 and Highway 18, which are shows in bold and thin grey lines, respectively.

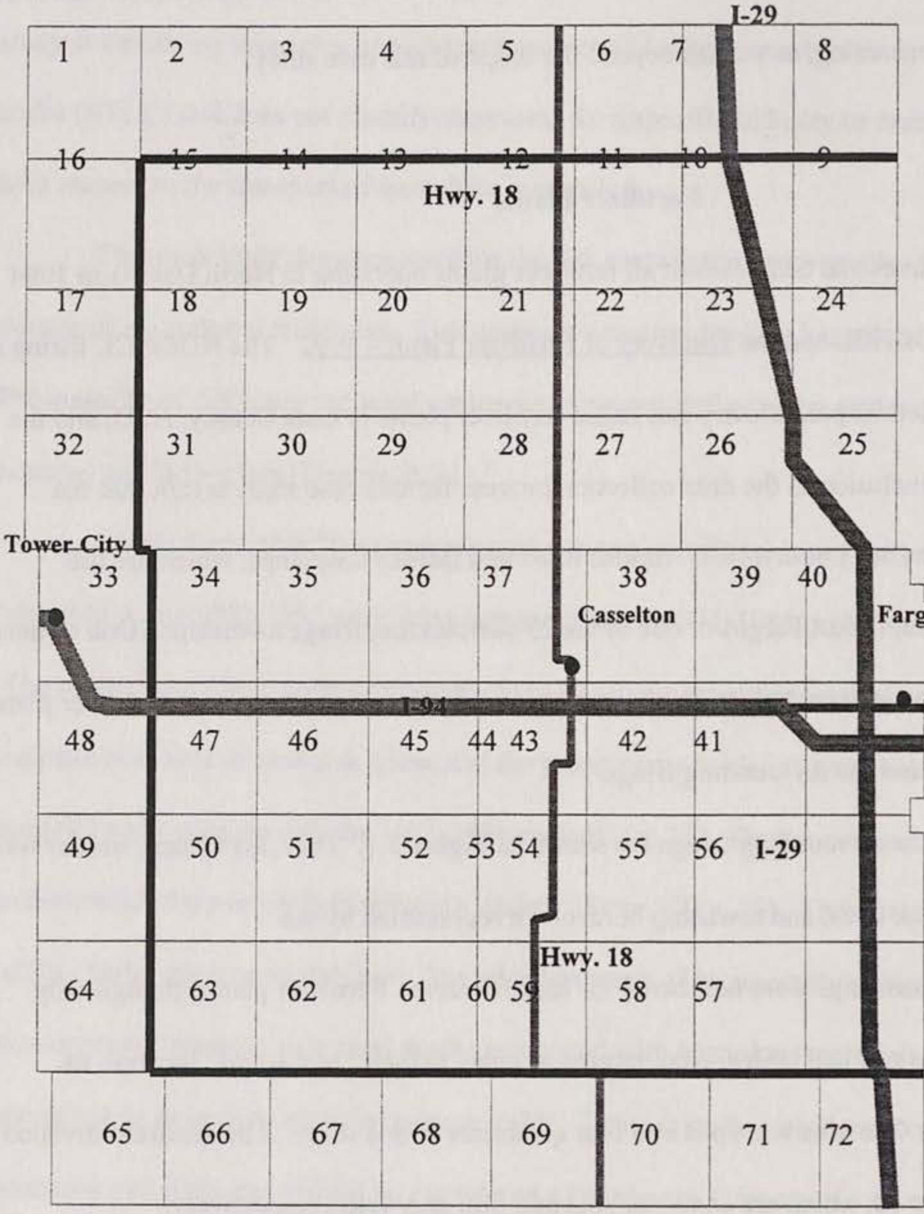


**Figure 2.1. Cass County Townships and Surrounding Fringe Townships, North Dakota.**

## Industry Trends and Competitive Forces

If implemented in North Dakota, the RMP guidelines would require many fertilizer managers to upgrade their current fertilizer containment facilities. Making the necessary upgrades would increase capital spending, thus affecting overall profitability. To better understand how the fertilizer industry structure and profitability may react to changes; industry trends and an analysis of competitive forces affecting the fertilizer industry are presented.

### *Industry Trends*

The United States is a leading fertilizer producer for the world (U. S. Industrial Outlook 1994, p. 11-13). The United States also leads in phosphate production and ranks third in the production of ammonia (U. S. Industrial Outlook 1994, p. 11-13). "Because of demand and cost pressures, the number of fertilizer companies [manufacturers] in the United States has declined in recent years. Economic trends, climatic conditions, and government programs that encourage farmers to reduce planted acreage directly affect demand for and supply of fertilizer chemicals" (U.S. Industrial Outlook 1994, p. 11-13).

The United States is forecast to continue leading world consumption, production, and trade of phosphatic fertilizer for the remainder of the 1990s, although it will continue to lose some of its world market share (U.S. Industrial Outlook 1994, p. 11-15). Real growth in the United States nitrogenous and phosphatic fertilizers is projected to be between 1 and 2 percent annually (U.S. Industrial Outlook 1994, p. 11-14). This growth rate is a reflection of the uncertainty in export markets (U.S. Industrial Outlook 1994, p. 11-1).

*Competitive Forces*

This analysis of the retail fertilizer industry is derived from Porters theory on the five forces driving industry competition: the threat of new entrants, rivalry among existing firms, threat of substitute products or services, bargaining power of buyers, and bargaining power of suppliers (Porter, p. 5). According to Porter, "the collective strength of these [five] forces determines the ultimate profit potential in the industry . . ." (p. 3).

The threat of new entrants to an industry brings new capacity, desire for market share, and often considerable resources (Porter, p. 7). A firm considering entry at the retail level of the fertilizer industry must be prepared to overcome many barriers.[8] Economies of size are inherent in the retail fertilizer industry, meaning the new entrant must acquire substantial volume quickly to produce profit (Rogers and Akridge, p. 3). Another possible barrier is government involvement in the industry. Many aspects of the retail fertilizer industry are already regulated, including transport of fertilizers and reporting of spills. Government has taken a more active role in the retail fertilizer industry over the past twenty years and is expected to increase its future involvement (Rogers and Akridge, p. 3). Rogers and Akridge believe the existence and threat of government regulation serves as an entry deterrent in the retail fertilizer industry (p. 3).

The second competitive force is rivalry among existing firms. Several factors have lead to fierce rivalry in the retail fertilizer industry. First, the retail fertilizer industry can be classified as a mature industry. In mature industries, the rate of growth has peaked and begun to decline (Porter, p. 21). The mature stage of the retail fertilizer industry in the United States is also recognized by the U. S. Industrial Outlook 1994. "Total U. S. nutrient [fertilizer] consumption in 1993 was projected at 20 million short tons, down 4 percent from 1992. Nitrogen was projected at about 11 million tons, down more than 4

[8]Porter identifies six potential barriers to entry: economies of size, product differentiation, capital requirements, switching costs, access to distribution channels, and government policy (p. 7-13).

percent from 1992; phosphates at 4 million tons, down more than 2 percent, and potash at 5 million tons, down 4 percent" (p. 11-13). Dahl, Cobia, and Dooley concur, noting that, "Fertilizer usage in North Dakota, which increased steadily from 1950 to 1980, has leveled off" (p. 1).

A second influence on rivalry is exit barriers. Exit barriers, such as specific assets, fixed costs of exit, and strategic interrelationships, are factors that may keep a plant in operation even though it is netting low or negative returns (Porter, p. 20). The retail fertilizer industry is typified by specific assets, meaning the assets are only useful in one business or location. Fertilizer storage facilities are both use-specific and site-specific. It would be difficult to clean and move fertilizer storage facilities for use by another business, other than the storage of chemicals for an agricultural or industrial use.

High fixed costs of exit may also be associated with fertilizer plants because of the hazardous nature of some fertilizers. The land on which the fertilizer plant operates and where the fertilizer is stored may be difficult to sell because of its previous use. The land site and any groundwater will certainly be tested for contamination before resale. Cleanup is quite costly if contamination exists, and the current owner is responsible for cleanup costs. Furthermore, in North Dakota a number of fertilizer plants are associated with another agriculture related business. Many fertilizer plants in North Dakota have strategic interrelationships with elevators because they operate on the same site or under the same management[9]. In industries where high exit barriers exist, "excess capacity does not leave the industry, and companies that lose the competitive battle do not give up" (Porter, p. 21). Low profitability for the entire industry is the result.

The threat of substitute products or services is the third competitive force recognized by Porter. Industry profitability is affected by the threat of substitute products or services. "Substitutes limit the

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[9]Strategic interrelationships with elevators or another firm may affect fertilizer plant decisions to remain in operation or exit the industry. Firms with strategic interrelationships may be better able to maintain their position in the industry because they are able to share costs with another firm.

potential returns of an industry by placing a ceiling on the prices firms in the industry can profitably charge" (Porter, p. 23). Substitutes are available for some services in the retail fertilizer industry. One substitute, noted by Rogers and Akridge, is when farmers fulfill some or all of the fertilizer plant functions (p. 3). They also acknowledged that "more and more specialists and consultants are emerging who are providing the same services a dealer [fertilizer plant] provides" (Rogers and Akridge, p. 3). Although in the past farmers generally took responsibility for application of fertilizer at their farm, future government regulation of the retail fertilizer industry may cause farmers to turn back to fertilizer plants for custom application.

Porter's fourth competitive forc, bargaining power of buyers, has a substantial effect on profitability in the retail fertilizer industry. Since fertilizers are for the most part standard and can be purchased from a number of plants, farmers have the option to shop around for the best price and service.

Bargaining power of suppliers [fertilizer manufacturers] is the final competitive force. Production of agricultural fertilizers is controlled by a few companies; therefore, the manufacturing side of the fertilizer industry is much more concentrated than the retail fertilizer industry (Rogers and Akridge, p. 4). "Suppliers selling to more fragmented buyers will usually be able to exert considerable influence in prices, quality, and terms" (Porter, p. 27).

In their review of the five competitive forces, Rogers and Akridge proposed that the retail fertilizer industry is not apt to be very profitable. Although the threat of new entrants in the retail fertilizer industry is low, creating a positive effect on industry profitability, the following competitive forces have an adverse effect on the retail fertilizer industrys profitability: rivalry among existing firms, threat of substitute products or services, bargaining power of buyers, and bargaining power of suppliers. Government regulation in the retail fertilizer industry, which would increase start-up costs for retail fertilizer plants, is critical in determining future profitability in the retail fertilizer industry (Rogers and Akridge, p. 5). In an industry where both high entry and exit barriers exist, "profit potential is high, but is usually accompanied by more risk. Although entry is deterred, unsuccessful firms will stay and fight in the industry" (Porter, p. 22).

## Federal and State Regulations

### *Federal Regulation*

The Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Department of Transportation (DOT) are the main federal agencies responsible for regulating agricultural fertilizers. The laws enforced by these federal agencies are minimum requirements. State and local governments can either refer to the federal laws or create their own laws with higher minimum requirements. State and local laws can be "equal to or more stringent than federal laws and regulations but not less stringent" (Kammel et al., p. 4).

The EPA regulates "air and water pollution, safe drinking water, solid and hazardous waste management, radiation, toxic substances and pesticides," and also oversees environmental programs at the state and local level (Kammel et al., p. 3). Transportation of hazardous materials in any mode is regulated by the DOT. Workers in manufacturing and distributing operations are protected by OSHA, the government agency responsible for worker safety. The list of federal laws affecting the retail fertilizer industry is as follows:

1. Resource Conservation Recovery Act. The Resource Conservation Recovery Act (RCRA), implemented in 1976, regulates solid and hazardous waste management. It also covers "generating, transporting, storing, treating and disposing waste that may pose a threat to human life, health or the environment" (Kammel et al., p. 3).
2. Clean Air Act. Stationary and mobile sources of air pollution are regulated by the Clean Air Act (CAA) of 1990. CAA regulations include dusts, vapors and fumes from . . . fertilizer plants" (Kammel et al., p. 3).

3. Clean Water Act. "The Clean Water Act (CWA) and its amendments address the discharges of point source and non-point source pollutants in surface and ground water. Spills and point source run-off that enter water from a facility are regulated under this act" (Kammel et al., p. 3). A related act, the Safe Drinking Water Act (SDWA) stresses the protection of drinking water (Kammel et al., p. 3).

4. Comprehensive Environmental Response, Compensation, and Liability Act. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), enacted in 1980, allows the government to clean up a contaminated site and then seek reimbursement from responsible parties (Kammel et al.). The generator of the contamination also is held forever responsible by CERCLA. This act is sometimes referred to as Superfund. "Title III of Superfund Amendments and Reauthorization Act (SARA), known as the Emergency Planning and Community Right To Know Act, revises and expands the Superfund Act. It requires owners/operators of facilities to advise communities of the types and amounts of hazardous chemicals or pesticides used and stored at a site so a community can plan for emergency situations" (Kammel et al., p. 3).

5. Worker Right to Know Act. OSHA, the federal agency responsible for worker safety, administers the Worker Right to Know Act. This act creates compulsory guidelines for handling hazardous materials (Kammel et al., p. 3).

6. Material Safety Data Sheets. The Worker Right-to-Know Law, SARA, and Emergency Planning and Community Right-to-Know Law require that Material Safety

Data Sheets (MSDS) be provided with fertilizers upon request (Kammel et al., p. 3). MSDS must be obtained from the manufacturer.[10]

***State Regulation***

North Dakotas retail fertilizer industry is regulated by the NDDHCL. The NDDHCL recently developed the RMP guidelines for fertilizer plants. The RMP includes guidelines for site location, storage and handling of liquid fertilizer, storage and handling of dry fertilizer, and an accidental discharge response plan. Although these recommendations are not law, following these guidelines would bring North Dakota fertilizer plants up to the standards set by states that regulate their fertilizer industries.

**Summary**

The references summarized in this chapter helped to form the assumptions describing fertilizer plants in Cass County, N. D. The North Dakota RMP specifically refers to Kammel et al. Therefore, the material and construction recommendations provided by Kammel et al. were the basis for assumptions related to liquid fertilizer plant upgrades and the construction of containment facilities in this case study. The liquid and dry fertilizer plant sizes and the costs associated with each plant size used in this case study were supported by Dahl et al. and by Rogers and Akridge. The cost calculations for liquid plant upgrades in this case study are consistent with Henley's projected costs for diking and other compliance measures (p. 22).

[10]For further information about these federal regulations, refer to Kammel et al.

# CHAPTER 3. EMPIRICAL MODEL

## Objective Function

A mixed-integer linear programming (MIP) model was used in this case study to minimize the cost of operating fertilizer plants in Cass County and the surrounding fringe townships in North Dakota. The objective function sums fixed and variable operating costs of fertilizer plants, transportation cost of bringing fertilizer into the plant, cost of transporting fertilizer from the plant to farm, and fertilizer application costs. All costs are calculated on a per ton basis, except for application cost which is calculated on a per acre basis.

The mixed-integer linear programming approach to solving location problems is referred to as "perhaps the most promising" of all methods used in solving location problems (Ballou, p. 337).[11] Ballou notes the main "benefit associated with the mixed-integer linear programming approach - a benefit not always offered by other methods - is its ability to handle fixed costs in an optimal way." (p. 339). The main disadvantage of the MIP approach is that complex problems tend to require long computer running times and substantial computer memory (Ballou, p. 339). Ballou also noted that the solution to a "real-world location problem can be no better than the models description of the problem realities" (p. 342).

Ballou describes and discusses a warehouse location problem that can be adapted to describe the fertilizer plant location problem in this case study (p. 339). The location problem in this case study can be solved by determining the number, size, and location of dry and liquid fertilizer that will minimize

[11]For more references in support of this viewpoint, refer to the following: Geoffrion and Graves, "Multicommodity Distribution System Design by Benders Decomposition," Management Science, 20, no. 5 (January 1974), 822-44; Bender, Northrup, and Shapiro, "Practical Modeling for Resource Management," Harvard Business Review, 59, no. 2 (March-April 1981), 163-73; and Karrenbauer and Graves, "Integrated Logistics Systems Design" in Masters and Coykendale, Eds., "Logistics Education and Research: A Global Perspective," Proceedings of the Eighteenth Annual Transportation and Logistics Educators Conference (St. Louis, MO: October 22, 1989), 142-71.

fixed and variable costs associated with transporting fertilizer and operating fertilizer plants in Cass County and the surrounding fringe.

Location problems can be solved using general integer linear programming computer software. LINDO was used to solve the model in this case study. A "mathematical programming software package available on the NDSU mainframe computer," LINDO finds an initial solution, then changes the location or size of the fertilizer plants one by one to determine if the change increases or decreases total cost (Dooley et al., p. 19). After all possible changes are tried, the solution with the lowest total cost is chosen as the optimal solution.

## The Mathematical Model

Four similar models were used to evaluate the effect of hazardous materials regulations on the optimal number and size of fertilizer plants in this case study. The basic model is presented in this section. The model assumes that the retail fertilizer industry strives to minimize total fixed and variable operating costs, transportation costs, and application costs, subject to several specific constraints. The objective function form is as follows:

$$
\begin{aligned}
(3.1)\, Minimize\ Cost = {} & [\sum_{mp} DTRANCOST_{mp}\ DRYTONS_{mp} + \sum_{np} LTRANCOST_{np}\ LIQTONS_{np}] \\
& + [\sum_{pi} DRYFC_{pi}\ DIS_{pi} + \sum_{pj} LIQFC_{pj}\ LIS_{pj} + \sum_{pij} FIRMFC_{pij}\ FIS_{pij}] \\
& + VC\ [\sum_{pi} DTONS_{pi} + \sum_{pj} LTONS_{pj}] \\
& + TRANCOST_{pf}\ [\sum_{pf} TRFD_{pf} + \sum_{pf} TRFL_{pf}] \\
& + APPCOST_{f}\ [\sum_{f} DAPP_{f} + \sum_{f} LAPP_{f}]
\end{aligned}
$$

where:

Cost is the sum of fertilizer transportation cost from manufacturer to fertilizer plant, fixed operating cost, variable operating cost, fertilizer transportation cost from fertilizer plant to farm, and application cost for fertilizer plants operating in Cass County and the surrounding fringe townships in North Dakota.

The value of $m$ indicates the dry fertilizer origination point, $m = 1$ or 2, where 1 denotes that the dry fertilizer was transported by truck from Minneapolis, Minn., and 2 denotes that the dry fertilizer was transported by rail from Tampa, Fla.

The value of $p$ represents the different fertilizer plant locations, $p = 1 - 7, 10 - 19, 21 - 23$, and 25 - 28. (The numbers are not consecutive, because some locations were eliminated from the case study.)

The value of $n$ indicates the liquid fertilizer origination point, $n = 1$ or 2, where 1 denotes that the liquid fertilizer originated in Enderlin, N. D., and 2 denotes that the liquid fertilizer originated in Hendrum, Minn.

$DTRANCOST_{mp}$ is the cost of transporting one ton of dry fertilizer from manufacturer $m$ to fertilizer plant site $p$.

$DRYTONS_{mp}$ is the annual number of tons of dry fertilizer transported from manufacturer $m$ to fertilizer plant site $p$.

$LTRANCOST_{np}$ is the cost of transporting one ton of liquid fertilizer from manufacturer $n$ to fertilizer plant site $p$.

$LIQTONS_{np}$ is the annual number of tons of liquid fertilizer transported from manufacturer $n$ to fertilizer plant site $p$.

The value of $i$ represents the different sized dry fertilizer plants possible at each location, $i = 1, 2, 3, 4$ correspond to dry fertilizer plants Size A, B, C, and D which have annual storage capacities of 1,395 tons, 2,232 tons, 3,627 tons, and 5,580 tons, respectively.

The value of $j$ represents the different sized liquid fertilizer plants possible at each location, $j = 1, 2, 3$ correspond to liquid fertilizer plants Size A, B, and C which have annual storage capacities of 279 tons, 1,395 tons, and 5,022 tons, respectively.

$DRYFC_{pi}$ is the annual fixed cost of constructing and operating a dry fertilizer plant of size $i$ at fertilizer plant site $p$.

$DIS_{pi}$ is a binary (0-1) integer variable that allows the annual fixed cost of constructing and operating a dry fertilizer of size $i$ at fertilizer plant site $p$ to be added to total cost. $DIS_{pi}$ will equal one if dry plant $p$ at size $i$ is open, and zero otherwise.

$LIQFC_{pj}$ is the annual fixed cost of constructing and operating a liquid fertilizer plant of size $j$ at fertilizer plant site $p$.

$LIS_{pj}$ is a binary (0-1) integer variable that allows the annual fixed cost of constructing and operating a liquid fertilizer of size $j$ at fertilizer plant site $p$ to be added to total cost. $LIS_{pj}$ will equal one if liquid plant $p$ at size $j$ is open, and zero otherwise.

$FIRMFC_{pij}$ is the annual joint "firm" fixed cost associated with operating both a dry fertilizer plant of size $i$ and a liquid fertilizer plant of size $j$ at the same fertilizer plant site $p$. "Firm" fixed costs are those costs associated with operating a dry fertilizer plant and operating a liquid fertilizer plant that are the same. For instance, licensing fees or labor expenses are considered firm fixed costs.

$FIS_{pij}$ is a binary integer variable that allows the annual joint "firm" fixed cost associated with operating a dry fertilizer plant of size $i$ and a liquid fertilizer plant of size $j$ at the same fertilizer plant site $p$ to be added to total cost.

$VC$ is the variable cost per ton of operating a dry or liquid fertilizer plant.

$DTONS_p$ is the number of tons of dry fertilizer transported to fertilizer plant site $p$.

$LTONS_p$ is the number of tons of liquid fertilizer transported to fertilizer plant site $p$.

The value of $f$ identifies the different farms by their township and location within the township, $f$ = FA01, FA02, FA03, . . . , FD39, FA42, . . . , FD72. A, B, C, and D represent the NW, NE, SE, and SW quarters of each township, respectively. Farm FA01 is located in the NW quarter of township 01, and farm FA02 is located in NW quarter of township 02, etc.

$TRANCOST_{pf}$ is the cost of transporting one ton of fertilizer, either dry or liquid, from fertilizer plant $p$ to farm $f$.

$TRFD_{pf}$ is the number of tons of dry fertilizer transported from fertilizer plant site $p$ to farm $f$.

$TRFL_{pf}$ is the number of tons of liquid fertilizer transported from fertilizer plant site $p$ to farm $f$.

$APPCOST_f$ is the average cost of custom applying one ton of fertilizer, either dry or liquid, at farm $f$.

$DAPP_f$ is the number of tons of dry fertilizer applied at farm $f$.

$LAPP_f$ is the number of tons of liquid fertilizer applied at farm $f$.

**Constraints**

The objective function, equation 3.1, is minimized subject to constraints 3.2 through 3.17. The first constraint, equation 3.2, states that there is an unlimited supply of dry fertilizer from all manufacturers. $DRYTONS_{mp}$ represents the tons of dry fertilizer produced annually for transport to Cass County and the surrounding fringe townships in North Dakota.

$$(3.2)\ \sum_p DRYTONS_{mp} \geq 0 \ \ for\ all\ m.$$

Equation 3.3 states that there is an unlimited supply of liquid fertilizer from all liquid fertilizer manufacturers. $LIQTONS_{np}$ represents the tons of liquid fertilizer produced annually for transport to Cass County and the surrounding fringe townships in North Dakota.

$$(3.3)\ \sum_{p} LIQTONS_{np} \geq 0 \text{ for all } n.$$

Equations 3.4 and 3.5 are transfer rows which transfer dry and liquid fertilizer from the manufacturer to the variable costing activity for dry and liquid fertilizer, respectively. The dry and liquid fertilizer is stored upon arrival at the fertilizer plant and variable operating costs are realized in the objective function. In the model, variable operating costs are constant across all sized plants for both dry and liquid fertilizer.

$$(3.4)\ \sum_{m} DRYTONS_{mp} - DTONS_{p} \geq 0 \text{ for all } p.$$

$$(3.5)\ \sum_{n} LIQTONS_{np} - LTONS_{p} \geq 0 \text{ for all } p.$$

Equation 3.6 is the capacity constraint for dry fertilizer plants of size $i$. $DCAP_i$ is the storage capacity for the four sizes of dry fertilizer plants: A, B, C, and D. Equation 3.7 is the capacity constraint for liquid fertilizer plants at size i, and it works in the same manner as equation 3.6. $LCAP_j$ is the storage capacity for the three sizes of liquid fertilizer plants: A, B, and C. Equations 3.6 and 3.7 state that the volume of fertilizer realized in the variable costing activity ($DRYTONS_{mp}$ or $LIQTONS_{np}$) must be less than the annual plant capacity. However, the model does permit several different sized plants at each site $p$.

$$(3.6)\ -DTONS_p + \sum_i DCAP_i \times DIS_{pi} \geq 0 \ for\ all\ p.$$

$$(3.7)\ -LTONS_p + \sum_j LCAP_j \times LIS_{pj} \geq 0 \ for\ all\ p.$$

Equations 3.8 and 3.9 are transfer rows that haul dry and liquid fertilizer from fertilizer plant *p* to farm *f*. The cost to load and haul fertilizer is realized in the objective function. These constraints also ensure that the amount of fertilizer handled at each plant equals the amount of fertilizer hauled to each farm.

$$(3.8)\ DTONS_p - \sum_f TRFD_{pf} \geq 0 \ for\ all\ p.$$

$$(3.9)\ LTONS_p - \sum_f TRFL_{pf} \geq 0 \ for\ all\ p.$$

The liquid and dry fertilizer on the farm is then transferred to the application activities in equations 3.10 and 3.11. The coefficient of 2,000 for $TRFD_{pf}$ and $TRFL_{pf}$ converts tons to pounds. *DAPPRATE* and *LAPPRATE* are the per acre application rates for dry and liquid fertilizer, respectively.

$$(3.10)\ 2000 \sum_p TRFD_{pf} - DAPPRATE \times DAPP_f \geq 0 \ for\ all\ f.$$

$$(3.11)\ 2000 \sum_p TRFL_{pf} - LAPPRATE \times LAPP_f \geq 0 \ for\ all\ f.$$

The farm level demand for dry and liquid fertilizer is $DRYFARMQ_D$ and $LIQFARMQ_D$, respectively. Equations 3.12 and 3.13 state that the amount of dry and liquid fertilizer applied on the farm must at least equal farm level demand.

$$(3.12)\ DAPP_f \geq DRYFARMQ_D \text{ for all } f.$$

$$(3.13)\ LAPP_f \geq LIQFARMQ_D \text{ for all } f.$$

Equations 3.14 and 3.15 allow that no more than one size dry and liquid fertilizer plant be built at any particular site *p*. $DIS_{pi}$ is a binary integer that forces the model to build a dry fertilizer plant or not, and $LIS_{pj}$ is a binary integer that works the same way by forcing the model to build a liquid fertilizer plant or not. Dry fertilizer plants are assumed to be specific sizes (1,395 tons, 2,232 tons, 3,627 tons, or 5,580 tons). Liquid fertilizer plants are assumed to be 279 tons, 1,392 tons, or 5,022 tons. In a real-world situation, fertilizer plants can choose to be any size, but allowing this choice in the case study would have increased the complexity of the model. Increasing the complexity of the model would have strained the computational and time resources available for this case study.

$$(3.14)\ \sum_i DIS_{pi} \leq 1 \text{ for all } p.$$

$$(3.15)\ \sum_j LIS_{pj} \leq 1 \text{ for all } p.$$

In equation 3.16, firm fixed costs are realized in the objective function. If a dry plant is operated at site *p*, the binary variable $DIS_{pi}$ takes a value of 1 and the first term is -0.5. Thus, the only way to satisfy the objective function is to also have a second binary variable, $LIS_{pj}$, take a value of 1 as well. If the value for $LIS_{pj}$ takes a value of 1, the constraint acts in the same manner. The coefficients of -0.5 for $DIS_{pi}$ and $LIS_{pj}$ allows for both liquid and dry fertilizer plants at the same site.

$$(3.16)\ -0.5 \times DIS_{pi} - 0.5 \times LIS_{pj} + FIS_{pij} \geq 0 \text{ for all } p.$$

A specific number of combinations were specified in the model. For example, a firm might choose to operate a small dry fertilizer plant with a small liquid fertilizer plant, or a medium dry fertilizer plant with a large liquid fertilizer plant. Thus, the final constraint, equation 3.17, limits each site $p$ to only one combination of dry and liquid plants.

$$(3.17) \sum_{ij^*} FIS_{pij} \leq 1 \quad \text{for all } p.$$

# CHAPTER 4. COST COEFFICIENT ESTIMATES

The first section of this chapter presents the data sources used for cost calculations, right hand side (RHS) values, and technical coefficients in this case study. This section summarizes information obtained from the fertilizer plant surveys. The next section discusses fertilizer plant costs including: variable operating cost, fixed operating cost, equipment cost, and fertilizer application cost. Fertilizer transportation costs will be presented in the third section, and the final section will cover liquid fertilizer plant upgrading and investment costs. That section includes a discussion of tanks, tank seats, containment area and diking, and loading pads. A Size B (1,395 ton) liquid plant upgrade cost example also is presented.

## Data Sources

Data used for the cost calculations, RHS values, and technical coefficients in this study came from a variety of sources. However, most data used in this case study were obtained from primary sources because few previous studies on agricultural fertilizer transportation and storage exist. Primary data were gathered through phone and personal interviews with retail fertilizer industry representatives and also through a survey of fertilizer plants operating in Cass County, N. D. and the surrounding fringe townships. The survey provided a profile of fertilizer plants in Cass County and the surrounding fringe, and established an approximate inventory of agricultural fertilizer storage capacity. The survey also helped portray the fertilizer supply chain and determine fertilizer plant characteristics. Information from the survey included liquid and dry storage capacities, number of tanks used for liquid fertilizer storage, largest tank size used for liquid fertilizer storage, and rail access.

A cover letter and survey were mailed to 32 fertilizer plants on Sept. 28, 1994 (Appendix A).[12] Eight surveys were returned within four weeks. A second cover letter and survey, sent to all

[12]The survey instrument includes additional questions that pertain to another study.

nonrespondents on Dec. 6, 1994, yielded ten additional surveys. On Feb. 1, 1995, the remaining 14 fertilizer plants were contacted and surveyed by telephone. Information from surveys 201 and 202 was combined to form one plant, as was information from surveys 203 and 204. These plants are under the same management and are located in close proximity to each other. Six plants were eliminated because they had gone out of business or their fertilizer storage capacity did not meet the case study specifications. The storage criteria are as follows:

(1) the fertilizer plant must have dry fertilizer storage capacity greater than 200 tons, and/or

(2) the fertilizer plant must have liquid fertilizer storage capacity greater than 100 tons.

After eliminations and combinations, 24 fertilizer plants remained for analysis. Information pertaining to this case study and obtained from the mail and phone surveys is summarized in Table 4.1.

The assumed plant capacity represents the actual tons of fertilizer storage available at each plant (Table 4.1). These capacities were used because they were the most common among the sizes reported by fertilizer plants included in this study.

**Table 4.1. Summary of Information Obtained from Fertilizer Plant Surveys, 1995**

| Fertilizer Plant Size | | Assumed Plant Capacity (Tons) | Estimated Annual Storage Capacity Turnover Per Plant (Tons) | Number of Fertilizer Plants | Estimated Annual Storage Capacity Turnover (Tons per Size) | Number of Fertilizer Plants with Rail Access |
|---|---|---|---|---|---|---|
| Dry: | | | | | | |
| | A | 500 | 1,395 | 6 | 8,370 | 6 |
| | B | 800 | 2,232 | 3 | 6,696 | 1 |
| | C | 1,300 | 3,627 | 3 | 10,881 | 3 |
| | D | 2,000 | 5,580 | 11 | 61,380 | 11 |
| Total Dry | | | | 23 | 87,327 | 21 |
| Liquid: | | | | | | |
| | A | 100 | 279 | 8 | 2,232 | 8 |
| | B | 500 | 1,395 | 5 | 6,975 | 5 |
| | C | 1,800 | 5,022 | 1 | 5,022 | 1 |
| Total Liquid | | | | 14 | 14,229 | 14 |
| Total Dry and Liquid: | | | | 24 | 101,556 | 23 |

The estimated annual storage capacity turnover per plant is the plants' assumed capacity multiplied by the calculated fertilizer storage capacity turnover rate of 2.79. The annual storage capacity turnover rate is calculated for the state of North Dakota. It is calculated as follows:

$$(4.1)\ Turnover = TTS \div TTSC.$$

Where:

Turnover identifies the annual storage capacity turnover rate.

*TTS* represents total ton sales, which is the sum of individual fertilizer plant ton sales. The 1994 TTS for Cass County and the surrounding fringe townships in North Dakota is approximately 485,076 tons.[13]

*TTSC* is the total tons of storage capacity. It is the sum of both individual dry and individual liquid fertilizer storage capacity.[14] The 1994 TTSC for Cass County and the surrounding fringe townships in North Dakota is approximately 172,852 tons.

The annual storage capacity turnover rate is approximate, because individual ton sales for 1994 were unavailable for some fertilizer plants.

A farm level demand of 49,534 tons was assumed for dry fertilizer, and a farm level demand of 5,944 tons was assumed for liquid fertilizer. To arrive at these figures, total cropland acres (minus a 4 percent adjustment for summer fallow) was multiplied by the fertilizer application rate per acre (lbs./acre rate) for each type of fertilizer and divided by 2,000 pounds.[15] Cropland represents the actual "farmable" acres. It is different from farmland acres which may include areas filled with water, roads, or fence lines. A dry fertilizer application rate of 100 pounds per acre was assumed, and a liquid fertilizer application rate of 12 pounds per acre was assumed in this case study.

A listing of all farms operating in Cass County in 1994 was obtained from the Cass County CFSA Office. The document listed all farms numerically, reported farmland acres, cropland acres, and grid description. All farms having less than 55 cropland acres were eliminated. Of the 1,823 farms in

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[13]Individual fertilizer ton sales were obtained from the NDDHCL.

[14]Dry and liquid tons of storage capacity were provided by fertilizer plant managers operating fertilizer plants in North Dakota. This number varies from the estimated annual turnover shown in Table 4.1 because actual storage capacities were rounded to fit the assumed plant capacities used in this case study.

[15]Appendix B summarizes dry fertilizer farm level demand at each group farm and liquid fertilizer farm level demand at each group farm.

Cass County, 157 farms were eliminated. Thus, 1,666 farms were left for calculating farm level demand for dry and liquid agricultural fertilizer.

It was determined that the average cropland acres available differed throughout Cass County. Thus, Cass County was divided into quadrants: NW, NE, SW, and SE.[16] The grid description was used to place the farms in the NE, NW, SE, or SW quadrants of Cass County. The number of "real" farms in each quadrant was then divided among each of the townships in that particular quadrant. To decrease the complexity of the model, the real farms were grouped (Table 4.2 shows how many real farms comprise a "group" farm in each quadrant). Therefore, four "group" farms were located in each township within Cass County. Only one group farm was located in each fringe townships to simplify the model.

Different average cropland acres per group farm were determined for each quadrant (Table 4.2). A group farm located in a fringe township has an average cropland base that is four times that of a group farm located in the nearest Cass County township. Therefore, group farm FA01, which is located in township 1, would have an average cropland base of four times 3,295 acres or 13,182 acres (Table 4.2).[17] Table 4.2 summarizes cropland acres per quadrant, real farms per quadrant, cropland acres per real farm, real farms per township, real farms per group farm, cropland acres per group farm in Cass County townships, and cropland acres per group farm in fringe townships.

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[16]The northern and southern quadrants are split by I-94, and the eastern and western quadrants are split by Highway 18.

[17]Refer to Figure 2.1 for township locations.

**Table 4.2. Summary of Cropland and Farm Statistics, 1995**

| | Quadrants | | | | |
|---|---|---|---|---|---|
| Acres and Farm Numbers: | NW | NE | SW | SE | Total |
| Total Farmland Acres[1] | 329,515 | 152,964 | 237,879 | 280,516 | 1,000,875 |
| Total Cropland Acres | 316,334 | 146,854 | 228,364 | 269,295 | 960,847 |
| Total Real Farms | 584 | 263 | 453 | 367 | 1,666 |
| Total Townships | 25 | 14 | 20 | 11 | 70 |
| Cropland Acres Per Real Farm | 564 | 583 | 525 | 765 | |
| Real Farms per Township | 23.35 | 18.75 | 22.65 | 33.33 | |
| Real Farms Per "Group" Farm | 5.84 | 4.69 | 5.66 | 8.33 | |
| Cropland Acres Per "Group" Farm in a Cass Co. Township | 3,295 | 2,732 | 2,973 | 6,375 | |
| Cropland Acres Per "Group" Farm in a Fringe Township[2] | 13,181 | 10,926 | 11,894 | 25,501 | |

[1]These farmland acres are adjusted to account for summer fallow acres. A summer fallow rate of 4% was used to account for acres that were not used for cropland during the year. The 4% rate was determined using 1992 North Dakota Agricultural Statistics Service data.

[2]Numbers found in Table 4.2 may vary slightly from numbers in Appendices B and C due to rounding.

The remainder of data needed for this case study were obtained from secondary sources. Dahl et al. is the main secondary source for data related to dry fertilizer plants. Though the publication is only related to dry fertilizer plants, some cost information in their study was judged to be applicable to both liquid and dry fertilizer plants. Therefore, some information from Dahl et al. was used to supplement primary cost data related to liquid fertilizer plants. Their study is the source used to determine the cost and types of equipment used at different sized fertilizer plants. Dahl et al. also summarized the formulas for depreciation, land value, and opportunity costs. These formulas were used for both liquid and dry fertilizer plants in this case study.

Kammel et al. is the basis for the storage, containment area, and diking layout and dimensions. The type and quality of material used in constructing the facilities in this case study are also based on recommendations found in this publication. The facility calculations used in the book are conservative, as are the calculations used in this case study (p.1).

The remaining information needed to complete the cost profiles of the liquid fertilizer plants came from industry representatives. Mark Dooley, manager of a liquid and dry fertilizer plant in Cass County, N. D., indicated the type of equipment needed at a liquid fertilizer plants. It was assumed that separate equipment would be needed for liquid and dry plants. For example, if a plant distributed both liquid and dry fertilizer, that plant would need separate tender trucks for hauling both types of fertilizer because different types of accessories would be necessary to transport the two types of fertilizer. The only exception to this assumption was a pickup, which could be used for soil testing by liquid and dry fertilizer plants operating at the same site. Dooley also confirmed the fertilizer custom application cost estimate of $3.00 per acre[18] and the fertilizer delivery cost estimate of $4.00 per mile per ton. The cost estimates for application and delivery apply to both liquid and dry fertilizer.

Dooley suggested liquid and dry fertilizer manufacturing origins for fertilizer plants operating in Cass County and the surrounding fringe were as follows: Hendrum, Minn.; Enderlin, N. D.; Minneapolis, Minn.; and Tampa, Fla. These origin points were verified by Gary Walters, a sales representative for Terra. The manufacturing origins were used in determining distance between manufacturer and fertilizer plant. A truck transportation rate of $1.00 per mile per 25 ton truckload, provided by Walters, was used to calculate manufacturer to fertilizer plant transportation costs for both dry and liquid fertilizer.

Rail transportation costs were estimated using the Uniform Railroad Costing System (URCS). "URCS Phase III is an IBM-compatible micro computer costing program. It is a flexible and convenient tool for estimating the costs that a railroad experiences in moving freight" (Interstate Commerce

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[18]The 1993 North Dakota Agricultural Statistics Service estimated a custom fertilizer application rate of $3.00 per acre for both liquid and dry fertilizer (p. 102).

Commission, p. ii). For simplicity, a one car individual movement was assumed for all fertilizer shipments. Also, URCS only estimates the variable cost of shipping by rail. It does not include an analysis of constant or fixed costs associated with a rail shipment.

The tank dimensions and cost estimates for each tank size were obtained from Fargo Tank Company and O'Day Tank and Steel Company, industry representatives in Cass County. Both sources recommended crushed rock as the best material for tank seat construction.

Two local sources, Kost Bros. Inc. and F-M Ready Mix Inc., were also contacted for a concrete cost estimate. Both gave an estimate of \$65.75 per cubic yard of 4,000 psi concrete.[19] A cost per cubic yard estimate for crushed rock also was obtained. The cost of crushed rock with a diameter between one to one-and-a-half inches was estimated at \$16.87 per cubic yard.

[19]Psi refers to the quality of concrete. Kammel et al. recommends a high quality concrete with a psi between 4,000 and 4,500 (p. 67). Concrete used for construction and cost estimates in this case study has a psi equal to 4,000.

## Fertilizer Plant Costs

### *Variable Operating Cost*

Five cost components combine to form variable operating cost per ton in this model: advertising and promotion, utilities, inspection and tonnage report fee, maintenance and repair, and opportunity cost of working capital (Table 4.3). Variable costs per ton associated with liquid and dry fertilizer plants were assumed to be the same. Advertising and promotion expenses are represented by a $0.90 per ton charge, which was consistent with industry norms for advertising and promotion (Dahl et al., p. 16). The utility charge of $0.04 per ton is the average cost of operating the electric motors needed to run the equipment at each different sized facility (Dahl et al., p. 16). The NDDHCL requires an inspection and tonnage report fee of $0.20 per ton be paid for each ton of fertilizer sold at a plant (Dahl et al., p. 14). Dahl et al. assumed a maintenance and repair expense of $5.09 per ton and indicated the assumption parallels industry norms for plants of comparable size (p. 12). The final component is opportunity cost of working capital. Opportunity cost of working capital is calculated from the average monthly variable operating cost, which is the sum of the first four cost components in Table 4.3. This average monthly cost is then multiplied by a short term interest rate (6.53 percent) to obtain an opportunity cost of working capital per ton ($0.03) (Dahl et al., p.15).

**Table 4.3. Variable Operating Cost Per Ton of Fertilizer, 1995**

| Cost Component | $/Ton |
|---|---|
| Advertising and promotion | $0.90 |
| Utilities | $0.04 |
| Inspection and tonnage report fee | $0.20 |
| Maintenance and repair | $5.09 |
| Opportunity cost - working capital | $0.03 |
| Total Variable Operating Cost Per Ton | $6.26 |

Adapted from Dahl, Bruce L., David W. Cobia, and Frank J. Dooley. Distribution Costs for Dry Fertilizer Cooperatives. Report 339. Fargo, ND: North Dakota State University Agricultural Economics Department, November 1995.

***Fixed Operating Cost***

The dry and liquid Size B fertilizer plants (which are 2,232 tons and 1,395 tons, respectively) were used as examples to show how fixed operating costs are calculated (Table 4.4). The cost components for firm fixed operating costs at a Size B fertilizer plant also were listed. Fixed operating costs for all fertilizer plant types and sizes were summarized in Appendix C. The costs included in fixed operating cost in this case study were as follows: labor costs, insurance, licenses, lease for railroad trackage, depreciation, and opportunity cost.

The plant (or firm) fixed operating costs in this case study included all fixed operating costs, except facility and equipment depreciation, and opportunity cost of inventory in facilities, equipment and land. The plant fixed operating costs are those costs that are only incurred once if the fertilizer plant stores both dry and liquid fertilizer. The remaining costs (facility and equipment depreciation and opportunity cost of inventory in facilities, equipment, and land) are referred to as sunk costs. For instance, if a Size B fertilizer plant stores only dry fertilizer, its total fixed operating cost would be

$96,526.40. If the same fertilizer plant only stored liquid fertilizer, its total fixed operating cost would be $75,966.32. However, if the same fertilizer plant stored both dry and liquid fertilizer, its total fixed operating cost would be $128,478.85 ($96,526.40 + $75,966.32 - $44,013.87 = $128,478.85). Subtracting the firm fixed operating cost, $44,013.87, eliminates "double" counting (Appendix C). For example, a fertilizer plant storing both dry and liquid fertilizer would only need to pay the lease for railroad trackage once. This cost difference would have a substantial impact on the fertilizer plant's decisions about continuing operation, expanding, or upgrading its facilities. The following is a discussion of each of the cost components summarized in Table 4.4.

Labor cost is the first fixed operating cost component. It is broken down into two categories as follows: (1) manager and assistant manager, and (2) bookkeeping staff. All labor costs are considered firm fixed operating costs. A bookkeeping staff is not employed by fertilizer plants at Sizes A or B. Dahl et al. identified labor costs for dry fertilizer plants at four different sized facilities (p.12). These labor costs were used for dry fertilizer plants of similar or equal storage capacity and for liquid fertilizer plants of similar storage capacity in similar or equal storage capacity and for liquid fertilizer plants of similar storage capacity in this case study. Manager and assistant manager labor costs were $27,768, $33,510, $67,020, and $72,762 for dry fertilizer plants at Size A, B, C, and D, respectively (Table 4.4 and Appendix C). Manager and assistant manager labor costs for liquid fertilizer plants at Size A, B, and C were $27,768, $33,510, and $72,762 (Table 4.4 and Appendix C). The bookkeeping staff labor costs were $9,566 and $19,132 for a dry fertilizer plant at Size C and D, respectively (Appendix C). Bookkeeping staff labor cost at a liquid fertilizer plant at Size C was $19,132 (Appendix C).

**Table 4.4. Annual Fixed Operating Cost at Size B Fertilizer Plants, 1995**

| Cost Components | Dry Fertilizer Plant - Size B | Liquid Fertilizer Plant - Size B | Firm Cost[1] Medium |
|---|---|---|---|
| Labor Costs: | | | |
| Manager & Asst. Manager | $33,510.00 | $33,510.00 | $33,510.00 |
| Bookkeeping Staff | | | |
| Insurance: | | | |
| Directors & Officers | $750.00 | $750.00 | $750.00 |
| Facility & Inventory | $2,992.00 | $2,992.00 | $2,992.00 |
| Equipment | $1,420.00 | $1,420.00 | $1,420.00 |
| Licenses | | | |
| Annual Distribution Fee | $50.00 | $50.00 | $50.00 |
| Equipment | $346.00 | $346.00 | $346.00 |
| Lease for Railroad Trackage | $850.00 | $850.00 | $850.00 |
| Depreciation | | | |
| Facility | $7,682.85 | $545.27 | $0.00 |
| Equipment | $36,981.80 | $29,696.20 | $3,200.00 |
| Opportunity Cost | | | |
| Working Capital | $227.87 | $227.87 | $227.87 |
| Facility | $5,262.75 | $373.51 | $0.00 |
| Equipment | $6,333.13 | $5,085.47 | $548.00 |
| Land | $120.00 | $120.00 | $120.00 |
| Sunk - Fixed Operating Cost | $56,380.53 | $35,820.45 | $3,868.00 |
| Plant - Fixed Operating Cost[1] | $40,145.87 | $40,145.87 | $40,145.87 |
| Total Fixed Operating Cost | $96,526.40 | $75,966.32 | $44,013.87 |

Adapted from Dahl, Bruce L., David W. Cobia, and Frank J. Dooley. Distribution Costs for Dry Fertilizer Cooperatives. Report 339. Fargo, ND: North Dakota State University Agricultural Economics Department, November 1995.

[1]Firm costs only need to be incurred once at a plant that is managing both dry and liquid fertilizer. Plant Fixed Operating Cost is the total of all fixed costs that are considered firm costs. Sunk Fixed Operating Cost is the total of all fixed operating costs that are **not** considered firm costs. The sum of Plant Fixed Operating Cost and Sunk - Fixed Operating Cost is Total Fixed Operating Cost.

The second cost component of fixed operating cost is insurance. Insurance, a firm fixed cost, is divided into three categories: directors and officers, facility and inventory, and equipment. Insurance costs were adapted from Dahl et al. for dry and liquid fertilizer plants in this case study (p. 12). Insurance costs were assumed the same for liquid and dry fertilizer plants at Size B (Table 4.4). A complete summary of insurance costs for all sizes and types of fertilizer plants is in Appendix C.

Licenses are the third fixed operating cost component summarized in Table 4.4. Dahl et al. determined "An annual licensing fee of $50 was required to distribute fertilizers within North Dakota" (p.14). The licensing fee is the same for all fertilizer plant sizes, whether dry or liquid. Dahl et al. also included an "over-width fee of $50" for each fertilizer applicator per season and a license cost of $229 per eight-ton truck and/or $478 per 16-ton truck (p. 10). Equipment licenses for dry or liquid plants at Size B was $346. License costs for all sizes and types of fertilizer plants are summarized in Appendix C.

The cost of a lease for railroad trackage ranged from $850 to $1,700 (Dahl et al., p. 14). Once again, the lease cost for railroad trackage identified by Dahl et al. for dry fertilizer plants was applied to liquid fertilizer plants in this case study. The cost of lease for trackage at dry fertilizer plants at Size A, B, and C and liquid fertilizer plants at Size A, and B was $850 (Table 4.4 and Appendix C). The lease for trackage cost was $1,700 at dry and liquid fertilizer at Size D and C, respectively (Table 4.4 and Appendix C).

Depreciation, the fifth component of fixed operating cost, was split into the two categories of facility and equipment. Depreciation was calculated with a straight-line method. Facility and equipment depreciation were calculated based on the total cost of construction and total purchase cost, respectively, assuming zero salvage value (Dahl et al., p. 13). "Facilities were expensed over a 20-year period" and equipment was expensed over a five-year period (Dahl et al., p. 13). Equation 4.2 shows the facility depreciation calculation for a 2,232 ton dry fertilizer plant (Size B).

$$(4.2)\ FD = TCC_{DrySizeB} \div DP.$$

where:

$FD$ is facility depreciation.

$TCC_{Dry\ Size\ B}$ is the total construction cost of a 2,232 ton dry fertilizer plant (Size B). $TCC_{Dry\ Size\ B}$ is equal to \$153,657.

$DP$ denotes the depreciation period. The depreciation period is the number of years over which the facility is expensed. A depreciation period of 20 years is assumed for all facilities in this case study.

A dry fertilizer plant at Size B had an annual facility depreciation of \$7,682.85. The depreciation cost of equipment was calculated similarly and was shown in equation (4.3).

$$(4.3)\ ED = TEC_{DrySizeB} \div DP.$$

where:

$ED$ is equipment depreciation.

$TEC_{Dry\ Size\ B}$ represents total equipment cost at a 2,232 ton dry fertilizer plant (Size B). $TEC_{Dry\ Size\ B}$ is equal to \$184,909.

$DP$ denotes the depreciation period. The depreciation period is the number of years over which the equipment is expensed. A depreciation period of five years was assumed for all equipment in this case study.

A dry fertilizer plant at Size B had an equipment depreciation of \$36,981.80. Total construction costs and depreciation costs for all sizes and types of fertilizer plants were summarized in Appendix D.

Opportunity cost is the final component of fixed operating cost. Opportunity cost is divided into four categoriesas follows: working capital, inventory in facilities, inventory in equipment, and inventory in land. "Opportunity cost represents foregone potential income by investing in land, equipment and working capital rather than in its next best alternative" (Dahl et al., p. 15). The opportunity costs for working capital, inventory in facilities, inventory in equipment, and inventory in land calculated by Dahl et al. were used for dry and liquid fertilizer plants in this case study (p. 12). The only exception was opportunity cost of inventory in facilities for liquid fertilizer plants. This opportunity cost was calculated using the long term interest rate identified by Dahl et al. (6.85 percent) and the total cost of construction appropriate for the liquid fertilizer plant size being considered (p. 15). Construction and purchase costs are shown in Appendix D. Working capital was assumed to be represented by one month of fixed operating expenses. "There was an upward bias in opportunity cost for plant and equipment because the initial purchase price, rather than average book value, was used in the calculation. This upward bias compensated for anticipated replacement costs" (Dahl et al., p. 15). The fixed cost portion of opportunity cost of working capital is calculated as follows for a 2,232 ton dry fertilizer plant (Size B):

(4.4) $OC_{WorkingCapital} = (AFOC \div 12months)\ i_L.$

where:

$OC_{Working\ Capital}$ is the opportunity cost of working capital.

*AFOC* represents the annual fixed operating cost. For a 2,232 ton dry fertilizer plant (Size B), the AFOC equals \$39,918. *AFOC* includes labor costs, insurance, licenses, and lease for railroad trackage.

The value of $i_L$ is the long term interest rate, 6.85 percent.

Equation (4.5) shows how opportunity costs for facilities or equipment was calculated.

$$(4.5)\ OC = (Construction\ or\ Purchase\ Cost \div 2) \times i_L.$$

where:

$OC$ is the opportunity cost.

The value of $i_L$ represents the long term interest rate, 6.85 percent.

The opportunity costs of facilities and equipment for a 2,232 ton dry fertilizer plant (Size B) were $5,262.75, and $6,333.13, respectively. In calculating the opportunity cost of land, the purchase cost was simply multiplied by the long term interest rate. A 2,232 ton dry fertilizer plant was assumed to operate on two acres of land. The price per acre was assumed to be $875.91; therefore, the opportunity cost of land for this plant was $120. All opportunity costs are summarized in Appendix D.

*Equipment Cost*

Equipment specifications for the different sized dry fertilizer plants were adapted from Table 3 in Dahl et al. (pg. 10). "Distribution equipment complements . . . were specified to be typical for high density areas similar to southeastern or eastern North Dakota" by Dahl et al. (p. 8). Mark Dooley, a fertilizer plant manager in Cass County, identified the type of equipment that would be typically used at a liquid fertilizer plant. Table 4.5 shows the cost of equipment and the equipment requirements at the different sized liquid and dry fertilizer plants, as well as the "firm" equipment requirements. "Firm" equipment requirements are those items that could be used for both dry and liquid fertilizer plant operations. For example, it was assumed that separate tender trucks and applicators would be needed, but pickups for soil testing could be used in both operations.

**Table 4.5. Summary of Equipment Requirements and Costs, 1995**

| | | Dry | | | | Liquid | | | Firm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Cost ($) | Size A | Size B | Size C | Size D | Size A | Size B | Size C | Small | Medium | Large |
| Custom Applicators: | | | | | | | | | | | |
| New (top of the line) | $160,000 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| New | $120,000 | 0 | 1 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| Used Terragator | $85,000 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Used Truck | $40,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tender Trucks: | | | | | | | | | | | |
| 16 Ton Diesel Twin Screw | $55,251 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 16 Ton Diesel Tag Axle | $43,941 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 16 Ton Gas Tag Axle | $37,941 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 8 Ton Gas | $28,481 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| Rental Cart Spreaders | $4,357 | 3 | 4 | 5 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Loaders: | | | | | | | | | | | |
| Articulated Loaders | $26,000 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Large Skid Steer Loader | $19,000 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Small Skid Steer Loader | $16,000 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pickups for Soil Testing | $16,000 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |

Adapted from Dahl, Bruce L., David W. Cobia, and Frank J. Dooley. Distribution Costs for Dry Fertilizer Cooperatives. Report 339. Fargo, ND: North Dakota State University Agricultural Economics Department, November 1995.

Note: Total equipment costs are summarized in Appendix D.

## Fertilizer Transportation Costs

### *Manufacturer to Fertilizer Plant - Transportation Cost*

Two types of transportation are available for transporting fertilizer: rail and truck. Although dry fertilizer may be transported by either mode, it was assumed that only those plants not having rail access trucked dry fertilizer. Two fertilizer plants did not have rail access: P04 and P12. The remaining fertilizer plants railed their dry fertilizer. Dry fertilizer may be railed from Tampa, Fla. or trucked from Minneapolis, Minn. A truck transportation cost of $1.00 per mile and a truckload capacity of 25 tons were assumed. The cost for rail transport of dry fertilizer from Tampa, Fla. to each plant was calculated by the Uniform Railroad Costing System (URCS).

All fertilizer plants had the option of trucking liquid fertilizer from either Hendrum, Minn. or Enderlin, N. D. A truck transportation rate of $0.1442 per mile per ton was assumed. All transportation costs were converted to cost per ton (Appendix E).

### *Fertilizer Plant to Farm - Transportation Cost*

A transportation rate of $0.40 per ton per mile was assumed for transportation of dry or liquid fertilizer from fertilizer plant to farm. Mark Dooley, a fertilizer plant manager in Cass County, N. D., confirmed the rate of $0.40 per ton per mile and also verified that transportation rates for liquid and dry fertilizer were the same. Transportation rates from each fertilizer plant to each farm were summarized in Appendix F.

## Liquid Fertilizer Plant Upgrading and Investment Costs

Table 4.6 shows the upgrade investments each different sized liquid fertilizer plant made to comply with the basic guidelines summarized in the RMP. As the RMP guidelines gave no specifics on construction, all construction techniques and specifications used in this case study were derived from equations, figures, and examples in Kammel et al. The RMP specifically refers fertilizer plant managers to Designing Facilities for Pesticide and Fertilizer Containment (Kammel et al., p. ii).

Four components might need to be upgraded at liquid fertilizer facilities that are already in existence and do not plan to increase storage capacity: tanks, tank seats, secondary containment and diking, and loading pads. Table 4.6 summarizes the components and the cost of individual components involved in upgrading a liquid fertilizer plant.

***Tanks***

If a plant was already in operation, it was assumed that it had the tanks needed to meet the capacity constraints set for that plant size and would not incur any additional tank costs (Table 4.6). However, if a plant expanded its fertilizer storage capacity, additional tanks would need to be purchased as shown in the "A to B" or the "A to C" columns. For example, a plant operating at Size B was assumed to already own three 27,500 gallon tanks ("B" column in Table 4.6). The total cost of these tanks would not be incurred when a plant at Size B upgraded its facility, but did not expand storage capacity. However, the cost of three 27,500 gallon tanks would be incurred if a Size A plant decided to upgrade its current facility to a Size B facility ("A to B" column in Table 4.6).

**Table 4.6. Upgrade Components Required By Each Liquid Fertilizer Plant Size, 1995**

| | Plant Upgrade Action | | | | | |
|---|---|---|---|---|---|---|
| Upgrade Component | A | A to B | A to C | B | B to C | C |
| Tanks: | | | | | | |
| 9,000 Gallon Tank* | [2] | [2] | [2] | [2] | [2] | [2] |
| 23,000 Gallon Tank | | | 4 | | 4 | [4] |
| 27,500 Gallon Tank | | 3 | 8 | [3] | [3] 5 | [8] |
| Tank Seat** | 2 | 5 | 14 | 5 | 14 | 14 |
| Containment Area/Diking** (cubic yards) | 39.77 | 99.69 | 181.0 | 99.69 | 181.0 | 181.0 |
| Loading Pad* (cubic yards) | 53.60 | 53.60 | 107.2 | 53.60 | 107.2 | 107.2 |

Sources Fargo Tank Company. Fargo, ND. Personal communication. Sales Representative. 1994; F-M Ready Mix Inc. Fargo, ND. Personal communication. Sales Representative. 1994; Kost Bros. Inc. Fargo, ND. Personal communication. Sales Representative. 1994; O'Day Tank and Steel Company. Fargo, ND. Personal communication. Sales Representative. 1994.

* The brackets around some numbers in Table 4.5. designate tanks the liquid fertilizer plant already owns. This means, for example, that plants at Size A, Size B, or Size D will not have to purchase *any* tanks.

** The calculations for tank seats, containment areas and diking, and loading pads are explained in further detail in the following sections.

Many different tank sizes are available and used by fertilizer plants, because tanks are made according to buyer specification. However, the model assumed that only three tank sizes were used in this case study (Table 4.7). This simplified upgrading and calculation of materials needed for tank seats and containment. Even though the dimensions of tanks used in the study differed from the majority of tanks used by fertilizer plants, the capacities of tanks used in the study to characterize liquid fertilizer plants were consistent with the capacities of tanks used by liquid fertilizer plants in Cass County.

**Table 4.7. Liquid Fertilizer Tank Specifications, 1995**

| | Tank Size | | |
|---|---|---|---|
| Specifications | 9,000 Gallon | 23,000 Gallon | 27,500 Gallon |
| Ton Volume | 50 | 125 | 150 |
| Base Diameter*, feet | 12 | 12 | 12 |
| Tank Height, feet | 13 | 27.5 | 32.5 |
| Volume Per Foot of Height, cubic feet/foot** | 113.1 | 113.1 | 113.1 |
| Tank Unit Cost | $3,250.00 | $6,520.00 | $7,600.00 |

Sources Kost Bros. Inc. Fargo, ND. Personal communication. Sales Representative. 1994; O'Day Tank and Steel Company. Fargo, ND. Personal communication. Sales Representative. 1994; Kammel, David W., Ronald T. Noyes, Gerald L. Riskowski, and Vernon L. Hofman, Designing Facilities for Pesticide and Fertilizer Containment. Ames, IA: Midwest Plan Service, 1991.

* Although the 9,000 gallon tank actually has a diameter of 11 feet, a diameter of 12 feet was assumed for calculations in this case study. This will also make future facility changes easier (Kammel et al., p. 38).

** Found in Table 6. (Kammel et al., p. 30).

The 9,000, 23,000, and 27,500 gallon tanks held approximately 50, 125, and 150 tons of liquid fertilizer respectively.[20] The tanks were vertical and cylindrical, and were assumed to be standard tanks with a 12-foot diameter, quarter-inch bottom thickness, and ten-gauge top. The thickness of the sides varied from 0.25 to 0.1875 inches, increasing with the height of the tank (Fargo Tank Company, 1994 and O'Day Tank and Steel Company, 1994).

When constructing a liquid fertilizer secondary containment facility, it is advantageous to plan the construction using the largest tank diameter. The facility may need all large tanks later, and designing

[20]Assume liquid fertilizer weighs 11 pounds per gallon, and one ton equals 2,000 pounds.

the facility for all large tanks allows for flexibility (Kammel et al., p. 38). In this case study, secondary containment facilities are designed assuming all tanks have a diameter of 12 feet, thus allowing for modifications in the future.

### *Tank Seat*

Each tank rested on a crushed rock tank seat. The purpose of the tank seat was to keep the tank bottom dry, hinder corrosion, and help in the detection of leaks. "This method also allows the tank to be easily leveled on containment floors . . ." (Kammel et al., p. 29).

The crushed rock used to make the tank seat was one to one-and-a-half inches in diameter. This type of crushed rock costs approximately $16.87 per cubic yard (F-M Ready Mix Inc., 1994 and Kost Bros. Inc., 1994).

Since each tank was assumed to have the same diameter, regardless of capacity, the tank seats all needed the same amount of material and were identically constructed. Each tank seat had a depth of four to six inches and had a diameter six to twelve inches wider than the tank diameter (Kammel et al., p. 30). For simplicity, a tank seat depth of six inches and diameter of 13 feet were assumed. The volume of crushed rock needed to construct each tank seat was 265 cubic feet and was calculated as follows:

(4.6) $V = \pi\ r^2\ h.$

Where:

The value of $V$ is the voume of crushed rock needed to construct one tank seat.

The value of $\pi$ is 3.14.

The value of $r$ represents the tank seat diameter in feet.

The value of $h$ denotes tank seat height in feet.

Tank seat volume was then converted from 265 cubic feet to 9.8 cubic yards. After converting the volume to cubic yards, total cost of the tank seat was calculated by multiplying by cost per cubic yard. Each tank seat cost $165.33 (Table 4.8).

*Containment Area and Diking*

The containment area and diking was also referred to as secondary containment. The secondary containment had to be large enough to hold the capacity of the largest liquid fertilizer tank and any other items or equipment that may occupy or be stored in the containment area (Kammel et al., p. 35). This included other tanks, tank seats, and an allowance for precipitation that fell within the diked area. To account for precipitation, a freeboard factor of 125 percent was used. This means that the capacity of the secondary containment held 100 percent of the volume of the largest tank, other tanks, tank seats, and still provide extra volume. The extra 25 percent was, in effect, a safety net to prevent a major spill from breaching secondary containment. This safety net could be reduced if effects of precipitation were lessened by a roof (Kammel et al., p. 37). No volume for extra equipment was included in calculations for this case study.

The RMP specified the capacity of the secondary containment in another way. It stated that the design and construction of the secondary containment should be "adequate to contain 100 percent of the volume of the largest container within the diked area, plus sufficient volume to contain the precipitation from the greatest twenty-four hour storm event that has occurred in the last twenty-five years. If the diked area is covered to prevent the accumulation of rainfall, it is not necessary to account for the storm event in the total capacity . . . If multiple vessels will be placed within the dike, adjust the containment capacity upward to account for the portion of those vessels below the top of the dike" (NDDHCL, p. 5). The freeboard factor described by Kammel et al. will be used to account for the precipitation from the "greatest twenty-four hour storm event that has occurred in the last twenty-five years."

Kammel et al. also recommends using a high quality cement. Cement quality was defined by an assigned psi number. A high quality cement has a psi between 4,000 and 4,500 (Kammel et al., p. 67). A cement with a psi rating of 4,000 was used for cost estimates and construction in this case study. Under no circumstances should asphalt be used in the construction of secondary containment. "Asphalt is not an acceptable substitute for concrete" (NDDHCL, p. 4).

The first step in determining the amount of cement needed to construct the secondary containment area and dike was to calculate the containment area's dimensions. Equation (4.7) calculates containment floor area (CFA) dimensions inside secondary containment walls.[21]

(4.7) $CFA = LTV \times FF \div CVD + TBA.$

Where:

*CFA* is the containment floor area. *CFA* is the inside dimensions of the containment walls measured in square feet.

*LTV* represents the largest tanks' volume in cubic feet.[22] Assume the tank is full.

*FF* is the freeboard factor. *FF* equals 125 percent for all calculations in this study.

*CVD* denotes the secondary containment depth in feet. Assume a *CVD* of three feet for all calculations in this study.

*TBA* represents the sum of tank base areas in square feet. The base area of the largest tank is not included, as it is accounted for by *LTV*. Values for the tank base areas are found in Table 6.[23] $TBA = BA_1 + BA_2 + \ldots + BA_n$

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[21]This formula only applies to secondary containments vertical tanks. For calculation of CFA's with non-vertical tanks and elevated vertical tanks, refer to Kammel et al. (p. 39).

[22]To convert gallons to cubic feet, assume one gallon equals 7.5 cubic feet.

[23]Use the cubic feet per foot of height values in Table 6 in Kammel et al. (p. 30).

*BA* is the base area of an individual tank in square feet. $BA = \pi r^2$.

The largest tank volume (*LTV*) is calculated as follows:

$$(4.8)\ LTV = VPF \times (LTH - TBE).$$

Where:

*VPF* represents the volume per unit of depth. *VPF* is measured in cubic feet per foot of height. This is determined by Table 6 in Kammel et al.[24]

*LTH* denotes the height of largest tank in feet

*TBE* is the tank base elevation, which is measured in feet. Since all tanks in this case study are set on a rock base, the $TBE = 0$.

The *LTV* calculation for a Size A liquid fertilizer plant is based on a 9,000 gallon tank. The *VPF* equals 113.1 cubic feet per foot, and the *LTH* equals 13 feet. The *LTV* for a 9,000 gallon tank is 1470.3 cubic feet.

The calculated CFA for a Size A liquid fertilizer plant is 726.25 square feet. At times, the required CFA or minimum containment floor area (MCFA) may be larger than the calculated CFA. The MCFA also should be calculated to ensure a three foot clearance space between tanks and containment walls. The larger of the two calculations should be used for determining the floor area of secondary containment. The MCFA is calculated for a Size A liquid fertilizer facility as follows:

$$(4.9)\ MCFA_{SizeA} = (D + 6)\ (2D + 9).$$

Where:

*MCFA* is the minimum square feet of floor needed for the containment area.

[24]Table 6 in Kammel et al. shows that a tank with a diameter of 12 feet has a VPF equal to 113.1 cubic feet per foot (p.30).

$D$ denotes the tank diameter in feet. Assume tank diameter is 12 feet for *MCFA* calculations in this case study.

The $MCFA_{Size\ A}$ equals 594 square feet, whereas the $CFA_{Size\ A}$ equals 725.73 square feet. In this case, the $CFA_{Size\ A}$ is used. The dimensions for the containment area of a Size A plant are 20.75 feet by 35 feet.[25]

The dike walls are constructed with a width of eight inches or 0.67 ft. The cubic yards needed to construct the containment area was calculated in equation 4.10.

$$(4.10)\ Cubic\ Yards = [(L \times W_{Floor} \times D) + 2(L \times W_{Dike} \times H) + 2(W \times W_{Dike} \times H)$$

Where:

$L$ denotes the length of the containment floor. For a Size A liquid fertilizer plant, the floor length is 35 feet.

$W_{Floor}$ represents the width of the containment floor. For a Size A liquid fertilizer plant, the floor width is 20.75 feet.

$D$ is the containment floor depth. Assume a depth of 14 inches or 1.17 feet

$W_{Dike}$ represents the width of the containment dike wall. Assume a width of eight inches or 0.67 feet.

$H$ is the height of the containment dike wall. Assume a height of three feet. This is the same figure as CVD, the secondary containment depth.

Note: Dividing by 27 changes the cubic feet to cubic yards.

A total of 39.77 cubic yards was needed to construct a containment area and dike for a Size A plant. The total cubic yards was then multiplied by the cost per cubic yard, $65.75. The cubic yard cost estimate for

[25]Dimensions were rounded up to the nearest quarter of a foot.

cement was for 4,000 psi cement, which was considered a high quality cement (Kammel et al., p. 67). The total cost of constructing a containment area and dike for a Size A plant was $2,614.88.

### *Loading Pad*

The loading pad had two functions. Fertilizer delivery trucks and applicators were cleaned and loaded there, and it is where fertilizers were mixed. If a spill did occur during loading or mixing, the spilled material was more easily contained and cleaned.

Kammel et al. suggested different locations and designs for loading pads, but only one type was used in this case study: a rectangular single sump mixing/loading pad.[26] The layout for this type of loading pad is shown in Appendix G. Loading pad dimensions were assumed to be 40 feet by 40 feet for this case study. If the pesticide and rinsate storage area were replaced with a liquid fertilizer secondary containment area (such as described in this case study), the layout would resemble the type of liquid fertilizer containment facility envisioned for construction in this case study.

The loading pad described in this case study was constructed with a rounded drive-over curb (Appendix H). For simplification, the cost of reinforcement bars was not included in the total cost estimate. However, steel reinforcement bars would be necessary in actual construction.

As shown in Appendix G, a sump pump was located in the center of the loading pad. The calculations for the amount of cement needed to encase the sump pump were based on Figure 41 in Kammel et al. (p. 51). The cost of purchasing the sump pump and stainless steel sump liner were not included in the total cost of constructing the loading pad.

Construction of one loading pad requires 53.6 cubic yards of 4,000 psi cement. At $65.75 per cubic yard, one loading pad cost $3,524.20 (F-M Ready Mix and Kost Bros. Inc., 1994). The Size A and

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[26]Refer to Kammel et al. for suggestions on improving efficiency and function through loading pad placement and design (p. 48).

B liquid fertilizer plants were assumed to need only one loading pad, while the Size C liquid fertilizer plants were assumed to utilize two loading pads.

***Size B (500 ton) Liquid Plant Upgrade Cost Example***

Using the calculations for tanks, tank seats, containment area, and diking, the Table 4.8 shows the difference in upgrading cost when a liquid plant already in operation at Size B (500 tons) upgraded its facility and when a liquid plant at Size A (100 tons) upgraded and enlarged to become a Size B.

A liquid fertilizer plant that had 100 tons of storage (Size A), but planned to increase its storage capacity to 500 tons (Size B) and bring its facility into compliance would necessarily incurred a greater cost than a Size B plant that brought its facility into compliance. Table 4.8 shows the difference between these two different scenarios. A plant that originated at 100 tons of annual storage capacity (Size A), had to purchase three more tanks to increase its storage capacity to that of a 500 ton liquid fertilizer plant (Size B). The three tanks cost $7,600 each; therefore, the added cost for this plant to increase its storage capacity to 500 tons was $22,800 (Table 4.8).

**Table 4.8. Investment Cost Comparison of Size B Liquid Plants, 1995**

| Investment Component | Number of Units | Cost per Unit | Plant Original Size: Size A<br>Action: Compliance and Increase Size | Plant Original Size: Size B<br>Action: Compliance |
|---|---|---|---|---|
| Tanks* | 3 | $7,600.00 | $22,800.00 | ** |
| Tank Seats | 5 | $165.33 | $826.65 | $826.65 |
| Containment/Diking (cubic yards) | 88.49 | $65.75 | $5,818.22 | $5,818.22 |
| Loading Pad (cubic yards) | 53.6 | $65.75 | $3,524.20 | $3,524.20 |
| Total Compliance Cost | | | $32,969.07 | $10,169.07 |

* Each tank had a capacity of 27,500 gallons in this example.

** A plant originating at Size B did not have to purchase tanks if it only planned to upgrade its current facility.

## CHAPTER 5. RESULTS

This chapter is divided into two sections. First, the results of running the model under each of the four scenarios is presented, as well as a summary of ton-miles associated with the transport of dry and liquid fertilizer. Second, an analysis of the results is presented. This section includes a discussion about cost savings in each cost perspective, changes in annual fertilizer plant and industry storage capacity, and fertilizer plant size upgrades in each cost perspective.

### Summary of Results

The results of running the model under each scenario are presented in this section. Total fixed and variable costs, as well as total cost resulting in each of the four scenarios are presented in Tables 5.1 and 5.2. These costs were divided into the broad categories used in the objective function: fixed operating cost, variable operating cost, manufacturer to fertilizer plant transportation cost, fertilizer plant to farm transportation cost, and application cost. Table 5.3 summarizes the ton-miles associated with liquid and dry fertilizer transportation in each scenario.

Table 5.1 summarizes costs associated with the full cost perspective scenarios: Scenarios 1 and 3. Scenario 1 is the full cost baseline. Scenario 3, full cost with investment, advances one step further by allowing fertilizer plants to remain at the same capacity, increase their capacity, or exit the industry. In Scenario 1 total cost was $12,611,848 (Table 5.1). Fixed operating costs accounted for 39 percent of total cost. Variable operating costs, transportation costs from manufacturer to fertilizer plant, transportation costs from fertilizer plant to farm, and application costs represent 3, 10, 1, and 47 percent of total costs, respectively (total variable costs account for 61 percent of total costs).

**Table 5.1. Cost Comparison of Full Cost Scenarios, Baseline and Investment, 1995**

| Description | Scenario 1<br>Full Cost Baseline | Scenario 3<br>Full Cost with Investment | Comparison of Scenarios 1 and 3<br>Cost Savings | Percent Change |
|---|---|---|---|---|
| Fixed Costs: | | | | |
| Operating Cost: | | | | |
| Fixed Operating Cost - Dry Fertilizer Plant | $3,221,788 | $1,631,449 | $1,590,339 | (49.36)% |
| Fixed Operating Cost - Liquid Fertilizer Plant | $519,310 | $376,476 | $142,834 | (27.50)% |
| Fixed Operating Cost - Firm | $1,114,604 | $864,707 | $249,897 | (22.42)% |
| Total Fixed Operating Cost | $4,855,702 | $2,872,632 | $1,983,070 | (40.84)% |
| Variable Costs: | | | | |
| Operating Cost: | | | | |
| Variable Operating Cost - Dry Fertilizer Plant | $301,168 | $301,168 | $0 | 0.00% |
| Variable Operating Cost - Liquid Fertilizer Plant | $36,140 | $36,140 | $0 | 0.00% |
| Total Variable Operating Cost | $337,308 | $337,308 | $0 | 0.00% |
| Transportation Costs From Manufacturer To Fertilizer Plant: | | | | |
| Rail Transport - Dry Fertilizer | $1,294,212 | $1,265,874 | $28,338 | 2.19% |
| Truck Transport - Dry Fertilizer | $0 | $44,838 | ($44,838) | NA |
| Truck Transport from Enderlin - Liquid Fertilizer | $9,746 | $13,443 | ($3,697) | 37.93% |
| Truck Transport from Hendrum - Liquid Fertilizer | $10,050 | $9,208 | $842 | (8.38)% |
| Total Manufacturer to Fertilizer Plant Transportation Cost | $1,314,008 | $1,333,363 | ($19,355) | 1.47% |
| Transportation Costs From Fertilizer Plant To Farm: | | | | |
| Transportation of Dry | $139,947 | $198,395 | ($58,448) | 41.76% |
| Transportation of Liquid | $20,787 | $34,724 | ($13,937) | 67.05% |
| Total Fertilizer Plant To Farm Transportation Cost | $160,734 | $233,119 | ($72,385) | 45.03% |
| Total Transportation Cost | $1,474,742 | $1,566,482 | ($91,740) | 6.22% |
| Application Costs: | | | | |
| Application Cost - Dry | $2,972,048 | $2,972,048 | $0 | 0.00% |
| Application Cost - Liquid | $2,972,048 | $2,972,048 | $0 | 0.00% |
| Total Application Cost | $5,944,096 | $5,944,096 | $0 | 0.00% |
| Total Fixed Cost | $4,855,702 | $2,872,632 | $1,983,070 | (40.84)% |
| Total Variable Cost | $7,756,146 | $7,847,886 | ($91,740) | 1.18% |
| Total Cost | $12,611,848 | $10,720,518 | $1,891,330 | (15.00)% |
| Cost Per Ton | $227.33 | $193.24 | $34.09 | (15.00)% |

In Scenario 3, the full cost model was modified to require fertilizer plants to incur compliance costs and allow fertilizer plants to remain at the same storage capacity, increase storage capacity, or exit the industry. Total cost in this scenario was $10,720,518 (Table 5.1). Total fixed operating costs represented 27 percent of total costs in Scenario 3. Variable operating costs, transportation costs from manufacturer to fertilizer plant, transportation costs from fertilizer plant to farm and application costs represented 3, 13, 2, and 55 percent of total costs, respectively (total variable costs accounted for 73 percent of total costs).

Table 5.2 summarizes the costs associated with the sunk capital perspective scenarios: Scenarios 2 and 4. Lytle and Hill discuss the sunk capital hypothesis used in Scenarios 2 and 4. As in their study, the capital structure of the fertilizer industry in Cass County may have affected the optimum number and size of fertilizer plants. "Most elevator facilities in the county [analyzed by Lytle and Hill] are depreciated nearly to zero, and there are no alternative uses for the invested capital" (p. 205).[27] Therefore, fertilizer plants can effectively ignore depreciation costs, except on the purchase of new equipment and facilities (Lytle and Hill, p. 205). In the sunk capital hypothesis perspective, construction,

purchase, and depreciation costs of existing fertilizer plants are subtracted from total fixed operating cost.

[27]Depreciation is "the annual charge which estimates the amount of capital equipment [facilities] used up in each year's production [operation]" (McConnell, p. 152).

**Table 5.2. Cost Comparison of Sunk Capital Scenarios, Baseline and Investment, 1995**

| Description | Scenario 2<br>Sunk Capital Hypothesis Baseline | Scenario 4<br>Sunk Capital Hypothesis with Investment | Comparison of Scenarios 2 and 4<br>Cost Savings | Percent Change |
|---|---|---|---|---|
| Fixed Costs: | | | | |
| Operating Cost: | | | | |
| Fixed Operating Cost - Dry Fertilizer Plant | $569,856 | $219,391 | $350,465 | (61.50)% |
| Fixed Operating Cost - Liquid Fertilizer Plant | $519,310 | $325,003 | $194,307 | (37.42)% |
| Fixed Operating Cost - Firm | $1,114,604 | $820,693 | $293,911 | (26.37)% |
| Total Fixed Operating Cost | $2,203,770 | $1,365,087 | $838,683 | (38.06)% |
| Variable Costs: | | | | |
| Operating Cost: | | | | |
| Variable Operating Cost - Dry Fertilizer Plant | $301,168 | $301,168 | $0 | 0.00% |
| Variable Operating Cost - Liquid Fertilizer Plant | $36,140 | $36,140 | $0 | 0.00% |
| Total Variable Operating Cost | $337,308 | $337,308 | $0 | 0.00% |
| Transportation Costs From Manufacturer To Fertilizer Plant: | | | | |
| Rail Transport - Dry Fertilizer | $1,294,212 | $1,263,440 | $30,772 | (2.38)% |
| Truck Transport - Dry Fertilizer | $0 | $45,899 | ($45,899) | NA |
| Truck Transport from Enderlin - Liquid Fertilizer | $9,746 | $5,592 | $4,154 | (42.62)% |
| Truck Transport from Hendrum - Liquid Fertilizer | $10,050 | $12,854 | ($2,804) | 27.90% |
| Total Manufacturer to Fertilizer Plant Transportation Cost | $1,314,008 | $1,327,785 | ($13,777) | 1.05% |
| Transportation Costs From Fertilizer Plant To Farm: | | | | |
| Transportation of Dry | $139,947 | $207,195 | ($67,248) | 48.05% |
| Transportation of Liquid | $20,787 | $32,900 | ($12,113) | 58.27% |
| Total Fertilizer Plant To Farm Transportation Cost | $160,734 | $240,095 | ($79,361) | 49.37% |
| Total Transportation Cost | $1,474,742 | $1,567,880 | ($93,138) | 6.32% |
| Application Costs: | | | | |
| Application Cost - Dry | $2,972,048 | $2,972,048 | $0 | 0.00% |
| Application Cost - Liquid | $2,972,048 | $2,972,048 | $0 | 0.00% |
| Total Application Cost | $5,944,096 | $5,944,096 | $0 | 0.00% |
| Total Fixed Cost | $2,203,770 | $1,365,087 | $838,683 | (38.06)% |
| Total Variable Cost | $7,756,146 | $7,849,284 | ($93,138) | 1.20% |
| Total Cost | $9,959,916 | $9,214,371 | $745,545 | (7.49)% |
| | | | | 0.00% |
| Cost Per Ton | $179.53 | $166.09 | $13.44 | (7.49)% |

Scenario 2 of this case study uses the sunk capital hypothesis to form a second baseline. Scenario 2 and Scenario 1 costs were the same, except for the exclusion of sunk costs (i.e., construction, purchase, and depreciation costs associated with facilities, equipment, and land) in Scenario 2, because annual fertilizer storage capacity at each plant was set for both scenarios. Total cost in Scenario 2 (sunk capital hypothesis baseline) was $9,959,916 (Table 5.2). Fixed operating cost accounted for 22 percent of total cost in Scenario 2. Variable operating costs, transportation costs from manufacturer to fertilizer plant, transportation costs from fertilizer plant to farm and application costs represented 3, 13, 2, and 60 percent of total costs, respectively (total variable costs accounted for 78 percent of total costs).

In Scenario 4, in addition to subtracting all sunk costs of existing fertilizer plants, the model was adjusted to allow fertilizer plants to remain at the same capacity, increase their storage capacity, or exit the industry. Total cost in Scenario 4 was $9,214,371 (Table 5.2). Total cost was comprised of 15 percent fixed costs and 85 percent variable costs. The variable costs broke down into 4 percent variable operating cost, 14 percent transportation costs from manufacturer to fertilizer plant, 3 percent transportation costs from fertilizer plant to farm, and 65 percent application costs.

Ton-miles associated with dry and liquid fertilizer transportation are summarized in Table 5.3. Ton-miles was the measure used to describe movement of one ton over one mile. It also served as a measure of the amount of fertilizer transported, " and hence the risk exposure" associated with fertilizer transportation (Dennis, p. 13). "While no one measure is likely to capture all aspects of risk exposure, the most useful measures are probably ton-miles and carloads" (Dennis, p. 13). Total ton-miles increased 38 percent under the full cost perspective and 37 percent under the sunk capital hypothesis perspective (Table 5.3). The percent change in dry and liquid fertilizer ton-miles under each cost perspective was approximately 30 percent and 40 percent, respectively. Although environmental and exposure costs were not included in this case study, Table 5.3 shows that the risk exposure level increased. Therefore, accidents and spills occur more often if compliance measures affect the industry structure.

**Table 5.3. Summary of Liquid and Dry Fertilizer Ton-Miles for Cass County, North Dakota and the Surrounding Fringe Townships, 1995**

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Description | Full Cost Baseline | Sunk Capital Hypothesis Baseline | Full Cost With Investment | Sunk Capital Hypothesis With Investment |
| Dry Ton-Miles | 76,356,661 | 76,356,661 | 112,169,743 | 112,367,879 |
| Liquid Ton-Miles | 11,251,992 | 11,251,992 | 19,240,728 | 18,774,124 |
| Total Ton-Miles | 190,539,191 | 190,539,191 | 305,212,217 | 301,079,106 |

## Analysis of Results

An analysis of the results is presented in this section. Analysis of the results is split into three segments: cost savings and percent change, annual fertilizer storage capacity, and fertilizer plant characteristics.

### *Cost Savings and Percent Change*

In each perspective, full cost and sunk capital hypothesis, the total cost savings was calculated (Table 5.1 and Table 5.2). Total cost savings represented the dollar amount saved by decreasing excess fertilizer storage capacity and allowing fertilizer plants to remain at the same storage capacity, increase their storage capacity or exit the industry. Under the full cost perspective, a cost savings of $1,891,330 resulted (Scenario 3 total cost, $12,611,848, minus Scenario 1 total cost, $10,720,518). The per ton cost savings amounted to $34.09 (Table 5.1). The savings in this cost perspective was attributed to lower fixed operating costs. The lower fixed operating cost was a natural result of fewer fertilizer plants and less annual storage capacity (Appendix I). In the full cost baseline, Scenario 1, the industry included 24 fertilizer plants with a total of 101,000 tons of storage capacity. The excess capacity (11 fertilizer plants and 38,502 tons of storage capacity) left the industry in Scenario 3 and a cost savings of $1,891,330 (a 41 percent change from Scenario 1) resulted from lower fixed operating costs (Appendix I and Table 5.1).

Variable operating costs and application costs remained the same in the full cost perspective. Demand for dry and liquid fertilizer remained the same at the farm level; and as it was specified that demand must be met within the model, variable costs and application costs were constant in Scenarios 1 and 3 (Table 5.1).

Transportation costs from manufacturer to fertilizer plant and transportation costs from fertilizer plant to farm caused an increase in variable costs and adversely affected cost savings. A 2 percent increase in transportation costs from manufacturer to fertilizer plant resulted in a cost increase of $19,355, and a 45 percent increase in transportation costs from fertilizer plant to farm resulted in a cost increase of $72,385 (Table 5.1). The increase in manufacturer to fertilizer plant was largely the result of trucking dry fertilizer to fertilizer plant P12, which did not have rail access. The increase in transportation costs from fertilizer plant to farm was attributed to higher costs of transportation associated with fewer fertilizer plants transporting fertilizer longer distances and probably at a higher cost per mile in Scenario 3 than in Scenario 1. If the model allowed price breaks for bulk shipments, the cost increase would not have been as great for manufacturer to plant transportation. Given the increases in inbound and outbound fertilizer transportation costs, total transportation cost generated a 6 percent or $91,740 cost increase (Table 5.1).

The net effect of all variable costs in Scenario 3 decreased costs savings by $91,740 (Table 5.1). However, that cost increase combined with the cost savings generated by lower total fixed costs resulted in a 15 percent savings ($1,891,330) when comparing Scenario 1 to Scenario 3 (Table 5.1).

Total cost savings in the sunk capital perspective was $745,545 (Table 5.2). As in the full cost comparison, the cost savings resulted from lower fixed operating costs. A 38 percent decrease in fixed operating cost generated a cost savings of $838,683 in the sunk capital hypothesis perspective (Table 5.2).

As in the full cost perspective, variable operating costs and application costs remained the same in the sunk capital hypothesis perspective. Demand for dry and liquid fertilizer remained the same at the farm level; and as it was specified that demand must be met within the model, variable costs and application costs were constant in Scenarios 2 and 4 (Table 5.2).

The large change in variable costs is due to the 6 percent increase in transportation costs within the sunk capital perspective. Transportation cost from manufacturer to plant rose 1 percent and generated a cost increase of $13,777 (Table 5.2). However, the 49 percent increase in fertilizer plant to farm transportation costs ($79,361) was the major factor behind the overall transportation cost increase (Table 5.2). As in the full cost perspective, the increase in manufacturer to fertilizer plant transportation costs was mainly the result of trucking dry fertilizer to fertilizer plant P12. Fewer fertilizer plants transporting fertilizer longer distances and possibly at a higher cost per mile was the probable cause for the increase in fertilizer plant to farm transportation costs. As in the full cost perspective, those cost savings also could have been increased by bulk transportation rates.

The combined effect of all variable costs resulted in a total variable cost increase ($93,138) from Scenario 2 to 4 (Table 5.2). When the effect of total variable cost was combined with the larger cost savings created by total fixed costs, a net cost savings of 7 percent ($745,545) resulted in the sunk capital hypothesis perspective. The result was a cost savings of $13.44 per ton (Table 5.2).

Table 5.4 summarizes the cost comparison between the Scenario 3, full cost with compliance, and Scenario 4, sunk capital hypothesis with compliance. As expected, the sunk capital hypothesis had a considerable effect on fixed operating costs in this case study, but it had a small effect on variable costs.

The 87 percent difference between total fixed operating cost from Scenario 3 to Scenario 4 was largely the result of excluding sunk costs (facility construction and depreciation, equipment purchase and depreciation, and land depreciation) in Scenario 4. Part of this cost savings also resulted from fewer fertilizer plants choosing to increase their fertilizer storage capacity in Scenario 4 as compared to Scenario 3 (Appendix I). When a plant chose to increase its storage capacity in Scenarios 3 or 4, the full cost of facility construction and depreciation, equipment purchase and depreciation, and land depreciation associated with the new plant capacity was included in total fixed operating cost.

As in the previous comparisons, variable operating costs and application costs were the same in Scenarios 3 and 4 because of the constraints placed on the model. Total transportation costs increased from Scenario 3 to 4, but only by $1,398, which was less than a 1 percent increase (Table 5.4). When comparing Scenario 3 to Scenario 4, the net cost savings was $1,506,147 or $27.15 per ton (Table 5.4). The net increase in cost savings was the result of lower fixed operating cost and was also attributed to a change in the composition of fertilizer plants remaining the Scenario 4 solution (Appendix I and Table 5.4).

**Table 5.4. Cost Comparison of Scenario 3, Full Cost with Investment, and Scenario 4, Sunk Capital Hypothesis with Investment, 1995**

| Description | Scenario 3 Full Cost with Investment | Scenario 4 Sunk Capital Hypothesis with Investment | Comparison of Scenarios 3 and 4 Cost Savings | Comparison of Scenarios 3 and 4 Percent Change |
|---|---|---|---|---|
| Fixed Costs: | | | | |
| Operating Cost: | | | | |
| Fixed Operating Cost - Dry Fertilizer Plant | $1,631,449 | $219,391 | $1,412,058 | (86.55)% |
| Fixed Operating Cost - Liquid Fertilizer Plant | $376,476 | $325,003 | $51,473 | (13.67)% |
| Fixed Operating Cost - Firm | $864,707 | $820,693 | $44,014 | (5.09)% |
| Total Fixed Operating Cost | $2,872,632 | $1,365,087 | $1,507,545 | (52.48)% |
| Variable Costs: | | | | |
| Operating Cost: | | | | |
| Variable Operating Cost - Dry Fertilizer Plant | $301,168 | $301,168 | $0 | 0.00% |
| Variable Operating Cost - Liquid Fertilizer Plant | $36,140 | $36,140 | $0 | 0.00% |
| Total Variable Operating Cost | $337,308 | $337,308 | $0 | 0.00% |
| Transportation Costs From Manufacturer To Fertilizer Plant: | | | | |
| Rail Transport - Dry Fertilizer | $1,265,874 | $1,263,440 | $2,434 | (0.19)% |
| Truck Transport - Dry Fertilizer | $44,838 | $45,899 | ($1,061) | 2.37% |
| Truck Transport from Enderlin - Liquid Fertilizer | $13,443 | $5,592 | $7,851 | (58.40)% |
| Truck Transport from Hendrum - Liquid Fertilizer | $9,208 | $12,854 | ($3,646) | 39.60% |
| Total Manufacturer to Fertilizer Plant Transportation Cost | $1,333,363 | $1,327,785 | $5,578 | (0.42)% |
| Transportation Costs From Fertilizer Plant To Farm: | | | | |
| Transportation of Dry | $198,395 | $207,195 | ($8,800) | 4.44% |
| Transportation of Liquid | $34,724 | $32,900 | $1,824 | (5.25)% |
| Total Fertilizer Plant To Farm Transportation Cost | $233,119 | $240,095 | ($6,976) | 2.99% |
| Total Transportation Cost | $1,566,482 | $1,567,880 | ($1,398) | 0.09% |
| Application Costs: | | | | |
| Application Cost - Dry | $2,972,048 | $2,972,048 | $0 | 0.00% |
| Application Cost - Liquid | $2,972,048 | $2,972,048 | $0 | 0.00% |
| Total Application Cost | $5,944,096 | $5,944,096 | $0 | 0.00% |
| Total Fixed Cost | $2,872,632 | $1,365,087 | $1,507,545 | (52.48)% |
| Total Variable Cost | $7,847,886 | $7,849,284 | ($1,398) | 0.02% |
| Total Cost | $10,720,518 | $9,214,371 | $1,506,147 | (14.05)% |
| Cost Per Ton | $193.24 | $166.09 | $27.15 | (14.05)% |

*Annual Fertilizer Storage Capacity*

The fertilizer industry (i.e., Cass County and the surrounding fringe townships in North Dakota) currently has approximately 14,000 tons of liquid and 87,000 tons of dry fertilizer storage capacity, which equaled approximately 101,000 tons of total fertilizer storage at 24 fertilizer plants (14 liquid fertilizer plants and 23 dry fertilizer plants). Overcapacity in the industry was evident in a comparison of the full cost scenarios and the sunk capital hypothesis scenarios. In the full cost perspective, total fertilizer storage dropped 38 percent, from 101,000 tons to 63,000 tons. Total fertilizer storage dropped 39 percent, from 101,000 tons to 62,000 tons, in the sunk capital hypothesis perspective. Furthermore, three dry fertilizer plants entered the solutions of Scenarios 1 and 2, but did not have any sales volume. The fixed cost of operating those plants enters into total cost in Scenarios 1 and 2, but because there are no sales, no variable costs were incurred. This partially accounts for the larger proportion of fixed cost to total cost in Scenarios 1 and 2. Fixed costs represented 38 and 17 percent of total cost in Scenarios 1 and 2; whereas in Scenarios 3 and 4, fixed costs represented 27 and 11 percent of total cost.

The extra capacity for dry fertilizer also was evident in the comparison between scenarios in the same perspective. Dry fertilizer storage capacity dropped by approximately 42 percent in both the full cost and sunk capital hypothesis perspectives, but dry fertilizer storage capacity was 837 tons less in Scenario 4 than in Scenario 3 (Appendix I). Liquid fertilizer storage capacity decreased by 16 percent in both perspectives (from 14,000 tons to 12,000 tons). The extra dry fertilizer storage capacity in Scenario 3 (when compared to Scenario 4) indicated that excess capacity still existed. A summary of liquid and dry fertilizer storage capacity and a breakdown of the annual storage capacity of individual plants in each scenario is in Appendix I. Since the large difference in fixed operating costs was attributed mainly to the exclusion of sunk costs and annual fertilizer storage capacities and variable costs are quite similar between the two cost perspectives (full cost and sunk capital hypothesis), the value of the sunk capital hypothesis in this case study was better shown by an analysis of fertilizer plant characteristics within the cost perspectives.

*Fertilizer Plant Characteristics*

The overcapacity in the industry generally meant that when extra costs (compliance costs) are forced on the industry, some firms would exit. This was especially true in a mature industry, such as the fertilizer industry in Cass County and the surrounding fringe townships, where growth peaked and was beginning to decline (Porter, p. 21). This idea was further supported by the results of comparing the industry before and after allowing investment and operating decisions in each cost perspective in this case study. In both perspectives, when compliance costs were forced on fertilizer plants, 11 fertilizer plants choose to exit and 13 fertilizer plants were left to meet demand for dry and liquid fertilizer in Cass Country and the surrounding fringe townships. Table 5.5 summarizes the number and fertilizer storage capacity of dry and liquid fertilizer plants entering the solution in each scenario.

The variable costs in the full cost and sunk capital hypothesis perspective baseline scenarios were necessarily the same because of the constraints placed on the model. Since the large difference in fixed operating cost was largely attributed to the exclusion of sunk costs in Scenario 4, the only other difference between the two perspectives evident in Table 5.5 was the size distribution of dry fertilizer plants between Scenarios 3 (full cost with investment) and Scenario 4 (sunk capital hypothesis with investment). In Scenario 3, there are zero, three, three, and six dry fertilizer plants at 1,395, 2,232, 3,627, and 5,580 tons of annual storage capacity, respectively (Table 5.5). In Scenario 4, there are one, two, three, and six dry fertilizer plants at 1,395, 2,232, 3,627, and 5,580 tons of annual storage capacity, respectively (Table 5.5). The size distribution of liquid fertilizer plants (zero, five and one at 279, 1,395, and 5,022 tons of annual storage capacity, respectively) was the same for both Scenario 3 and 4 (Table

5.5). However, the size distribution did not fully explain the difference between Scenarios 3 and 4. The real difference was shown by an analysis of the fertilizer plants that chose to increase the size of their fertilizer storage capacity (either dry or liquid) in Scenarios 3 and 4.

**Table 5.5. Summary of Fertilizer Plants Entering the Solution for Each Scenario, 1995**

| Description: | Scenario 1<br>Full Cost Baseline | Scenario 2<br>Sunk Capital Hypothesis Baseline | Scenario 3<br>Full Cost with Investment | Scenario 4<br>Sunk Capital Hypothesis with Investment |
|---|---|---|---|---|
| Fertilizer plants entering the solution: | | | | |
| Dry Size A | 6 | 6 | 0 | 1 |
| Dry Size B | 3 | 3 | 3 | 2 |
| Dry Size C | 3 | 3 | 3 | 3 |
| Dry Size D | 11 | 11 | 6 | 6 |
| Liquid Size A | 8 | 8 | 0 | 0 |
| Liquid Size B | 5 | 5 | 5 | 5 |
| Liquid Size C | 1 | 1 | 1 | 1 |
| Number of dry/liquid combination fertilizer plants:[28] | 13 | 13 | 5 | 5 |
| Number of Fertilizer Plants Able to Store Only Dry Fertilizer:* | 10 | 10 | 7 | 7 |
| Number of Fertilizer Plants Able to Store Only Liquid Fertilizer: | 1 | 1 | 1 | 1 |
| Total Fertilizer Plants Entering the Solution: | 24 | 24 | 13 | 13 |

*In Scenarios 1 and 2, three fertilizer plants with only dry fertilizer storage enter the solution, but have no sales volume.

[28]"Dry/liquid combination" means that the fertilizer plant has both dry and liquid fertilizer storage capacity.

The state of overcapacity in the industry also logically led to the belief that fertilizer plants would choose not to increase storage capacity when upgrading their facilities to comply with the RMP guidelines. Table 5.6, which summarizes the number and type of fertilizer plants that chose to increase their facility size under each cost perspective, shows this idea does not hold in this case study.

**Table 5.6. Summary of Size Increases in the Full Cost and Sunk Capital Hypothesis Perspectives, 1995**

| | Number of Size Increases When Comparing Scenario 1 to Scenario 3<br>Full Cost Perspective | Number of Size Increases When Comparing Scenario 2 to Scenario 4<br>Sunk Capital Hypothesis Perspective |
|---|---|---|
| Dry Fertilizer Plant Size Upgrades : | 3 | 0 |
| Liquid Fertilizer Plant Size Upgrades: | 5 | 1 |
| Total Fertilizer Plant Size Upgrades: | 8 | 1 |

Three dry fertilizer plants and five liquid fertilizer plants (a total of eight fertilizer plants) chose to increase their storage capacity when given that choice in Scenario 3, which was under the full cost perspective (Table 5.6). Only one liquid fertilizer plant chose to increase its size in Scenario 4, which employed the sunk capital hypothesis (Table 5.6).

In Scenario 3 (full cost with investment), all construction, purchase, and depreciation costs associated with established fertilizer plants were included in total cost. Compliance with the guidelines outlined in the RMP was a requirement in Scenario 3, and the fertilizer plants were able to choose to stay at the same storage capacity, increase their storage capacity at full cost of construction and depreciation, or exit the industry.

Nine fertilizer plants (eight dry plants and one dry/liquid combination plant) chose to remain at the same capacity, and eight fertilizer plants chose to "upsize" (increase their fertilizer storage capacity) in Scenario 3 (Appendix I). In Lytle and Hill, existing firms were able to better maintain their position in the industry when the cost of capital (interest rate) was higher (p. 206). When the cost of capital (interest rate) was low, entry in the industry and "upsizing" was more advantageous because returns to capital on that investment would be higher. In Scenario 3, a "lower cost of capital" situation was created because all costs of construction and depreciation for existing firms were included in total fixed cost (Lytle and Hill, p. 206). Therefore, "upsizing" was advantageous in Scenario 3. This was demonstrated by the eight fertilizer plants that chose to increase their fertilizer storage capacities (Table 5.6).

Three dry and five liquid fertilizer plants increased their storage capacity in Scenario 3. Two dry fertilizer plants increased their storage capacity from Size A (500 tons) to Size B (800 tons), and one increased its storage capacity from Size A (500 tons) to Size D (2,000 tons). Four liquid fertilizer plants increased their storage capacity from Size A (100 tons) to Size B (500 tons), and one increased its liquid fertilizer storage capacity to Size C (1,800 tons) from Size A (100 tons).

Given the requirements and choices in Scenario 3, a total of 11 fertilizer plants chose to exit (Table 5.7). Five dry/liquid combination plants continued their operation, but only with **either** dry or liquid fertilizer storage capacity. Of the five dry/liquid combination plants with either dry or liquid storage capacity still in use, those that exited included three, one, and one liquid fertilizer plants at Size A (100 tons), Size B (500 tons), and Size C (1,800 tons), respectively (Appendix I and Table 5.7).

Three of the 11 total fertilizer plants that exited the industry were dry/liquid combination plants. The dry/liquid combination plants included the following: one liquid fertilizer plant at Size A (500 tons), two liquid fertilizer plants at Size B (800 tons), and three dry fertilizer plants at Size D (2,000 tons) (Appendix I and Table 5.7). Eight of the

11 that exited had only dry fertilizer storage capacity: three at Size A (500 tons), two at Size B (800 tons), and three at Size D (2,000 tons) (Appendix I and Table 5.7).

In Scenario 4 (sunk capital hypothesis with investment), the construction, purchase, and depreciation costs associated with established fertilizer plants were not included in total cost. All plants were forced to comply with the guidelines outlined in the RMP, and fertilizer plants can choose to remain at the same fertilizer storage capacity, increase their storage capacity at full cost of construction and depreciation, or exit the industry.

Twelve fertilizer plants (seven dry plants, one liquid plants, and four dry/liquid combination plants) chose to remain at the same storage capacity (Appendix I). One dry/liquid combination plant chose to leave its dry fertilizer storage capacity the same, but chose to increase its liquid fertilizer storage capacity from Size A (100 tons) to Size B (500 tons) (Appendix I). A total of 13 fertilizer plants remained in the solution for Scenario 4, sunk capital hypothesis with investment.

At a higher cost of capital (interest rate) "existing firms maintained their relative positions" in the industry (Lytle and Hill, p. 206). This same situation (a high cost of capital) can be created by lowering fixed cost for existing firms by a comparable amount. A situation characterized by high interest rates was created in Scenario 4 because the construction and depreciation costs associated with existing fertilizer plants was subtracted from total cost. Therefore, existing firms were better able to retain their storage capacity (protect their market share) and "upsizing" was disadvantageous because returns to capital on the investment were low. Lower returns on capital in Scenario 4, as compared to Scenario 3, was the reason why only one plant chose to increase its liquid fertilizer storage capacity and at the same time bring its facility into compliance. The reason for this plant's decision may have been based on its location. Also, its manufacturer to fertilizer plant and fertilizer plant to farm transportation costs may have been lower than other liquid fertilizer plants competing for the same market share.

Eleven fertilizer plants chose to exit the industry in Scenario 4 (Table 5.7). Four dry/liquid combination plants continued their operation, but only with either dry or liquid storage capacity. Of the four dry/liquid combination plants with either dry or liquid storage capacity still in use, those that exited included three liquid fertilizer plants at 100 tons (Size A) and one dry fertilizer plant at 2,000 tons (Size D).

Of the 11 fertilizer plants that exited the industry, another four were dry/liquid combination plants. The four dry/liquid combination plants that exited (neither dry nor liquid storage capacity were utilized in Scenario 4) included the following: three liquid fertilizer plants at 100 tons (Size A), one liquid fertilizer plant at 500 tons (Size B), two dry fertilizer plants at 500 tons (Size A), and two dry fertilizer plants at 2,000 tons (Size D) (Table 5.7 and Appendix I).

Six of the 11 fertilizer plants that exited had only dry storage capacity [three at 500 tons (Size A), one at 800 tons (Size B), and two at 2,000 tons (Size D)], and one of the 11 that exited had only 100 tons of liquid fertilizer storage capacity (Size A) (Table 5.7 and Appendix I).

**Table 5.7. Summary of Fertilizer Plants Exiting the Industry in Scenario 3, Full Cost with Investment, and Scenario 4, Sunk Capital Hypothesis with Investment, 1995**

| Description | Scenario 3<br>Full Cost<br>with Investment | Scenario 4<br>Sunk Capital Hypothesis<br>with Investment |
|---|---|---|
| Fertilizer plants exiting the industry: | | |
| Dry Size A | 3 | 5 |
| Dry Size B | 0 | 1 |
| Dry Size C | 2 | 0 |
| Dry Size D | 6 | 6 |
| Liquid Size A | 4 | 7 |
| Liquid Size B | 3 | 1 |
| Liquid Size C | 1 | 0 |
| Of the dry/liquid combination fertilizer plants, the number where **either** dry or liquid storage continues to be used: | 5 | 4 |
| Of the dry/liquid combination fertilizer plants, the number where **neither** dry or liquid storage continues to be used: | 3 | 4 |
| The number of fertilizer plants that are able to store only dry fertilizer: | 8 | 6 |
| The number of fertilizer plants that are able to store only liquid fertilizer: | 0 | 1 |
| Total number of fertilizer plants exiting the industry: | 11 | 11 |

# CHAPTER 6. SUMMARY AND CONCLUSIONS

Future regulation of the agricultural fertilizer industry is uncertain at present. Within the past year, representatives of the agricultural fertilizer industry in North Dakota approached the NDDHCL about introducing legislation that would create and support consistency within the industry (Vandel, 1996). The federal government did not adopt uniform nationwide regulations for regulating agricultural fertilizer storage and transportation. Although North Dakota did not adopt agricultural fertilizer legislation, it created the RMP guidelines and asked fertilizer plants to begin compliance.

As the RMP guidelines were implemented, the cost of operation, transportation, and storage of agricultural fertilizers changed. Therefore, fertilizer plants must evaluate their current operations and consider whether upgrading equipment and facilities, to comply with RMP guidelines, is profitable. If upgrading is not profitable, the fertilizer plant may exit the industry. A potential problem with the exit of many fertilizer plants is the industry's concentration could increase. A possible benefit of exit is that economies of size could lower operating costs for fertilizer plants and ultimately lower fertilizer purchase costs at the farm level.

The objectives of this case study were to compare how compliance with the RMP guidelines affected the logistical, operating, and investment costs of fertilizer plants and evaluate the effect on fertilizer plant size and the market structure of the fertilizer industry. The information used to evaluate the effect on fertilizer plant size and the market structure of the fertilizer industry was gathered from various primary and secondary sources. The secondary data sources included a review of agricultural fertilizer secondary data, interviews with industry representatives and state officials, and a literature review. Primary data sources were a mail and phone survey of fertilizer plant managers operating fertilizer plants in the Cass County and surrounding fringe township geographic area. The survey was designed to collect information about each fertilizer plant, including dry and liquid fertilizer storage capacity, and rail access.

## Summary

To better understand how the agricultural fertilizer industry structure and profitability may react to changes; industry trends and an analysis of competitive forces affecting the fertilizer industry are presented in Chapter 2. The focus is upon competitive forces that affect the retail (fertilizer plant) level of the fertilizer industry.

The threat of new entrants in the retail fertilizer industry is low, and entry is made more unappealing by discussion of industry regulation. Economies of size and the existence of excess capacity were other entry barriers that firms considering entry or expansion need to consider. The relatively low threat of entrants created a positive effect on industry profitability.

Conversely, the following had an adverse effect on profitability: rivalry, threat of substitutes, power of buyers, and power of suppliers. Firms in the retail fertilizer industry (i.e., Cass County and the surrounding fringe townships) were quite competitive because the industry was mature and profits leveled. Furthermore, excess capacity created an even more competitive atmosphere as firms competed for market share and profit potential.

Industry profitability also was affected by the threat of substitute products and services. However, since fertilizer was a somewhat standardized product, the effect of enforcing the RMP guidelines on the threat of substitute products was minimal. Because fertilizer products were considered standard, farmers were able to exert buyer power by shopping around for the best price. This meant fertilizer plants that were forced to incur compliance costs had to be cautious when deciding how much of the additional cost they passed on to farmers in the cost of fertilizers.

Production of agricultural fertilizers was controlled by a few manufacturers; therefore, suppliers had greater bargaining power than retail fertilizer plants. However, an industry "shake-out" could create more price flexibility for retail fertilizer plants in the form of bulk shipment discounts.

The negative effects of the last four competitive forces on profitability could be overcome by the cost savings associated with a "shake-out" in the industry. The net effect on profitability will depend on how fiercely firms fight to stay viable in the industry after regulations are adopted and the "shake-out" begins.

A mixed-integer linear programming (MIP) model was developed in Chapter 3 to minimize the cost of operating fertilizer plants in this case study. The objective function sums fixed and variable operating costs, transportation cost from manufacturer to fertilizer plant, transportation cost from fertilizer plant to farm, and application cost. The objective function and constraints placed on the model were presented in Chapter 3.

The various cost calculations, right hand side values, and technical coefficients were determined in Chapter 4. The data sources for these calculations also were presented.

Four scenarios were developed and solved using the LINDO program. Two scenarios were under the "full cost" perspective, and two scenarios were under the "sunk capital hypothesis" cost perspective. The results from the four scenarios were presented and analyzed in Chapter 5. The results of Scenario 3 (full cost with investment) and Scenario 4 (sunk capital hypothesis with investment) were compared to analyze the effect of the sunk capital hypothesis on fertilizer plant decisions regarding compliance with RMP guidelines and increasing storage capacity.

**Conclusions and Implications**

Staying on top of potential regulations affecting the agricultural fertilizer industry is challenging for retail level fertilizer plant managers. This is especially true in North Dakota where no uniform regulations have been adopted, but compliance with RMP guidelines is recommended. Fertilizer plant managers may want to comply with the RMP guidelines (which are not law) to spread out the cost, but no one can guarantee that the improvements made today will meet the requirements of future legislation.

If legislation similar to the RMP is adopted, existing fertilizer plants will be required to bring their current facilities into compliance and a "shake-out" of the excess capacity in the agricultural fertilizer industry will likely occur. The results of this case study show that if agricultural fertilizer plants were required to comply with the RMP guidelines, almost half of the fertilizer plants in Cass County and the surrounding fringe township would exit the industry. The exit of these fertilizer plants would obviously decrease fixed operating cost. Reducing industry capacity in this study saved approximately $746,000 in fixed operating costs. However, decreasing the number of firms operating in the industry will increase transportation costs because fewer firms will be expected to deliver the same amount of liquid and dry fertilizer to the same number of farms.

Total ton-miles increased by approximately 37 percent; therefore, transportation costs also increased (6 percent or approximately $93,000). However, this increase in transportation cost was not great enough to overshadow the cost savings created by lower fixed operating costs. Furthermore, manufacturer to plant transportation costs would probably be reduced by bulk shipment discounts.

Another adverse affect of increased ton-miles was the increased risk of exposure due to accidents and spills. Although costs associated with spill clean-up were not included in this study, they are important and fertilizer plant management should prepare and plan for accident and spill situations.

Delayed response times or ability to fill fertilizer orders promptly was an additional factor that could be correlated with a smaller number of fertilizer plants and longer average distances from plant to farm. As farming is sometimes a high-stress occupation, especially during spring and fall when the majority of farm-work (i.e., fertilizer application) is completed, prompt response to farmer demands is critical. Therefore, on-time performance also may be a factor in the number of fertilizer plants that remain in operation after an industry shake-out.

Current fertilizer plant size (tons of dry or liquid storage capacity) did not seem to be a factor in whether the firm entered the solution for Scenarios 3 or 4, because a number of Size A liquid and Size D dry plants exited the industry in both scenarios. While Size A to Size B increases in fertilizer storage capacity were the most common, no conclusions about this information could be formed because most size increases only occurred in Scenario 3. As there was only one size increase (liquid Size A to Size B) in Scenario 4, one can conclude that few size investments would occur if regulations such as the RMP guidelines are implemented.

The use of the sunk capital hypothesis affected the market structure, but not the number of fertilizer plants entering in the solution for Scenario 4 (i.e., there was no change in the number of firms, but there was a change in the number of size investment from Scenario 2 to Scenario 4). The number of increases in storage capacity declined drastically (from eight to one) and the actual plants that remained in the solution changed from Scenario 3 (full cost with investment) to Scenario 4 (sunk capital hypothesis with investment).

Although the results appear to be the same in Scenarios 3 and 4, they were quite different. The use of the sunk capital hypothesis in this case study provides a more realistic picture of how increased government regulation affects (1) logistic and operating costs, (2) investment decisions, (3) fertilizer plant size and number, and (4) industry structure in the agricultural fertilizer industry.

### Limitations and Areas for Further Study

This case study is the first to analyze the effect of government regulation on the retail fertilizer industry in North Dakota. The study was limited geographically to one county in southeastern North Dakota and its immediate surrounding townships, so results obtained from the four scenarios in this case study also may have limited application in other areas of North Dakota where agriculture is less intense. However, the results of this study are probably reflective of results that would be obtained for areas in eastern North Dakota. Furthermore, the model could be used with data corresponding to other areas of North Dakota to create results for other areas of the state.

In addition, all fertilizer was assumed custom applied in this case study. If a percentage of custom applied acres could be determined and incorporated into farm demand, the model and results could be made more realistic. The study also was limited in that fertilizer plants could only purchase a set number of tender trucks and applicators. Implementing an option to purchase more equipment might provide more realistic results. Furthermore, the option to purchase more equipment may enable the "smaller number of firms" to provide better on-time service.

Also, this case study focused mainly on government regulations affecting the storage, containment, and facility construction costs associated with liquid fertilizer. It was assumed that dry facility construction costs covered all necessary structures for minimum compliance with the brief guidelines outlined for dry fertilizer storage in the fifth section of the RMP. Furthermore, the last section of the RMP, which addresses an accidental discharge plan, was not considered in this case study. Further research could determine if additional costs would be involved in compliance with RMP recommendations for dry fertilizer storage, containment, and handling and in implementation of an accidental discharge plan.

Although environmental and social costs are associated with the transport, storage, and handling of hazardous materials, such as agricultural fertilizers, these costs were not included in the case study. Ton-miles are summarized in this study to indicate the effect of having to transport longer distances. The 37 or 38 percent increase in ton-miles after enforcing compliance measures and giving firms a choice regarding their plant capacity signifies a large increase in risk associated with the transport of fertilizer in this case study. Further study of the costs associated with the increased risk would be beneficial in helping fertilizer plant managers prepare for potential accidents or spills.

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# APPENDIX A

## Cover Letter and Survey

September 28, 1994

Fertilizer Plant
c/o Manager
Address 1
Address 2
City, State, and Zipcode

Dear Manager:

The Upper Great Plains Transportation Institute is working with the North Dakota Department of Transportation to develop a database which includes an inventory of all major transportation modes and transportation generators in North Dakota. The completed system will allow the NDDOT to determine the most efficient freight transport route, maintenance schedule, and emergency response procedure.

The enclosed survey is very brief, but it will help determine the amount of fertilizer being transported and stored by your facility. This information will in turn be coded into the database being compiled for the NDDOT.

If any question on the survey is irrelevant to your firm, please indicate this by writing "NA" in the blank. Please write your firm's address and phone number on the survey form, so if I have questions I can reach you. Please fill out the survey and return it in the enclosed envelope by October 20, 1994.

Thank you for your time. If you have any questions about the survey or the study, please call me at (701)298-1078.

Sincerely,

Suzanne Miller
Graduate Research Assistant
Upper Great Plains Transportation Institute

Enclosure

**Fertilizer Storage and Loading Capacity Survey**

Company Name: ______________________________

Contact: ______________________________

Address: ______________________________

Phone: ______________________________

1. Estimate fertilizer storage capacity in tons for each of the following:
   Bulk Fertilizer Storage:
   Liquid Fertilizer:__________tons
   How many tanks are used for fertilizer storage?__________
   What is the size of the largest tank? __________tons

   Dry Fertilizer: __________tons

   Anhydrous Ammonia: __________tons

   Bagged Fertilizer Storage: __________tons

2. Estimate the percentage of inbound fertilizer tonnage *delivered* by mode and service level:

| | Type of Fertilizer | | |
|---|---|---|---|
| | Liquid Fertilizer | Dry Fertilizer | Anhydrous Ammonia |
| 1 to 5 Rail Cars | | | |
| 6 to 50 Rail Cars | | | |
| > 50 Rail Cars | | | |
| Truck | | | |
| TOTAL | 100% | 100% | 100% |

3. How many units of the following can be loaded at the facility?
   Liquid Fertilizer:
   Blended: __________gallons/minute
   Straight: __________gallons/minute

   Dry Fertilizer:
   Blended: __________pounds/minute
   Straight: __________pounds/minute

   Anhydrous Ammonia: __________pounds/minute

4. How many tons/hour of dry fertilizer can be unloaded at the facility? _________tons/hour

5. Estimate the maximum track space in rail car equivalents: _________

6. Is custom application offered?_____Yes _____No

    6a. If yes, what is the average application rate per machine?
    _________acres/day/machine

    6b. If yes, how long is the average work day (ex. 8 hrs., 14 hrs.)?
    _________hours

7. What is your approximate service area? _________square miles

8. What is the maximum distance traveled from your facility to apply fertilizer?
_________miles

## APPENDIX B

## Farm Level Demand for Dry and Liquid Fertilizer

Appendix B. Farm Level Demand for Dry and Liquid Fertilizer

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FA01 | 13183.00 | 659.15 | 79.10 |
| FA02 | 13183.00 | 659.15 | 79.10 |
| FA03 | 13183.00 | 659.15 | 79.10 |
| FA04 | 13183.00 | 659.15 | 79.10 |
| FA05 | 13183.00 | 659.15 | 79.10 |
| FA06 | 10926.00 | 546.30 | 65.56 |
| FA07 | 10926.00 | 546.30 | 65.56 |
| FA08 | 10926.00 | 546.30 | 65.56 |
| FA09 | 2731.50 | 136.58 | 16.39 |
| FB09 | 2731.50 | 136.58 | 16.39 |
| FC09 | 2731.50 | 136.58 | 16.39 |
| FD09 | 2731.50 | 136.58 | 16.39 |
| FA10 | 2731.50 | 136.58 | 16.39 |
| FB10 | 2731.50 | 136.58 | 16.39 |
| FC10 | 2731.50 | 136.58 | 16.39 |
| FD10 | 2731.50 | 136.58 | 16.39 |
| FA11 | 2731.50 | 136.58 | 16.39 |
| FB11 | 2731.50 | 136.58 | 16.39 |
| FC11 | 2731.50 | 136.58 | 16.39 |
| FD11 | 2731.50 | 136.58 | 16.39 |
| FA12 | 2731.50 | 136.58 | 16.39 |
| FB12 | 2731.50 | 136.58 | 16.39 |
| FC12 | 2731.50 | 136.58 | 16.39 |
| FD12 | 2731.50 | 136.58 | 16.39 |
| FA13 | 3298.70 | 164.94 | 19.79 |
| FB13 | 3298.70 | 164.94 | 19.79 |
| FC13 | 3298.70 | 164.94 | 19.79 |
| FD13 | 3298.70 | 164.94 | 19.79 |
| FA14 | 3298.70 | 164.94 | 19.79 |

(Continued)

Appendix B. (Continued)

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FB14 | 3298.70 | 164.94 | 19.79 |
| FC14 | 3298.70 | 164.94 | 19.79 |
| FD14 | 3298.70 | 164.94 | 19.79 |
| FA15 | 3298.70 | 164.94 | 19.79 |
| FB15 | 3298.70 | 164.94 | 19.79 |
| FC15 | 3298.70 | 164.94 | 19.79 |
| FD15 | 3298.70 | 164.94 | 19.79 |
| FA16 | 13183.00 | 659.15 | 79.10 |
| FA17 | 13183.00 | 659.15 | 79.10 |
| FA18 | 3298.70 | 164.94 | 19.79 |
| FB18 | 3298.70 | 164.94 | 19.79 |
| FC18 | 3298.70 | 164.94 | 19.79 |
| FD18 | 3298.70 | 164.94 | 19.79 |
| FA19 | 3298.70 | 164.94 | 19.79 |
| FB19 | 3298.70 | 164.94 | 19.79 |
| FC19 | 3298.70 | 164.94 | 19.79 |
| FD19 | 3298.70 | 164.94 | 19.79 |
| FA20 | 3298.70 | 164.94 | 19.79 |
| FB20 | 3298.70 | 164.94 | 19.79 |
| FC20 | 3298.70 | 164.94 | 19.79 |
| FD20 | 3298.70 | 164.94 | 19.79 |
| FA21 | 3298.70 | 164.94 | 19.79 |
| FB21 | 3298.70 | 164.94 | 19.79 |
| FC21 | 3298.70 | 164.94 | 19.79 |
| FD21 | 3298.70 | 164.94 | 19.79 |
| FA22 | 2731.50 | 136.58 | 16.39 |
| FB22 | 2731.50 | 136.58 | 16.39 |
| FC22 | 2731.50 | 136.58 | 16.39 |
| FD22 | 2731.50 | 136.58 | 16.39 |

(Continued)

Appendix B. (Continued)

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FA23 | 2731.50 | 136.58 | 16.39 |
| FB23 | 2731.50 | 136.58 | 16.39 |
| FC23 | 2731.50 | 136.58 | 16.39 |
| FD23 | 2731.50 | 136.58 | 16.39 |
| FA24 | 2731.50 | 136.58 | 16.39 |
| FB24 | 2731.50 | 136.58 | 16.39 |
| FC24 | 2731.50 | 136.58 | 16.39 |
| FD24 | 2731.50 | 136.58 | 16.39 |
| FA25 | 2731.50 | 136.58 | 16.39 |
| FB25 | 2731.50 | 136.58 | 16.39 |
| FC25 | 2731.50 | 136.58 | 16.39 |
| FD25 | 2731.50 | 136.58 | 16.39 |
| FA26 | 2731.50 | 136.58 | 16.39 |
| FB26 | 2731.50 | 136.58 | 16.39 |
| FC26 | 2731.50 | 136.58 | 16.39 |
| FD26 | 2731.50 | 136.58 | 16.39 |
| FA27 | 2731.50 | 136.58 | 16.39 |
| FB27 | 2731.50 | 136.58 | 16.39 |
| FC27 | 2731.50 | 136.58 | 16.39 |
| FD27 | 2731.50 | 136.58 | 16.39 |
| FA28 | 3298.70 | 164.94 | 19.79 |
| FB28 | 3298.70 | 164.94 | 19.79 |
| FC28 | 3298.70 | 164.94 | 19.79 |
| FD28 | 3298.70 | 164.94 | 19.79 |
| FA29 | 3298.70 | 164.94 | 19.79 |
| FB29 | 3298.70 | 164.94 | 19.79 |
| FC29 | 3298.70 | 164.94 | 19.79 |
| FD29 | 3298.70 | 164.94 | 19.79 |
| FA30 | 3298.70 | 164.94 | 19.79 |

(Continued)

Appendix B. (Continued)

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FB30 | 3298.70 | 164.94 | 19.79 |
| FC30 | 3298.70 | 164.94 | 19.79 |
| FD30 | 3298.70 | 164.94 | 19.79 |
| FA31 | 3298.70 | 164.94 | 19.79 |
| FB31 | 3298.70 | 164.94 | 19.79 |
| FC31 | 3298.70 | 164.94 | 19.79 |
| FD31 | 3298.70 | 164.94 | 19.79 |
| FA32 | 13183.00 | 659.15 | 79.10 |
| FA33 | 13183.00 | 659.15 | 79.10 |
| FA34 | 3298.70 | 164.94 | 19.79 |
| FB34 | 3298.70 | 164.94 | 19.79 |
| FC34 | 3298.70 | 164.94 | 19.79 |
| FD34 | 3298.70 | 164.94 | 19.79 |
| FA35 | 3298.70 | 164.94 | 19.79 |
| FB35 | 3298.70 | 164.94 | 19.79 |
| FC35 | 3298.70 | 164.94 | 19.79 |
| FD35 | 3298.70 | 164.94 | 19.79 |
| FA36 | 3298.70 | 164.94 | 19.79 |
| FB36 | 3298.70 | 164.94 | 19.79 |
| FC36 | 3298.70 | 164.94 | 19.79 |
| FD36 | 3298.70 | 164.94 | 19.79 |
| FA37 | 3298.70 | 164.94 | 19.79 |
| FB37 | 3298.70 | 164.94 | 19.79 |
| FC37 | 3298.70 | 164.94 | 19.79 |
| FD37 | 3298.70 | 164.94 | 19.79 |
| FA38 | 2731.50 | 136.58 | 16.39 |
| FB38 | 2731.50 | 136.58 | 16.39 |
| FC38 | 2731.50 | 136.58 | 16.39 |
| FD38 | 2731.50 | 136.58 | 16.39 |

(Continued)

Appendix B. (Continued)

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FA39 | 2731.50 | 136.58 | 16.39 |
| FB39 | 2731.50 | 136.58 | 16.39 |
| FC39 | 2731.50 | 136.58 | 16.39 |
| FD39 | 2731.50 | 136.58 | 16.39 |
| FA42 | 6376.00 | 318.80 | 38.26 |
| FB42 | 6376.00 | 318.80 | 38.26 |
| FC42 | 6376.00 | 318.80 | 38.26 |
| FD42 | 6376.00 | 318.80 | 38.26 |
| FA43 | 6376.00 | 318.80 | 38.26 |
| FB43 | 6376.00 | 318.80 | 38.26 |
| FC43 | 6376.00 | 318.80 | 38.26 |
| FD43 | 6376.00 | 318.80 | 38.26 |
| FA44 | 2975.30 | 148.77 | 17.85 |
| FB44 | 2975.30 | 148.77 | 17.85 |
| FC44 | 2975.30 | 148.77 | 17.85 |
| FD44 | 2975.30 | 148.77 | 17.85 |
| FA45 | 2975.30 | 148.77 | 17.85 |
| FB45 | 2975.30 | 148.77 | 17.85 |
| FC45 | 2975.30 | 148.77 | 17.85 |
| FD45 | 2975.30 | 148.77 | 17.85 |
| FA46 | 2975.30 | 148.77 | 17.85 |
| FB46 | 2975.30 | 148.77 | 17.85 |
| FC46 | 2975.30 | 148.77 | 17.85 |
| FD46 | 2975.30 | 148.77 | 17.85 |
| FA47 | 2975.30 | 148.77 | 17.85 |
| FB47 | 2975.30 | 148.77 | 17.85 |
| FC47 | 2975.30 | 148.77 | 17.85 |
| FD47 | 2975.30 | 148.77 | 17.85 |
| FA48 | 11895.20 | 594.76 | 71.37 |

(Continued)

Appendix B. (Continued)

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FB50 | 2975.30 | 148.77 | 17.85 |
| FC50 | 2975.30 | 148.77 | 17.85 |
| FD50 | 2975.30 | 148.77 | 17.85 |
| FA49 | 11895.20 | 594.76 | 71.37 |
| FB51 | 2975.30 | 148.77 | 17.85 |
| FC51 | 2975.30 | 148.77 | 17.85 |
| FD51 | 2975.30 | 148.77 | 17.85 |
| FA50 | 2975.30 | 148.77 | 17.85 |
| FA51 | 2975.30 | 148.77 | 17.85 |
| FA52 | 2975.30 | 148.77 | 17.85 |
| FB52 | 2975.30 | 148.77 | 17.85 |
| FC52 | 2975.30 | 148.77 | 17.85 |
| FD52 | 2975.30 | 148.77 | 17.85 |
| FA53 | 2975.30 | 148.77 | 17.85 |
| FB53 | 2975.30 | 148.77 | 17.85 |
| FC53 | 2975.30 | 148.77 | 17.85 |
| FD53 | 2975.30 | 148.77 | 17.85 |
| FA54 | 6376.00 | 318.80 | 38.26 |
| FB54 | 6376.00 | 318.80 | 38.26 |
| FC54 | 6376.00 | 318.80 | 38.26 |
| FD54 | 6376.00 | 318.80 | 38.26 |
| FA55 | 6376.00 | 318.80 | 38.26 |
| FB55 | 6376.00 | 318.80 | 38.26 |
| FC55 | 6376.00 | 318.80 | 38.26 |
| FD55 | 6376.00 | 318.80 | 38.26 |
| FA56 | 6376.00 | 318.80 | 38.26 |
| FB56 | 6376.00 | 318.80 | 38.26 |
| FC56 | 6376.00 | 318.80 | 38.26 |
| FD56 | 6376.00 | 318.80 | 38.26 |

(Continued)

Appendix B. (Continued)

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FA57 | 6376.00 | 318.80 | 38.26 |
| FB57 | 6376.00 | 318.80 | 38.26 |
| FC57 | 6376.00 | 318.80 | 38.26 |
| FD57 | 6376.00 | 318.80 | 38.26 |
| FA58 | 6376.00 | 318.80 | 38.26 |
| FB58 | 6376.00 | 318.80 | 38.26 |
| FC58 | 6376.00 | 318.80 | 38.26 |
| FD58 | 6376.00 | 318.80 | 38.26 |
| FA59 | 6376.00 | 318.80 | 38.26 |
| FB59 | 6376.00 | 318.80 | 38.26 |
| FC59 | 6376.00 | 318.80 | 38.26 |
| FD59 | 6376.00 | 318.80 | 38.26 |
| FA60 | 2767.80 | 138.39 | 16.61 |
| FB60 | 2767.80 | 138.39 | 16.61 |
| FC60 | 2767.80 | 138.39 | 16.61 |
| FD60 | 2767.80 | 138.39 | 16.61 |
| FA61 | 2767.80 | 138.39 | 16.61 |
| FB61 | 2767.80 | 138.39 | 16.61 |
| FC61 | 2767.80 | 138.39 | 16.61 |
| FD61 | 2767.80 | 138.39 | 16.61 |
| FA62 | 2767.80 | 138.39 | 16.61 |
| FB62 | 2767.80 | 138.39 | 16.61 |
| FC62 | 2767.80 | 138.39 | 16.61 |
| FD62 | 2767.80 | 138.39 | 16.61 |
| FA63 | 2767.80 | 138.39 | 16.61 |
| FB63 | 2767.80 | 138.39 | 16.61 |
| FC63 | 2767.80 | 138.39 | 16.61 |
| FD63 | 2767.80 | 138.39 | 16.61 |
| FA64 | 11065.80 | 553.29 | 66.39 |

(Continued)

Appendix B. (Continued)

| Farm Number | Cropland Acres | Dry Fertilizer Farm Level Demand (Tons) | Liquid Fertilizer Farm Level Demand (Tons) |
|---|---|---|---|
| FA65 | 11065.80 | 553.29 | 66.39 |
| FA66 | 11065.80 | 553.29 | 66.39 |
| FA67 | 11065.80 | 553.29 | 66.39 |
| FA68 | 11065.80 | 553.29 | 66.39 |
| FA69 | 11065.80 | 553.29 | 66.39 |
| FA70 | 25504.00 | 1275.20 | 153.02 |
| FA71 | 25504.00 | 1275.20 | 153.02 |
| FA72 | 25504.00 | 1275.20 | 153.02 |
| Totals | 990,683 | 49,534 | 5,944 |

## APPENDIX C

**Annual Fixed Operating Costs**

Appendix C. Annual Fixed Operating Cost

| Cost Components | Dry Fertilizer Plant Size A | Dry Fertilizer Plant Size B | Dry Fertilizer Plant Size C | Dry Fertilizer Plant Size D |
|---|---|---|---|---|
| Labor Costs | | | | |
| Manager & Asst. Manager | $27,768.00 | $33,510.00 | $67,020.00 | $72,762.00 |
| Bookkeeping Staff | | | $9,566.00 | $19,132.00 |
| Insurance | | | | |
| Directors & Officers | $750.00 | $750.00 | $1,500.00 | $1,500.00 |
| Facility & Inventory | $1,917.00 | $2,992.00 | $3,993.00 | $5,591.00 |
| Equipment | $553.00 | $1,420.00 | $2,458.00 | $3,690.00 |
| Licenses | | | | |
| Annual Distribution Fee | $50.00 | $50.00 | $50.00 | $50.00 |
| Equipment | $50.00 | $346.00 | $1,352.00 | $1,947.00 |
| Lease for Railroad Trackage | $850.00 | $850.00 | $850.00 | $1,700.00 |
| Depreciation | | | | |
| Facility | $6,577.85 | $7,682.85 | $9,307.85 | $12,069.80 |
| Equipment | $22,814.20 | $36,981.80 | $81,429.60 | $131,551.20 |
| Opportunity Cost | | | | |
| Working Capital | $182.31 | $227.87 | $495.42 | $607.21 |
| Inventory in Facilities | $4,505.83 | $5,262.75 | $6,375.88 | $8,267.81 |
| Inventory in Equipment | $3,906.93 | $6,333.13 | $13,944.82 | $22,528.14 |
| Inventory in Land | $60.00 | $120.00 | $180.00 | $300.00 |
| Sunk - Fixed Operating Cost | $37,864.81 | $56,380.53 | $111,238.15 | $174,716.95 |
| Plant - Fixed Operating Cost | $32,120.31 | $40,145.87 | $87,284.42 | $106,979.21 |
| Total Fixed Operating Cost | $69,985.12 | $96,526.40 | $198,522.57 | $281,696.16 |

(Continued)

| Cost Components | Liquid Fertilizer Plant Size A | Liquid Fertilizer Plant Size B | Liquid Fertilizer Plant Size C |
|---|---|---|---|
| Labor Costs | | | |
| Manager & Asst. Manager | $27,768.00 | $33,510.00 | $72,762.00 |
| Bookkeeping Staff | | | $19,132.00 |
| Insurance | | | |
| Directors & Officers | $750.00 | $750.00 | $1,500.00 |
| Facility & Inventory | $1,917.00 | $2,992.00 | $5,591.00 |
| Equipment | $553.00 | $1,420.00 | $3,690.00 |
| Licenses | | | |
| Annual Distribution Fee | $50.00 | $50.00 | $50.00 |
| Equipment | $50.00 | $346.00 | $1,947.00 |
| Lease for Railroad Trackage | $850.00 | $850.00 | $1,700.00 |
| Depreciation | | | |
| Facility | $323.49 | $545.27 | $1,063.19 |
| Equipment | $17,000.00 | $29,696.20 | $121,122.80 |
| Opportunity Cost | | | |
| Working Capital | $182.31 | $227.87 | $607.21 |
| Inventory in Facilities | $221.59 | $373.51 | $728.28 |
| Inventory in Equipment | $2,911.25 | $5,085.47 | $20,742.28 |
| Inventory in Land | $60.00 | $120.00 | $300.00 |
| Sunk - Fixed Operating Cost | $20,516.33 | $35,820.45 | $143,956.55 |
| Plant - Fixed Operating Cost | $32,120.31 | $40,145.87 | $106,979.21 |
| Total Fixed Operating Cost | $52,636.64 | $75,966.32 | $250,935.76 |

(Continued)

Appendix C. (Continued)

| Cost Components | Firm Cost Small | Firm Cost Medium | Firm Cost Large |
|---|---|---|---|
| Labor Costs | | | |
| Manager & Asst. Manager | $27,768.00 | $33,510.00 | $72,762.00 |
| Bookkeeping Staff | | | $19,132.00 |
| Insurance | | | |
| Directors & Officers | $750.00 | $750.00 | $1,500.00 |
| Facility & Inventory | $1,917.00 | $2,992.00 | $5,591.00 |
| Equipment | $553.00 | $1,420.00 | $3,690.00 |
| Licenses | | | |
| Annual Distribution Fee | $50.00 | $50.00 | $50.00 |
| Equipment | $50.00 | $346.00 | $1,947.00 |
| Lease for Railroad Trackage | $850.00 | $850.00 | $1,700.00 |
| Depreciation | | | |
| Facility | $0.00 | $0.00 | $0.00 |
| Equipment | $0.00 | $3,200.00 | $6,400.00 |
| Opportunity Cost | | | |
| Working Capital | $182.31 | $227.87 | $607.21 |
| Inventory in Facilities | $0.00 | $0.00 | $0.00 |
| Inventory in Equipment | $0.00 | $548.00 | $1,096.00 |
| Inventory in Land | $60.00 | $120.00 | $300.00 |
| Sunk - Fixed Operating Cost | $60.00 | $3,868.00 | $7,796.00 |
| Plant - Fixed Operating Cost | $32,120.31 | $40,145.87 | $106,979.21 |
| Total Fixed Operating Cost | $32,180.31 | $44,013.87 | $114,775.21 |

(Continued)

Appendix C. (Continued)

| Cost Components | Liquid Upgrade A to B | Liquid Upgrade A to C | Liquid Upgrade B to C |
|---|---|---|---|
| Labor Costs | | | |
| Manager & Asst. Manager | $33,510.00 | $72,762.00 | $72,762.00 |
| Bookkeeping Staff | | $19,132.00 | $19,132.00 |
| Insurance | | | |
| Directors & Officers | $750.00 | $1,500.00 | $1,500.00 |
| Facility & Inventory | $2,992.00 | $5,591.00 | $5,591.00 |
| Equipment | $1,420.00 | $3,690.00 | $3,690.00 |
| Licenses | | | |
| Annual Distribution Fee | $50.00 | $50.00 | $50.00 |
| Equipment | $346.00 | $1,947.00 | $1,947.00 |
| Lease for Railroad Trackage | $850.00 | $1,700.00 | $1,700.00 |
| Depreciation | | | |
| Facility | $1,698.89 | $5,478.45 | $4,324.84 |
| Equipment | $29,696.20 | $121,122.80 | $121,122.80 |
| Opportunity Cost | | | |
| Working Capital | $227.87 | $607.21 | $607.21 |
| Inventory in Facilities | $1,163.74 | $3,752.74 | $2,962.51 |
| Inventory in Equipment | $5,085.47 | $20,742.28 | $20,742.28 |
| Inventory in Land | $120.00 | $300.00 | $300.00 |
| Sunk - Fixed Operating Cost | $37,764.30 | $151,396.27 | $149,452.43 |
| Plant - Fixed Operating Cost | $40,145.87 | $106,979.21 | $106,979.21 |
| Total Fixed Operating Cost | $77,910.17 | $258,375.48 | $256,431.64 |

## APPENDIX D

## Construction, Purchase, Depreciation, and Opportunity Costs

Appendix D. Depreciation and Opportunity Cost

| | | Facility Construction Cost | Facility Opportunity Cost | Facility Depreciation Cost |
|---|---|---|---|---|
| Dry Fertilizer Plant: | | | | |
| | Size A | $131,557.00 | $4,505.83 | $6,577.85 |
| | Size B | $153,657.00 | $5,262.75 | $7,682.85 |
| | Size C | $186,157.00 | $6,375.88 | $9,307.85 |
| | Size D | $241,396.00 | $8,267.81 | $12,069.80 |
| Liquid Fertilizer Plant: | | | | |
| | Size A | $6,469.74 | $221.59 | $323.49 |
| | Size B | $10,169.07 | $373.51 | $545.27 |
| | Size C | $35,669.60 | $728.28 | $1,063.19 |
| Firm Cost: | | | | |
| | Small | $0.00 | $0.00 | $0.00 |
| | Medium | $0.00 | $0.00 | $0.00 |
| | Large | $0.00 | $0.00 | $0.00 |
| Liquid Upgrade: | | | | |
| | A to B | $33,241.32 | $1,163.74 | $1,698.89 |
| | A to C | $123,974.80 | $3,752.74 | $5,478.45 |
| | B to C | $100,902.55 | $2,962.51 | $4,324.84 |

(Continued)

Appendix D. (Continued)

| | | Equipment Purchase Cost | Equipment Opportunity Cost | Equipment Depreciation Cost |
|---|---|---|---|---|
| Dry Fertilizer Plant: | | | | |
| | Size A | $114,071.00 | $3,906.93 | $22,814.20 |
| | Size B | $184,909.00 | $6,333.13 | $36,981.80 |
| | Size C | $407,148.00 | $13,944.82 | $81,429.60 |
| | Size D | $657,756.00 | $22,528.14 | $131,551.20 |
| Liquid Fertilizer Plant: | | | | |
| | Size A | $85,000.00 | $2,911.25 | $17,000.00 |
| | Size B | $148,481.00 | $5,085.47 | $29,696.20 |
| | Size C | $605,614.00 | $20,742.28 | $121,122.80 |
| Firm Cost: | | | | |
| | Small | $0.00 | $0.00 | $0.00 |
| | Medium | $16,000.00 | $548.00 | $3,200.00 |
| | Large | $32,000.00 | $1,096.00 | $6,400.00 |
| Liquid Upgrade: | | | | |
| | A to B | $148,481.00 | $5,085.47 | $29,696.20 |
| | A to C | $605,614.00 | $20,742.28 | $121,122.80 |
| | B to C | $605,614.00 | $20,742.28 | $121,122.80 |

(Continued)

Appendix D. (Continued)

| | | Land Purchase Cost | Land Opportunity Cost |
|---|---|---|---|
| Dry Fertilizer Plant: | | | |
| | Size A | $875.91 | $60.00 |
| | Size B | $1,751.82 | $120.00 |
| | Size C | $2,627.73 | $180.00 |
| | Size D | $4,379.55 | $300.00 |
| Liquid Fertilizer Plant: | | | |
| | Size A | $875.91 | $60.00 |
| | Size B | $1,751.82 | $120.00 |
| | Size C | $4,379.55 | $300.00 |
| Firm Cost: | | | |
| | Small | $875.91 | $60.00 |
| | Medium | $1,751.82 | $120.00 |
| | Large | $4,379.55 | $300.00 |
| Liquid Upgrade: | | | |
| | A to B | $1,751.82 | $120.00 |
| | A to C | $4,379.55 | $300.00 |
| | B to C | $4,379.55 | $300.00 |

## APPENDIX E

## Manufacturer to Fertilizer Plant - Transportation Costs

Appendix E. Manufacturer to Fertilizer Plant - Transportation Costs Per Ton

| Plant | Truck Dry Fertilizer from Minneapolis, Minn (cost per ton) | Rail Dry Fertilizer from Tampa, Fla. (cost per ton) | Truck Liquid Fertilizer from Hendrum, Minn. (cost per ton) | Truck Liquid Fertilizer from Enderlin, N. D. (cost per ton) |
|---|---|---|---|---|
| P01 | NA | $26.79 | $6.09 | $6.49 |
| P02 | NA | $26.66 | $4.15 | $7.71 |
| P03 | NA | $26.38 | $1.62 | $10.24 |
| P04 | $12.64 | NA | NA | NA |
| P05 | NA | $26.66 | NA | NA |
| P06 | NA | $26.48 | $3.57 | $8.29 |
| P07 | NA | $26.40 | NA | NA |
| P10 | NA | $26.07 | $3.21 | $8.65 |
| P11 | NA | $26.59 | NA | NA |
| P12 | $11.66 | NA | NA | NA |
| P13 | NA | $26.44 | NA | NA |
| P14 | NA | NA | $7.32 | $4.54 |
| P15 | NA | $26.21 | $6.45 | $5.41 |
| P16 | NA | $26.00 | $4.51 | $7.35 |
| P17 | NA | $26.39 | $9.05 | $2.81 |
| P18 | NA | $26.30 | $7.97 | $3.89 |
| P19 | NA | $29.38 | NA | NA |
| P21 | NA | $29.38 | $11.86 | $0.43 |
| P22 | NA | $26.42 | $9.19 | $2.67 |
| P23 | NA | $26.27 | $7.61 | $4.25 |
| P25 | NA | $26.63 | NA | NA |
| P26 | NA | $26.31 | $8.04 | $5.41 |
| P27 | NA | NA | $5.73 | $6.13 |
| P28 | NA | $26.53 | NA | NA |

# APPENDIX F

## Fertilizer Plant to Farm - Transportation Costs

Appendix F. Fertilizer Plant to Farm - Transportation Cost ($) Per Ton

| | Fertilizer Plants: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farms: | P01 | P02 | P03 | P04 | P05 | P06 | P07 | P10 | P11 | P12 | P13 | P14 |
| FA01 | 3.00 | 7.20 | 15.80 | 5.20 | 2.60 | 7.20 | 12.80 | 25.40 | 10.20 | 3.92 | 14.00 | 18.40 |
| FA02 | 1.40 | 4.80 | 13.40 | 4.40 | 5.00 | 4.80 | 10.40 | 23.00 | 12.60 | 5.20 | 11.60 | 16.00 |
| FA03 | 3.80 | 2.40 | 11.00 | 3.60 | 7.40 | 4.40 | 8.00 | 20.60 | 15.00 | 6.32 | 10.80 | 13.60 |
| FA04 | 6.20 | 0.80 | 8.60 | 2.16 | 9.80 | 6.80 | 5.60 | 18.20 | 17.40 | 6.32 | 13.20 | 11.20 |
| FA05 | 8.60 | 3.20 | 6.20 | 2.16 | 12.20 | 9.20 | 3.20 | 15.80 | 19.80 | 6.32 | 15.60 | 12.00 |
| FA06 | 11.00 | 5.60 | 3.80 | 3.44 | 14.60 | 11.60 | 4.00 | 13.40 | 22.20 | 5.04 | 18.00 | 14.40 |
| FA07 | 13.40 | 8.00 | 1.40 | 5.36 | 17.00 | 14.00 | 6.40 | 11.00 | 24.60 | 3.12 | 20.40 | 16.80 |
| FA08 | 15.80 | 10.40 | 3.40 | 7.28 | 19.40 | 16.40 | 8.80 | 8.60 | 27.00 | 1.36 | 22.80 | 19.20 |
| FA09 | 15.00 | 10.80 | 2.20 | 5.36 | 17.00 | 14.00 | 6.40 | 7.40 | 24.60 | 3.12 | 20.40 | 16.80 |
| FB09 | 16.20 | 12.00 | 3.40 | 6.32 | 18.20 | 15.20 | 7.60 | 6.60 | 25.80 | 2.16 | 21.60 | 18.00 |
| FC09 | 17.40 | 13.20 | 4.60 | 5.84 | 18.60 | 14.00 | 7.60 | 5.40 | 24.60 | 2.64 | 20.40 | 16.80 |
| FD09 | 16.20 | 12.00 | 3.40 | 4.88 | 17.40 | 12.80 | 6.40 | 6.20 | 23.40 | 3.60 | 19.20 | 15.60 |
| FA10 | 12.60 | 8.40 | 1.40 | 3.44 | 14.60 | 11.60 | 4.00 | 9.80 | 22.20 | 5.04 | 18.00 | 14.40 |
| FB10 | 13.80 | 9.60 | 1.00 | 4.40 | 15.80 | 12.80 | 5.20 | 8.60 | 23.40 | 4.08 | 19.20 | 15.60 |
| FC10 | 15.00 | 10.80 | 2.20 | 3.92 | 16.20 | 11.60 | 5.20 | 7.40 | 22.20 | 4.56 | 18.00 | 14.40 |
| FD10 | 13.80 | 9.60 | 2.60 | 2.96 | 15.00 | 10.40 | 4.00 | 8.60 | 21.00 | 5.52 | 16.80 | 13.20 |
| FA11 | 10.20 | 6.00 | 3.80 | 1.52 | 12.20 | 9.20 | 1.60 | 12.20 | 19.80 | 6.96 | 15.60 | 12.00 |
| FB11 | 11.40 | 7.20 | 2.60 | 2.48 | 13.40 | 10.40 | 2.80 | 11.00 | 21.00 | 6.00 | 16.80 | 13.20 |
| FC11 | 12.60 | 8.40 | 3.80 | 2.00 | 13.80 | 9.20 | 2.80 | 9.80 | 19.80 | 6.48 | 15.60 | 12.00 |
| FD11 | 11.40 | 7.20 | 5.00 | 1.04 | 12.60 | 8.00 | 1.60 | 11.00 | 18.60 | 7.44 | 14.40 | 10.80 |
| FA12 | 7.80 | 3.60 | 6.20 | 0.72 | 9.80 | 6.80 | 2.00 | 14.60 | 17.40 | 7.76 | 13.20 | 9.60 |
| FB12 | 9.00 | 4.80 | 5.00 | 0.72 | 11.00 | 8.00 | 0.80 | 13.40 | 18.60 | 7.76 | 14.40 | 10.80 |
| FC12 | 10.20 | 6.00 | 6.20 | 0.24 | 11.40 | 6.80 | 0.80 | 12.20 | 17.40 | 8.24 | 13.20 | 9.60 |
| FD12 | 9.00 | 4.80 | 7.40 | 0.72 | 10.20 | 5.60 | 2.00 | 13.40 | 16.20 | 8.24 | 12.00 | 8.40 |
| FA13 | 5.40 | 1.60 | 8.60 | 2.16 | 7.40 | 4.40 | 4.40 | 17.00 | 15.00 | 7.76 | 10.80 | 10.00 |
| FB13 | 6.60 | 2.40 | 7.40 | 1.20 | 8.60 | 5.60 | 3.20 | 15.80 | 16.20 | 7.76 | 12.00 | 8.80 |
| FC13 | 7.80 | 3.60 | 8.60 | 1.68 | 9.00 | 4.40 | 3.20 | 14.60 | 15.00 | 8.24 | 10.80 | 7.60 |
| FD13 | 6.60 | 2.80 | 9.80 | 2.64 | 7.80 | 3.20 | 4.40 | 15.80 | 13.80 | 8.24 | 9.60 | 8.80 |
| FA14 | 3.00 | 4.00 | 11.00 | 4.08 | 5.00 | 2.00 | 6.80 | 19.40 | 12.60 | 7.76 | 8.40 | 12.40 |
| FB14 | 4.20 | 2.80 | 9.80 | 3.12 | 6.20 | 3.20 | 5.60 | 18.20 | 13.80 | 7.76 | 9.60 | 11.20 |
| FC14 | 5.40 | 4.00 | 11.00 | 3.60 | 6.60 | 2.00 | 5.60 | 17.00 | 12.60 | 8.24 | 8.40 | 10.00 |
| FD14 | 4.20 | 5.20 | 12.20 | 4.56 | 5.40 | 0.80 | 6.80 | 18.20 | 11.40 | 8.24 | 7.20 | 11.20 |
| FA15 | 1.00 | 6.40 | 13.40 | 4.40 | 2.60 | 3.60 | 9.20 | 21.80 | 10.20 | 6.16 | 10.40 | 14.80 |

(Continued)

Appendix F. (Continued)

| Farms: | Fertilizer Plants: P01 | P02 | P03 | P04 | P05 | P06 | P07 | P10 | P11 | P12 | P13 | P14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FB15 | 1.80 | 5.20 | 12.20 | 4.40 | 3.80 | 2.40 | 8.00 | 20.60 | 11.40 | 7.12 | 9.20 | 13.60 |
| FC15 | 3.00 | 6.40 | 13.40 | 4.88 | 4.20 | 1.20 | 8.00 | 19.40 | 10.20 | 7.60 | 8.00 | 12.40 |
| FD15 | 2.20 | 7.60 | 14.60 | 4.88 | 3.00 | 2.40 | 9.20 | 20.60 | 9.00 | 6.64 | 9.20 | 13.60 |
| FA16 | 3.40 | 8.80 | 15.80 | 4.40 | 0.60 | 4.80 | 10.40 | 23.00 | 7.80 | 5.20 | 11.60 | 16.00 |
| FA17 | 5.80 | 11.20 | 18.20 | 5.20 | 3.00 | 5.20 | 12.80 | 20.60 | 5.40 | 4.72 | 9.20 | 13.60 |
| FA18 | 3.40 | 8.80 | 15.80 | 5.20 | 4.20 | 2.80 | 10.40 | 19.40 | 7.80 | 6.00 | 8.00 | 12.40 |
| FB18 | 4.20 | 7.60 | 14.60 | 5.20 | 5.40 | 1.60 | 9.20 | 18.20 | 9.00 | 6.96 | 6.80 | 11.20 |
| FC18 | 5.40 | 8.80 | 15.80 | 5.20 | 6.60 | 2.80 | 10.40 | 17.00 | 7.80 | 6.00 | 5.60 | 10.00 |
| FD18 | 4.60 | 10.00 | 17.00 | 5.20 | 5.40 | 4.00 | 11.60 | 18.20 | 6.60 | 5.04 | 6.80 | 11.20 |
| FA19 | 5.40 | 6.40 | 13.40 | 4.88 | 6.60 | 1.20 | 8.00 | 17.00 | 10.20 | 7.60 | 6.00 | 10.00 |
| FB19 | 6.60 | 5.20 | 12.20 | 3.92 | 7.80 | 2.40 | 6.80 | 15.80 | 11.40 | 7.60 | 7.20 | 8.80 |
| FC19 | 7.80 | 6.40 | 13.40 | 3.92 | 9.00 | 3.60 | 8.00 | 14.60 | 10.20 | 6.64 | 6.00 | 7.60 |
| FD19 | 6.60 | 7.60 | 14.60 | 4.88 | 7.80 | 2.40 | 9.20 | 15.80 | 9.00 | 6.64 | 4.80 | 8.80 |
| FA20 | 7.80 | 4.00 | 11.00 | 2.96 | 9.00 | 3.60 | 5.60 | 14.60 | 12.60 | 7.60 | 8.40 | 7.60 |
| FB20 | 9.00 | 4.80 | 9.80 | 2.00 | 10.20 | 4.80 | 4.40 | 13.40 | 13.80 | 7.60 | 9.60 | 6.40 |
| FC20 | 10.20 | 6.00 | 11.00 | 2.00 | 11.40 | 6.00 | 5.60 | 12.20 | 12.60 | 6.64 | 8.40 | 5.20 |
| FD20 | 9.00 | 5.20 | 12.20 | 2.96 | 10.20 | 4.80 | 6.80 | 13.40 | 11.40 | 6.64 | 7.20 | 6.40 |
| FA21 | 10.20 | 6.00 | 8.60 | 1.04 | 11.40 | 6.00 | 3.20 | 12.20 | 15.00 | 7.60 | 10.80 | 7.20 |
| FB21 | 11.40 | 7.20 | 7.40 | 0.88 | 12.60 | 7.20 | 2.00 | 11.00 | 16.20 | 7.60 | 12.00 | 8.40 |
| FC21 | 12.60 | 8.40 | 8.60 | 1.84 | 13.80 | 8.40 | 3.20 | 9.80 | 15.00 | 6.64 | 10.80 | 7.20 |
| FD21 | 11.40 | 7.20 | 9.80 | 1.84 | 12.60 | 7.20 | 4.40 | 11.00 | 13.80 | 6.64 | 9.60 | 6.00 |
| FA22 | 12.60 | 8.40 | 6.20 | 1.68 | 13.80 | 8.40 | 2.80 | 9.80 | 17.40 | 6.80 | 13.20 | 9.60 |
| FB22 | 13.80 | 9.60 | 5.00 | 2.64 | 15.00 | 9.60 | 4.00 | 8.60 | 18.60 | 5.84 | 14.40 | 10.80 |
| FC22 | 15.00 | 10.80 | 6.20 | 3.60 | 16.20 | 10.80 | 5.20 | 7.40 | 17.40 | 4.88 | 13.20 | 9.60 |
| FD22 | 13.80 | 9.60 | 7.40 | 2.64 | 15.00 | 9.60 | 4.00 | 8.60 | 16.20 | 5.84 | 12.00 | 8.40 |
| FA23 | 15.00 | 10.80 | 3.80 | 3.60 | 16.20 | 10.80 | 5.20 | 7.40 | 19.80 | 4.88 | 15.60 | 12.00 |
| FB23 | 16.20 | 12.00 | 3.40 | 4.56 | 17.40 | 12.00 | 6.40 | 6.20 | 21.00 | 3.92 | 16.80 | 13.20 |
| FC23 | 17.40 | 13.20 | 4.60 | 5.52 | 18.60 | 13.20 | 7.60 | 5.00 | 19.80 | 2.96 | 15.60 | 12.00 |
| FD23 | 16.20 | 12.00 | 5.00 | 4.56 | 17.40 | 12.00 | 6.40 | 6.20 | 18.60 | 3.92 | 14.40 | 10.80 |
| FA24 | 17.40 | 13.20 | 4.60 | 5.52 | 18.60 | 13.20 | 7.60 | 5.00 | 22.20 | 2.96 | 18.00 | 14.40 |
| FB24 | 18.60 | 14.40 | 5.80 | 6.48 | 19.80 | 14.40 | 8.80 | 4.20 | 23.40 | 2.00 | 19.20 | 15.60 |
| FC24 | 19.80 | 15.60 | 7.00 | 7.44 | 21.00 | 15.60 | 10.00 | 3.00 | 22.20 | 1.04 | 18.00 | 14.40 |
| FD24 | 18.60 | 14.40 | 5.80 | 6.48 | 19.80 | 14.40 | 8.80 | 3.80 | 21.00 | 2.00 | 16.80 | 13.20 |

(Continued)

Appendix F. (Continued)

| Farms: | P01 | P02 | P03 | P04 | P05 | P06 | P07 | P10 | P11 | P12 | P13 | P14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fertilizer Plants: | | | | | | | | | | | |
| FA25 | 19.80 | 15.60 | 7.00 | 7.44 | 21.00 | 15.60 | 10.00 | 2.60 | 19.80 | 1.04 | 15.60 | 12.00 |
| FB25 | 21.00 | 16.80 | 8.20 | 8.40 | 22.20 | 16.80 | 11.20 | 1.80 | 21.00 | 0.56 | 16.80 | 13.20 |
| FC25 | 22.20 | 18.00 | 9.40 | 9.36 | 23.40 | 18.00 | 12.40 | 0.60 | 19.80 | 0.88 | 15.60 | 12.00 |
| FD25 | 21.00 | 16.80 | 8.20 | 8.40 | 22.20 | 16.80 | 11.20 | 1.40 | 18.60 | 0.56 | 14.40 | 10.80 |
| FA26 | 17.40 | 13.20 | 6.20 | 5.52 | 18.60 | 13.20 | 7.60 | 5.00 | 17.40 | 2.96 | 13.20 | 9.60 |
| FB26 | 18.60 | 14.40 | 5.80 | 6.48 | 19.80 | 14.40 | 8.80 | 3.80 | 18.60 | 2.00 | 14.40 | 10.80 |
| FC26 | 19.80 | 15.60 | 7.00 | 7.44 | 21.00 | 15.60 | 10.00 | 2.60 | 17.40 | 1.04 | 13.20 | 9.60 |
| FD26 | 18.60 | 14.40 | 7.40 | 6.48 | 19.80 | 14.40 | 8.80 | 3.80 | 16.20 | 2.00 | 12.00 | 8.40 |
| FA27 | 15.00 | 10.80 | 8.60 | 3.60 | 16.20 | 10.80 | 5.20 | 7.40 | 15.00 | 4.88 | 10.80 | 7.20 |
| FB27 | 16.20 | 12.00 | 7.40 | 4.56 | 17.40 | 12.00 | 6.40 | 6.20 | 16.20 | 3.92 | 12.00 | 8.40 |
| FC27 | 17.40 | 13.20 | 8.60 | 5.52 | 18.60 | 13.20 | 7.60 | 5.00 | 15.00 | 2.96 | 10.80 | 7.20 |
| FD27 | 16.20 | 12.00 | 9.80 | 4.56 | 17.40 | 12.00 | 6.40 | 6.20 | 13.80 | 3.92 | 9.60 | 6.00 |
| FA28 | 12.60 | 8.40 | 11.00 | 2.80 | 13.80 | 8.40 | 5.60 | 9.80 | 12.60 | 5.68 | 8.40 | 4.80 |
| FB28 | 13.80 | 9.60 | 9.80 | 2.80 | 15.00 | 9.60 | 4.40 | 8.60 | 13.80 | 5.68 | 9.60 | 6.00 |
| FC28 | 15.00 | 10.80 | 11.00 | 3.76 | 16.20 | 10.80 | 5.60 | 7.40 | 12.60 | 4.72 | 8.40 | 4.80 |
| FD28 | 13.80 | 9.60 | 12.20 | 3.76 | 15.00 | 9.60 | 6.80 | 8.60 | 11.40 | 4.72 | 7.20 | 3.60 |
| FA29 | 10.20 | 6.40 | 13.40 | 2.96 | 11.40 | 6.00 | 8.00 | 12.20 | 10.20 | 5.68 | 6.00 | 5.20 |
| FB29 | 11.40 | 7.20 | 12.20 | 2.80 | 12.60 | 7.20 | 6.80 | 11.00 | 11.40 | 5.68 | 7.20 | 4.00 |
| FC29 | 12.60 | 8.40 | 13.40 | 3.76 | 13.80 | 8.40 | 8.00 | 9.80 | 10.20 | 4.72 | 6.00 | 2.80 |
| FD29 | 11.40 | 7.60 | 14.60 | 3.76 | 12.60 | 7.20 | 9.20 | 11.00 | 9.00 | 4.72 | 4.80 | 4.00 |
| FA30 | 7.80 | 8.80 | 15.80 | 4.88 | 9.00 | 3.60 | 10.40 | 14.60 | 7.80 | 5.68 | 3.60 | 7.60 |
| FB30 | 9.00 | 7.60 | 14.60 | 3.92 | 10.20 | 4.80 | 9.20 | 13.40 | 9.00 | 5.68 | 4.80 | 6.40 |
| FC30 | 10.20 | 8.80 | 15.80 | 3.92 | 11.40 | 6.00 | 10.40 | 12.20 | 7.80 | 4.72 | 3.60 | 5.20 |
| FD30 | 9.00 | 10.00 | 17.00 | 4.88 | 10.20 | 4.80 | 11.60 | 13.40 | 6.60 | 4.72 | 2.40 | 6.40 |
| FA31 | 5.80 | 11.20 | 18.20 | 5.20 | 6.60 | 5.20 | 12.80 | 17.00 | 5.40 | 4.72 | 5.60 | 10.00 |
| FB31 | 6.60 | 10.00 | 17.00 | 5.20 | 7.80 | 4.00 | 11.60 | 15.80 | 6.60 | 5.04 | 4.40 | 8.80 |
| FC31 | 7.80 | 11.20 | 18.20 | 5.20 | 9.00 | 5.20 | 12.80 | 14.60 | 5.40 | 4.72 | 3.20 | 7.60 |
| FD31 | 7.00 | 12.40 | 19.40 | 5.36 | 7.80 | 6.40 | 14.00 | 15.80 | 4.20 | 4.72 | 4.40 | 8.80 |
| FA32 | 8.20 | 13.60 | 20.60 | 6.32 | 5.40 | 7.60 | 15.20 | 18.20 | 3.00 | 4.72 | 6.80 | 11.20 |
| FA33 | 10.20 | 15.60 | 22.60 | 7.92 | 8.20 | 9.60 | 17.20 | 18.20 | 1.00 | 4.72 | 4.00 | 8.40 |
| FA34 | 8.20 | 13.20 | 20.20 | 6.00 | 9.40 | 7.20 | 14.80 | 15.80 | 3.40 | 4.72 | 2.80 | 7.20 |
| FB34 | 9.40 | 12.00 | 19.00 | 5.20 | 10.60 | 6.00 | 13.60 | 14.60 | 4.60 | 4.72 | 1.60 | 6.00 |
| FC34 | 10.60 | 13.20 | 20.20 | 6.00 | 11.80 | 7.20 | 14.80 | 15.80 | 4.20 | 4.72 | 0.80 | 4.80 |

(Continued)

Appendix F. (Continued)

| | Fertilizer Plants: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farms: | P01 | P02 | P03 | P04 | P05 | P06 | P07 | P10 | P11 | P12 | P13 | P14 |
| FD34 | 9.40 | 14.40 | 21.40 | 6.96 | 10.60 | 8.40 | 16.00 | 17.00 | 3.00 | 4.72 | 2.00 | 6.00 |
| FA35 | 10.60 | 10.80 | 17.80 | 4.72 | 11.80 | 6.40 | 12.40 | 13.40 | 5.80 | 4.08 | 1.60 | 4.80 |
| FB35 | 11.80 | 9.60 | 16.60 | 4.72 | 13.00 | 7.60 | 11.20 | 12.20 | 7.00 | 3.76 | 2.80 | 3.60 |
| FC35 | 13.00 | 10.80 | 17.80 | 5.68 | 14.20 | 8.80 | 12.40 | 13.40 | 6.60 | 3.12 | 2.00 | 2.40 |
| FD35 | 11.80 | 12.00 | 19.00 | 5.68 | 13.00 | 7.60 | 13.60 | 14.60 | 5.40 | 4.08 | 0.80 | 3.60 |
| FA36 | 13.00 | 8.80 | 15.40 | 4.72 | 14.20 | 8.80 | 10.00 | 11.00 | 8.20 | 3.76 | 4.00 | 2.40 |
| FB36 | 14.20 | 10.00 | 14.20 | 4.72 | 15.40 | 10.00 | 8.80 | 9.80 | 9.40 | 3.76 | 5.20 | 1.60 |
| FC36 | 15.40 | 11.20 | 15.40 | 5.68 | 16.60 | 11.20 | 10.00 | 11.00 | 9.00 | 2.80 | 4.40 | 0.40 |
| FD36 | 14.20 | 10.00 | 16.60 | 5.68 | 15.40 | 10.00 | 11.20 | 12.20 | 7.80 | 2.80 | 3.20 | 1.20 |
| FA37 | 15.40 | 11.20 | 13.00 | 4.72 | 16.60 | 11.20 | 7.60 | 8.60 | 10.60 | 3.76 | 6.40 | 2.80 |
| FB37 | 16.60 | 12.40 | 11.80 | 4.88 | 17.80 | 12.40 | 6.80 | 7.40 | 11.80 | 3.60 | 7.60 | 4.00 |
| FC37 | 17.80 | 13.60 | 13.00 | 5.84 | 19.00 | 13.60 | 8.00 | 8.60 | 11.40 | 2.64 | 6.80 | 2.80 |
| FD37 | 16.60 | 12.40 | 14.20 | 5.68 | 17.80 | 12.40 | 8.80 | 9.80 | 10.20 | 2.80 | 5.60 | 1.60 |
| FA38 | 17.80 | 13.60 | 10.60 | 5.84 | 19.00 | 13.60 | 8.00 | 6.20 | 13.00 | 2.64 | 8.80 | 5.20 |
| FB38 | 19.00 | 14.80 | 9.40 | 6.80 | 20.20 | 14.80 | 9.20 | 5.00 | 14.20 | 1.68 | 10.00 | 6.40 |
| FC38 | 20.20 | 16.00 | 10.60 | 7.76 | 21.40 | 16.00 | 10.40 | 6.20 | 13.80 | 0.72 | 9.20 | 5.20 |
| FD38 | 19.00 | 14.80 | 11.80 | 6.80 | 20.20 | 14.80 | 9.20 | 7.40 | 12.60 | 1.68 | 8.00 | 4.00 |
| FA39 | 20.20 | 16.00 | 8.20 | 7.76 | 21.40 | 16.00 | 10.40 | 3.80 | 15.40 | 0.72 | 11.20 | 7.60 |
| FB39 | 21.40 | 17.20 | 8.60 | 8.72 | 22.60 | 17.20 | 11.60 | 2.60 | 16.60 | 0.56 | 12.40 | 8.80 |
| FC39 | 22.60 | 18.40 | 9.80 | 9.68 | 23.80 | 18.40 | 12.80 | 3.80 | 16.20 | 1.20 | 11.60 | 7.60 |
| FD39 | 21.40 | 17.20 | 9.40 | 8.72 | 22.60 | 17.20 | 11.60 | 5.00 | 15.00 | 0.56 | 10.40 | 6.40 |
| FA42 | 22.60 | 18.40 | 10.60 | 9.68 | 23.80 | 18.40 | 12.80 | 6.20 | 16.20 | 1.20 | 11.60 | 7.20 |
| FB42 | 23.80 | 19.60 | 11.00 | 10.64 | 25.00 | 19.60 | 14.00 | 5.00 | 17.40 | 2.16 | 12.80 | 8.40 |
| FC42 | 24.20 | 20.00 | 11.40 | 10.96 | 25.40 | 20.00 | 14.40 | 5.40 | 17.80 | 2.48 | 13.20 | 8.80 |
| FD42 | 23.00 | 18.80 | 11.00 | 10.00 | 24.20 | 18.80 | 13.20 | 6.60 | 16.60 | 1.52 | 12.00 | 7.60 |
| FA43 | 20.20 | 16.00 | 13.00 | 7.76 | 21.40 | 16.00 | 10.40 | 8.60 | 13.80 | 0.72 | 9.20 | 4.80 |
| FB43 | 21.40 | 17.20 | 11.80 | 8.72 | 22.60 | 17.20 | 11.60 | 7.40 | 15.00 | 0.56 | 10.40 | 6.00 |
| FC43 | 21.80 | 17.60 | 12.20 | 9.04 | 23.00 | 17.60 | 12.00 | 7.80 | 15.40 | 0.56 | 10.80 | 6.40 |
| FD43 | 20.60 | 16.40 | 13.40 | 8.08 | 21.80 | 16.40 | 10.80 | 9.00 | 14.20 | 0.56 | 9.60 | 5.20 |
| FA44 | 17.80 | 13.60 | 15.40 | 6.64 | 19.00 | 13.60 | 10.00 | 11.00 | 11.40 | 1.84 | 6.80 | 2.40 |
| FB44 | 19.00 | 14.80 | 14.20 | 6.80 | 20.20 | 14.80 | 9.20 | 9.80 | 12.60 | 1.68 | 8.00 | 3.60 |
| FC44 | 19.40 | 15.20 | 14.60 | 7.12 | 20.60 | 15.20 | 9.60 | 10.20 | 13.00 | 1.36 | 8.40 | 4.00 |
| FD44 | 18.20 | 14.00 | 15.80 | 6.96 | 19.40 | 14.00 | 10.40 | 11.40 | 11.80 | 1.52 | 7.20 | 2.80 |

(Continued)

Appendix F. (Continued)

| Farms: | P01 | P02 | P03 | P04 | P05 | P06 | P07 | P10 | P11 | P12 | P13 | P14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FA45 | 15.40 | 11.20 | 17.80 | 6.64 | 16.60 | 11.20 | 12.40 | 13.40 | 9.00 | 2.16 | 4.40 | 2.00 |
| FB45 | 16.60 | 12.40 | 16.60 | 6.64 | 17.80 | 12.40 | 11.20 | 12.20 | 10.20 | 1.84 | 5.60 | 1.20 |
| FC45 | 17.00 | 12.80 | 17.00 | 6.96 | 18.20 | 12.80 | 11.60 | 12.60 | 10.60 | 1.52 | 6.00 | 1.60 |
| FD45 | 15.80 | 11.60 | 18.20 | 6.96 | 17.00 | 11.60 | 12.80 | 13.80 | 9.40 | 2.16 | 4.80 | 2.40 |
| FA46 | 13.00 | 13.20 | 20.20 | 6.64 | 14.20 | 8.80 | 14.80 | 15.80 | 6.60 | 4.08 | 2.00 | 4.40 |
| FB46 | 14.20 | 12.00 | 19.00 | 6.64 | 15.40 | 10.00 | 13.60 | 14.60 | 7.80 | 3.12 | 3.20 | 3.20 |
| FC46 | 14.60 | 12.40 | 19.40 | 6.96 | 15.80 | 10.40 | 14.00 | 15.00 | 8.20 | 3.12 | 3.60 | 3.60 |
| FD46 | 13.40 | 13.60 | 20.60 | 6.96 | 14.60 | 9.20 | 15.20 | 16.20 | 7.00 | 4.08 | 2.40 | 4.80 |
| FA47 | 10.60 | 15.60 | 22.60 | 7.92 | 11.80 | 9.60 | 17.20 | 18.20 | 4.20 | 4.72 | 3.20 | 6.80 |
| FB47 | 11.80 | 14.40 | 21.40 | 6.96 | 13.00 | 8.40 | 16.00 | 17.00 | 5.40 | 4.72 | 2.00 | 5.60 |
| FC47 | 12.20 | 14.80 | 21.80 | 7.28 | 13.40 | 8.80 | 16.40 | 17.40 | 5.80 | 4.72 | 2.40 | 6.00 |
| FD47 | 11.00 | 16.00 | 23.00 | 8.24 | 12.20 | 10.00 | 17.60 | 18.60 | 4.60 | 4.72 | 3.60 | 7.20 |
| FA48 | 12.60 | 18.00 | 25.00 | 9.84 | 10.60 | 12.00 | 19.60 | 20.60 | 3.00 | 4.72 | 5.60 | 9.20 |
| FA49 | 15.00 | 20.40 | 27.40 | 11.76 | 13.00 | 14.40 | 22.00 | 23.00 | 5.40 | 4.72 | 8.00 | 11.60 |
| FA50 | 13.00 | 18.00 | 25.00 | 9.84 | 14.20 | 12.00 | 19.60 | 20.60 | 6.60 | 4.72 | 5.60 | 9.20 |
| FB50 | 14.20 | 16.80 | 23.80 | 8.88 | 15.40 | 10.80 | 18.40 | 19.40 | 7.80 | 4.72 | 4.40 | 8.00 |
| FC50 | 15.40 | 18.00 | 25.00 | 9.84 | 16.60 | 12.00 | 19.60 | 20.60 | 9.00 | 4.72 | 5.60 | 9.20 |
| FD50 | 14.20 | 19.20 | 26.20 | 10.80 | 15.40 | 13.20 | 20.80 | 21.80 | 7.80 | 4.72 | 6.80 | 10.40 |
| FA51 | 15.40 | 15.60 | 22.60 | 8.56 | 16.60 | 11.20 | 17.20 | 18.20 | 9.00 | 4.08 | 4.40 | 6.80 |
| FB51 | 16.60 | 14.40 | 21.40 | 8.56 | 17.80 | 12.40 | 16.00 | 17.00 | 10.20 | 3.12 | 5.60 | 5.60 |
| FC51 | 17.80 | 15.60 | 22.60 | 9.52 | 19.00 | 13.60 | 17.20 | 18.20 | 11.40 | 3.12 | 6.80 | 6.80 |
| FD51 | 16.60 | 16.80 | 23.80 | 9.52 | 17.80 | 12.40 | 18.40 | 19.40 | 10.20 | 4.08 | 5.60 | 8.00 |
| FA52 | 17.80 | 13.60 | 20.20 | 8.56 | 19.00 | 13.60 | 14.80 | 15.80 | 11.40 | 2.16 | 6.80 | 4.40 |
| FB52 | 19.00 | 14.80 | 19.00 | 8.56 | 20.20 | 14.80 | 13.60 | 14.60 | 12.60 | 1.20 | 8.00 | 3.60 |
| FC52 | 20.20 | 16.00 | 20.20 | 9.52 | 21.40 | 16.00 | 14.80 | 15.80 | 13.80 | 1.20 | 9.20 | 4.80 |
| FD52 | 19.00 | 14.80 | 21.40 | 9.52 | 20.20 | 14.80 | 16.00 | 17.00 | 12.60 | 2.16 | 8.00 | 5.60 |
| FA53 | 20.20 | 16.00 | 17.80 | 8.56 | 21.40 | 16.00 | 12.40 | 13.40 | 13.80 | 0.24 | 9.20 | 4.80 |
| FB53 | 21.40 | 17.20 | 16.60 | 8.72 | 22.60 | 17.20 | 11.60 | 12.20 | 15.00 | 0.56 | 10.40 | 6.00 |
| FC53 | 22.60 | 18.40 | 17.80 | 9.68 | 23.80 | 18.40 | 12.80 | 13.40 | 16.20 | 1.20 | 11.60 | 7.20 |
| FD53 | 21.40 | 17.20 | 19.00 | 9.52 | 22.60 | 17.20 | 13.60 | 14.60 | 15.00 | 1.04 | 10.40 | 6.00 |
| FA54 | 22.60 | 18.40 | 15.40 | 9.68 | 23.80 | 18.40 | 12.80 | 11.00 | 16.20 | 1.20 | 11.60 | 7.20 |
| FB54 | 23.80 | 19.60 | 14.20 | 10.64 | 25.00 | 19.60 | 14.00 | 9.80 | 17.40 | 2.16 | 12.80 | 8.40 |
| FC54 | 25.00 | 20.80 | 15.40 | 11.60 | 26.20 | 20.80 | 15.20 | 11.00 | 18.60 | 3.12 | 14.00 | 9.60 |

(Continued)

Appendix F. (Continued)

| | Fertilizer Plants: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farms: | P01 | P02 | P03 | P04 | P05 | P06 | P07 | P10 | P11 | P12 | P13 | P14 |
| FD54 | 23.80 | 19.60 | 16.60 | 10.64 | 25.00 | 19.60 | 14.00 | 12.20 | 17.40 | 2.16 | 12.80 | 8.40 |
| FA55 | 25.00 | 20.80 | 13.00 | 11.60 | 26.20 | 20.80 | 15.20 | 8.60 | 18.60 | 3.12 | 14.00 | 9.60 |
| FB55 | 26.20 | 22.00 | 13.40 | 12.56 | 27.40 | 22.00 | 16.40 | 7.40 | 19.80 | 4.08 | 15.20 | 10.80 |
| FC55 | 27.40 | 23.20 | 14.60 | 13.52 | 28.60 | 23.20 | 17.60 | 8.60 | 21.00 | 5.04 | 16.40 | 12.00 |
| FD55 | 26.20 | 22.00 | 14.20 | 12.56 | 27.40 | 22.00 | 16.40 | 9.80 | 19.80 | 4.08 | 15.20 | 10.80 |
| FA56 | 27.40 | 23.20 | 14.60 | 13.52 | 28.60 | 23.20 | 17.60 | 6.20 | 21.00 | 5.04 | 16.40 | 12.00 |
| FB56 | 28.60 | 24.40 | 15.80 | 14.48 | 29.80 | 24.40 | 18.80 | 6.20 | 22.20 | 6.00 | 17.60 | 13.20 |
| FC56 | 29.80 | 25.60 | 17.00 | 15.44 | 31.00 | 25.60 | 20.00 | 7.40 | 23.40 | 6.96 | 18.80 | 14.40 |
| FD56 | 28.60 | 24.40 | 15.80 | 14.48 | 29.80 | 24.40 | 18.80 | 7.40 | 22.20 | 6.00 | 17.60 | 13.20 |
| FA57 | 29.80 | 25.60 | 17.00 | 15.44 | 31.00 | 25.60 | 20.00 | 8.60 | 23.40 | 6.96 | 18.80 | 14.40 |
| FB57 | 31.00 | 26.80 | 18.20 | 16.40 | 32.20 | 26.80 | 21.20 | 8.60 | 24.60 | 7.92 | 20.00 | 15.60 |
| FC57 | 32.20 | 28.00 | 19.40 | 17.36 | 33.40 | 28.00 | 22.40 | 9.80 | 25.80 | 8.88 | 21.20 | 16.80 |
| FD57 | 31.00 | 26.80 | 18.20 | 16.40 | 32.20 | 26.80 | 21.20 | 9.80 | 24.60 | 7.92 | 20.00 | 15.60 |
| FA58 | 27.40 | 23.20 | 15.40 | 13.52 | 28.60 | 23.20 | 17.60 | 11.00 | 21.00 | 5.04 | 16.40 | 12.00 |
| FB58 | 28.60 | 24.40 | 15.80 | 14.48 | 29.80 | 24.40 | 18.80 | 9.80 | 22.20 | 6.00 | 17.60 | 13.20 |
| FC58 | 29.80 | 25.60 | 17.00 | 15.44 | 31.00 | 25.60 | 20.00 | 11.00 | 23.40 | 6.96 | 18.80 | 14.40 |
| FD58 | 28.60 | 24.40 | 16.60 | 14.48 | 29.80 | 24.40 | 18.80 | 12.20 | 22.20 | 6.00 | 17.60 | 13.20 |
| FA59 | 25.00 | 20.80 | 17.80 | 11.60 | 26.20 | 20.80 | 15.20 | 13.40 | 18.60 | 3.12 | 14.00 | 9.60 |
| FB59 | 26.20 | 22.00 | 16.60 | 12.56 | 27.40 | 22.00 | 16.40 | 12.20 | 19.80 | 4.08 | 15.20 | 10.80 |
| FC59 | 27.40 | 23.20 | 17.80 | 13.52 | 28.60 | 23.20 | 17.60 | 13.40 | 21.00 | 5.04 | 16.40 | 12.00 |
| FD59 | 26.20 | 22.00 | 19.00 | 12.56 | 27.40 | 22.00 | 16.40 | 14.60 | 19.80 | 4.08 | 15.20 | 10.80 |
| FA60 | 22.60 | 18.40 | 20.20 | 10.48 | 23.80 | 18.40 | 14.80 | 15.80 | 16.20 | 2.00 | 11.60 | 7.20 |
| FB60 | 23.80 | 19.60 | 19.00 | 10.64 | 25.00 | 19.60 | 14.00 | 14.60 | 17.40 | 2.16 | 12.80 | 8.40 |
| FC60 | 25.00 | 20.80 | 20.20 | 11.60 | 26.20 | 20.80 | 15.20 | 15.80 | 18.60 | 3.12 | 14.00 | 9.60 |
| FD60 | 23.80 | 19.60 | 21.40 | 11.44 | 25.00 | 19.60 | 16.00 | 17.00 | 17.40 | 2.96 | 12.80 | 8.40 |
| FA61 | 20.20 | 16.00 | 22.60 | 10.48 | 21.40 | 16.00 | 17.20 | 18.20 | 13.80 | 2.16 | 9.20 | 6.80 |
| FB61 | 21.40 | 17.20 | 21.40 | 10.48 | 22.60 | 17.20 | 16.00 | 17.00 | 15.00 | 2.00 | 10.40 | 6.00 |
| FC61 | 22.60 | 18.40 | 22.60 | 11.44 | 23.80 | 18.40 | 17.20 | 18.20 | 16.20 | 2.96 | 11.60 | 7.20 |
| FD61 | 21.40 | 17.20 | 23.80 | 11.44 | 22.60 | 17.20 | 18.40 | 19.40 | 15.00 | 2.96 | 10.40 | 8.00 |
| FA62 | 17.80 | 18.00 | 25.00 | 10.48 | 19.00 | 13.60 | 19.60 | 20.60 | 11.40 | 4.08 | 6.80 | 9.20 |
| FB62 | 19.00 | 16.80 | 23.80 | 10.48 | 20.20 | 14.80 | 18.40 | 19.40 | 12.60 | 3.12 | 8.00 | 8.00 |
| FC62 | 20.20 | 18.00 | 25.00 | 11.44 | 21.40 | 16.00 | 19.60 | 20.60 | 13.80 | 3.12 | 9.20 | 9.20 |
| FD62 | 19.00 | 19.20 | 26.20 | 11.44 | 20.20 | 14.80 | 20.80 | 21.80 | 12.60 | 4.08 | 8.00 | 10.40 |

(Continued)

Appendix F. (Continued)

| Farms: | Fertilizer Plants: P01 | P02 | P03 | P04 | P05 | P06 | P07 | P10 | P11 | P12 | P13 | P14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FA63 | 15.40 | 20.40 | 27.40 | 11.76 | 16.60 | 14.40 | 22.00 | 23.00 | 9.00 | 4.72 | 8.00 | 11.60 |
| FB63 | 16.60 | 19.20 | 26.20 | 10.80 | 17.80 | 13.20 | 20.80 | 21.80 | 10.20 | 4.72 | 6.80 | 10.40 |
| FC63 | 17.80 | 20.40 | 27.40 | 11.76 | 19.00 | 14.40 | 22.00 | 23.00 | 11.40 | 4.72 | 8.00 | 11.60 |
| FD63 | 16.60 | 21.60 | 28.60 | 12.72 | 17.80 | 15.60 | 23.20 | 24.20 | 10.20 | 4.72 | 9.20 | 12.80 |
| FA64 | 17.40 | 22.80 | 29.80 | 13.68 | 15.40 | 16.80 | 24.40 | 25.40 | 7.80 | 5.20 | 10.40 | 14.00 |
| FA65 | 19.40 | 24.80 | 31.80 | 15.28 | 18.20 | 18.80 | 26.40 | 27.40 | 10.60 | 6.80 | 12.40 | 16.00 |
| FA66 | 19.40 | 22.40 | 29.40 | 13.36 | 20.60 | 16.40 | 24.00 | 25.00 | 13.00 | 4.88 | 10.00 | 13.60 |
| FA67 | 21.80 | 20.00 | 27.00 | 12.88 | 23.00 | 17.60 | 21.60 | 22.60 | 15.40 | 4.40 | 10.80 | 11.20 |
| FA68 | 24.20 | 20.00 | 24.60 | 12.88 | 25.40 | 20.00 | 19.20 | 20.20 | 17.80 | 4.40 | 13.20 | 8.80 |
| FA69 | 26.60 | 22.40 | 22.20 | 12.88 | 27.80 | 22.40 | 16.80 | 17.80 | 20.20 | 4.40 | 15.60 | 11.20 |
| FA70 | 29.00 | 24.80 | 19.80 | 14.80 | 30.20 | 24.80 | 19.20 | 15.40 | 22.60 | 6.32 | 18.00 | 13.60 |
| FA71 | 31.40 | 27.20 | 18.60 | 16.72 | 32.60 | 27.20 | 21.60 | 13.00 | 25.00 | 8.24 | 20.40 | 16.00 |
| FA72 | 33.80 | 29.60 | 21.00 | 18.64 | 35.00 | 29.60 | 24.00 | 11.40 | 27.40 | 10.16 | 22.80 | 18.40 |

(Continued)

| Farms: | Fertilizer Plants: P15 | P16 | P17 | P18 | P19 | P21 | P22 | P23 | P25 | P26 | P27 | P28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FA01 | 21.20 | 27.40 | 19.60 | 23.80 | 3.92 | 21.00 | 27.20 | 31.60 | 24.40 | 36.00 | 30.80 | 17.60 |
| FA02 | 18.80 | 25.00 | 17.20 | 21.40 | 3.92 | 18.60 | 24.80 | 29.20 | 22.00 | 33.60 | 28.40 | 15.20 |
| FA03 | 16.40 | 22.60 | 14.80 | 19.00 | 3.44 | 19.80 | 22.40 | 26.80 | 19.60 | 31.20 | 26.00 | 16.00 |
| FA04 | 14.00 | 20.20 | 14.40 | 16.60 | 3.44 | 22.20 | 20.00 | 24.40 | 21.20 | 28.80 | 23.60 | 18.40 |
| FA05 | 11.60 | 17.80 | 16.80 | 14.20 | 3.44 | 24.60 | 17.60 | 22.00 | 23.60 | 26.40 | 21.20 | 20.80 |
| FA06 | 12.00 | 15.40 | 19.20 | 16.20 | 2.16 | 27.00 | 19.60 | 19.60 | 26.00 | 24.00 | 18.80 | 23.20 |
| FA07 | 14.40 | 13.00 | 21.60 | 18.60 | 1.36 | 29.40 | 22.00 | 17.60 | 28.40 | 21.60 | 16.40 | 25.60 |
| FA08 | 16.80 | 11.40 | 24.00 | 21.00 | 1.68 | 31.80 | 24.40 | 20.00 | 30.80 | 21.20 | 14.80 | 28.00 |
| FA09 | 14.40 | 9.40 | 21.60 | 18.60 | 1.36 | 29.40 | 22.00 | 17.60 | 28.40 | 18.80 | 12.80 | 25.60 |
| FB09 | 15.60 | 10.20 | 22.80 | 19.80 | 1.36 | 30.60 | 23.20 | 18.80 | 29.60 | 20.00 | 13.60 | 26.80 |
| FC09 | 14.40 | 9.00 | 21.60 | 18.60 | 0.88 | 29.40 | 22.00 | 17.60 | 28.40 | 18.80 | 12.40 | 25.60 |
| FD09 | 13.20 | 8.20 | 20.40 | 17.40 | 0.88 | 28.20 | 20.80 | 16.40 | 27.20 | 17.60 | 11.60 | 24.40 |
| FA10 | 12.00 | 11.80 | 19.20 | 16.20 | 2.16 | 27.00 | 19.60 | 16.00 | 26.00 | 20.40 | 15.20 | 23.20 |
| FB10 | 13.20 | 10.60 | 20.40 | 17.40 | 1.36 | 28.20 | 20.80 | 16.40 | 27.20 | 19.20 | 14.00 | 24.40 |
| FC10 | 12.00 | 9.40 | 19.20 | 16.20 | 1.68 | 27.00 | 19.60 | 15.20 | 26.00 | 18.00 | 12.80 | 23.20 |
| FD10 | 10.80 | 10.60 | 18.00 | 15.00 | 2.64 | 25.80 | 18.40 | 14.80 | 24.80 | 19.20 | 14.00 | 22.00 |
| FA11 | 9.60 | 14.20 | 16.80 | 13.80 | 4.08 | 24.60 | 17.20 | 18.40 | 23.60 | 22.80 | 17.60 | 20.80 |
| FB11 | 10.80 | 13.00 | 18.00 | 15.00 | 3.12 | 25.80 | 18.40 | 17.20 | 24.80 | 21.60 | 16.40 | 22.00 |
| FC11 | 9.60 | 11.80 | 16.80 | 13.80 | 3.60 | 24.60 | 17.20 | 16.00 | 23.60 | 20.40 | 15.20 | 20.80 |
| FD11 | 8.40 | 13.00 | 15.60 | 12.60 | 4.56 | 23.40 | 16.00 | 17.20 | 22.40 | 21.60 | 16.40 | 19.60 |
| FA12 | 10.40 | 16.60 | 14.40 | 13.00 | 4.88 | 22.20 | 16.40 | 20.80 | 21.20 | 25.20 | 20.00 | 18.40 |
| FB12 | 9.20 | 15.40 | 15.60 | 12.60 | 4.88 | 23.40 | 16.00 | 19.60 | 22.40 | 24.00 | 18.80 | 19.60 |
| FC12 | 8.00 | 14.20 | 14.40 | 11.40 | 5.36 | 22.20 | 14.80 | 18.40 | 21.20 | 22.80 | 17.60 | 18.40 |
| FD12 | 9.20 | 15.40 | 13.20 | 11.80 | 5.36 | 21.00 | 15.20 | 19.60 | 20.00 | 24.00 | 18.80 | 17.20 |
| FA13 | 12.80 | 19.00 | 12.00 | 15.40 | 4.88 | 19.80 | 18.80 | 23.20 | 18.80 | 27.60 | 22.40 | 16.00 |
| FB13 | 11.60 | 17.80 | 13.20 | 14.20 | 4.88 | 21.00 | 17.60 | 22.00 | 20.00 | 26.40 | 21.20 | 17.20 |
| FC13 | 10.40 | 16.60 | 12.00 | 13.00 | 5.36 | 19.80 | 16.40 | 20.80 | 18.80 | 25.20 | 20.00 | 16.00 |
| FD13 | 11.60 | 17.80 | 10.80 | 14.20 | 5.36 | 18.60 | 17.60 | 22.00 | 17.60 | 26.40 | 21.20 | 14.80 |
| FA14 | 15.20 | 21.40 | 13.60 | 17.80 | 4.88 | 17.40 | 21.20 | 25.60 | 18.40 | 30.00 | 24.80 | 13.60 |
| FB14 | 14.00 | 20.20 | 12.40 | 16.60 | 4.88 | 18.60 | 20.00 | 24.40 | 17.60 | 28.80 | 23.60 | 14.80 |
| FC14 | 12.80 | 19.00 | 11.20 | 15.40 | 5.36 | 17.40 | 18.80 | 23.20 | 16.40 | 27.60 | 22.40 | 13.60 |
| FD14 | 14.00 | 20.20 | 12.40 | 16.60 | 5.36 | 16.20 | 20.00 | 24.40 | 17.20 | 28.80 | 23.60 | 12.40 |
| FA15 | 17.60 | 23.80 | 16.00 | 20.20 | 3.92 | 17.40 | 23.60 | 28.00 | 20.80 | 32.40 | 27.20 | 14.00 |

(Continued)

Appendix F. (Continued)

| Farms: | P15 | P16 | P17 | P18 | P19 | P21 | P22 | P23 | P25 | P26 | P27 | P28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FB15 | 16.40 | 22.60 | 14.80 | 19.00 | 4.24 | 16.20 | 22.40 | 26.80 | 19.60 | 31.20 | 26.00 | 12.80 |
| FC15 | 15.20 | 21.40 | 13.60 | 17.80 | 4.72 | 15.00 | 21.20 | 25.60 | 18.40 | 30.00 | 24.80 | 11.60 |
| FD15 | 16.40 | 22.60 | 14.80 | 19.00 | 4.40 | 16.20 | 22.40 | 26.80 | 19.60 | 31.20 | 26.00 | 12.80 |
| FA16 | 18.80 | 25.00 | 17.20 | 21.40 | 3.92 | 18.60 | 24.80 | 29.20 | 22.00 | 33.60 | 28.40 | 15.20 |
| FA17 | 16.40 | 22.60 | 14.80 | 19.00 | 4.72 | 16.20 | 22.40 | 26.80 | 19.60 | 31.20 | 26.00 | 12.80 |
| FA18 | 15.20 | 21.40 | 13.60 | 17.80 | 4.72 | 15.00 | 21.20 | 25.60 | 18.40 | 30.00 | 24.80 | 11.60 |
| FB18 | 14.00 | 20.20 | 12.40 | 16.60 | 4.72 | 13.80 | 20.00 | 24.40 | 17.20 | 28.80 | 23.60 | 10.40 |
| FC18 | 12.80 | 19.00 | 11.20 | 15.40 | 4.72 | 12.60 | 18.80 | 23.20 | 16.00 | 27.60 | 22.40 | 9.20 |
| FD18 | 14.00 | 20.20 | 12.40 | 16.60 | 4.72 | 13.80 | 20.00 | 24.40 | 17.20 | 28.80 | 23.60 | 10.40 |
| FA19 | 12.80 | 19.00 | 11.20 | 15.40 | 4.72 | 15.00 | 18.80 | 23.20 | 16.00 | 27.60 | 22.40 | 11.20 |
| FB19 | 11.60 | 17.80 | 10.00 | 14.20 | 4.72 | 16.20 | 17.60 | 22.00 | 15.20 | 26.40 | 21.20 | 12.40 |
| FC19 | 10.40 | 16.60 | 8.80 | 13.00 | 3.76 | 15.00 | 16.40 | 20.80 | 14.00 | 25.20 | 20.00 | 11.20 |
| FD19 | 11.60 | 17.80 | 10.00 | 14.20 | 4.40 | 13.80 | 17.60 | 22.00 | 14.80 | 26.40 | 21.20 | 10.00 |
| FA20 | 10.40 | 16.60 | 9.60 | 13.00 | 4.72 | 17.40 | 16.40 | 20.80 | 16.40 | 25.20 | 20.00 | 13.60 |
| FB20 | 9.20 | 15.40 | 10.80 | 11.80 | 4.72 | 18.60 | 15.20 | 19.60 | 17.60 | 24.00 | 18.80 | 14.80 |
| FC20 | 8.00 | 14.20 | 9.60 | 10.60 | 3.76 | 17.40 | 14.00 | 18.40 | 16.40 | 22.80 | 17.60 | 13.60 |
| FD20 | 9.20 | 15.40 | 8.40 | 11.80 | 3.76 | 16.20 | 15.20 | 19.60 | 15.20 | 24.00 | 18.80 | 12.40 |
| FA21 | 8.00 | 14.20 | 12.00 | 10.60 | 4.72 | 19.80 | 14.00 | 18.40 | 18.80 | 22.80 | 17.60 | 16.00 |
| FB21 | 6.80 | 13.00 | 13.20 | 10.20 | 4.72 | 21.00 | 13.60 | 17.20 | 20.00 | 21.60 | 16.40 | 17.20 |
| FC21 | 5.60 | 11.80 | 12.00 | 9.00 | 3.76 | 19.80 | 12.40 | 16.00 | 18.80 | 20.40 | 15.20 | 16.00 |
| FD21 | 6.80 | 13.00 | 10.80 | 9.40 | 3.76 | 18.60 | 12.80 | 17.20 | 17.60 | 21.60 | 16.40 | 14.80 |
| FA22 | 7.20 | 11.80 | 14.40 | 11.40 | 3.92 | 22.20 | 14.80 | 16.00 | 21.20 | 20.40 | 15.20 | 18.40 |
| FB22 | 8.40 | 10.60 | 15.60 | 12.60 | 2.96 | 23.40 | 16.00 | 14.80 | 22.40 | 19.20 | 14.00 | 19.60 |
| FC22 | 7.20 | 9.40 | 14.40 | 11.40 | 2.00 | 22.20 | 14.80 | 13.60 | 21.20 | 18.00 | 12.80 | 18.40 |
| FD22 | 6.00 | 10.60 | 13.20 | 10.20 | 2.96 | 21.00 | 13.60 | 14.80 | 20.00 | 19.20 | 14.00 | 17.20 |
| FA23 | 9.60 | 9.40 | 16.80 | 13.80 | 2.00 | 24.60 | 17.20 | 13.60 | 23.60 | 18.00 | 12.80 | 20.80 |
| FB23 | 10.80 | 8.20 | 18.00 | 15.00 | 1.04 | 25.80 | 18.40 | 14.00 | 24.80 | 16.80 | 11.60 | 22.00 |
| FC23 | 9.60 | 7.00 | 16.80 | 13.80 | 0.56 | 24.60 | 17.20 | 12.80 | 23.60 | 15.60 | 10.40 | 20.80 |
| FD23 | 8.40 | 8.20 | 15.60 | 12.60 | 1.04 | 23.40 | 16.00 | 12.40 | 22.40 | 16.80 | 11.60 | 19.60 |
| FA24 | 12.00 | 7.00 | 19.20 | 16.20 | 0.56 | 27.00 | 19.60 | 15.20 | 26.00 | 16.40 | 10.40 | 23.20 |
| FB24 | 13.20 | 7.80 | 20.40 | 17.40 | 0.88 | 28.20 | 20.80 | 16.40 | 27.20 | 17.60 | 11.20 | 24.40 |
| FC24 | 12.00 | 6.60 | 19.20 | 16.20 | 1.84 | 27.00 | 19.60 | 15.20 | 26.00 | 16.40 | 10.00 | 23.20 |
| FD24 | 10.80 | 5.80 | 18.00 | 15.00 | 0.88 | 25.80 | 18.40 | 14.00 | 24.80 | 15.20 | 9.20 | 22.00 |

(Continued)

Appendix F. (Continued)

| Farms: | Fertilizer Plants: P15 | P16 | P17 | P18 | P19 | P21 | P22 | P23 | P25 | P26 | P27 | P28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FA25 | 9.60 | 4.60 | 16.80 | 13.80 | 1.84 | 24.60 | 17.20 | 12.80 | 23.60 | 14.00 | 8.00 | 20.80 |
| FB25 | 10.80 | 5.40 | 18.00 | 15.00 | 2.80 | 25.80 | 18.40 | 14.00 | 24.80 | 15.20 | 8.80 | 22.00 |
| FC25 | 9.60 | 4.20 | 16.80 | 13.80 | 3.76 | 24.60 | 17.20 | 12.80 | 23.60 | 14.00 | 7.60 | 20.80 |
| FD25 | 8.40 | 3.40 | 15.60 | 12.60 | 2.80 | 23.40 | 16.00 | 11.60 | 22.40 | 12.80 | 6.80 | 19.60 |
| FA26 | 7.20 | 7.00 | 14.40 | 11.40 | 0.56 | 22.20 | 14.80 | 11.20 | 21.20 | 15.60 | 10.40 | 18.40 |
| FB26 | 8.40 | 5.80 | 15.60 | 12.60 | 0.88 | 23.40 | 16.00 | 11.60 | 22.40 | 14.40 | 9.20 | 19.60 |
| FC26 | 7.20 | 4.60 | 14.40 | 11.40 | 1.84 | 22.20 | 14.80 | 10.40 | 21.20 | 13.20 | 8.00 | 18.40 |
| FD26 | 6.00 | 5.80 | 13.20 | 10.20 | 0.88 | 21.00 | 13.60 | 10.00 | 20.00 | 14.40 | 9.20 | 17.20 |
| FA27 | 4.80 | 9.40 | 12.00 | 9.00 | 2.00 | 19.80 | 12.40 | 13.60 | 18.80 | 18.00 | 12.80 | 16.00 |
| FB27 | 6.00 | 8.20 | 13.20 | 10.20 | 1.04 | 21.00 | 13.60 | 12.40 | 20.00 | 16.80 | 11.60 | 17.20 |
| FC27 | 4.80 | 7.00 | 12.00 | 9.00 | 0.56 | 19.80 | 12.40 | 11.20 | 18.80 | 15.60 | 10.40 | 16.00 |
| FD27 | 3.60 | 8.20 | 10.80 | 7.80 | 1.04 | 18.60 | 11.20 | 12.40 | 17.60 | 16.80 | 11.60 | 14.80 |
| FA28 | 5.60 | 11.80 | 9.60 | 8.20 | 2.80 | 17.40 | 11.60 | 16.00 | 16.40 | 20.40 | 15.20 | 13.60 |
| FB28 | 4.40 | 10.60 | 10.80 | 7.80 | 2.80 | 18.60 | 11.20 | 14.80 | 17.60 | 19.20 | 14.00 | 14.80 |
| FC28 | 3.20 | 9.40 | 9.60 | 6.60 | 1.84 | 17.40 | 10.00 | 13.60 | 16.40 | 18.00 | 12.80 | 13.60 |
| FD28 | 4.40 | 10.60 | 8.40 | 7.00 | 1.84 | 16.20 | 10.40 | 14.80 | 15.20 | 19.20 | 14.00 | 12.40 |
| FA29 | 8.00 | 14.20 | 7.20 | 10.60 | 2.80 | 15.00 | 14.00 | 18.40 | 14.00 | 22.80 | 17.60 | 11.20 |
| FB29 | 6.80 | 13.00 | 8.40 | 9.40 | 2.80 | 16.20 | 12.80 | 17.20 | 15.20 | 21.60 | 16.40 | 12.40 |
| FC29 | 5.60 | 11.80 | 7.20 | 8.20 | 1.84 | 15.00 | 11.60 | 16.00 | 14.00 | 20.40 | 15.20 | 11.20 |
| FD29 | 6.80 | 13.00 | 6.00 | 9.40 | 2.48 | 13.80 | 12.80 | 17.20 | 12.80 | 21.60 | 16.40 | 10.00 |
| FA30 | 10.40 | 16.60 | 8.80 | 13.00 | 4.40 | 12.60 | 16.40 | 20.80 | 13.60 | 25.20 | 20.00 | 8.80 |
| FB30 | 9.20 | 15.40 | 7.60 | 11.80 | 3.44 | 13.80 | 15.20 | 19.60 | 12.80 | 24.00 | 18.80 | 10.00 |
| FC30 | 8.00 | 14.20 | 6.40 | 10.60 | 3.44 | 12.60 | 14.00 | 18.40 | 11.60 | 22.80 | 17.60 | 8.80 |
| FD30 | 9.20 | 15.40 | 7.60 | 11.80 | 4.40 | 11.40 | 15.20 | 19.60 | 12.40 | 24.00 | 18.80 | 7.60 |
| FA31 | 12.80 | 19.00 | 11.20 | 15.40 | 4.72 | 12.60 | 18.80 | 23.20 | 16.00 | 27.60 | 22.40 | 9.20 |
| FB31 | 11.60 | 17.80 | 10.00 | 14.20 | 4.72 | 11.40 | 17.60 | 22.00 | 14.80 | 26.40 | 21.20 | 8.00 |
| FC31 | 10.40 | 16.60 | 8.80 | 13.00 | 4.72 | 10.20 | 16.40 | 20.80 | 13.60 | 25.20 | 20.00 | 6.80 |
| FD31 | 11.60 | 17.80 | 10.00 | 14.20 | 4.72 | 11.40 | 17.60 | 22.00 | 14.80 | 26.40 | 21.20 | 8.00 |
| FA32 | 14.00 | 20.20 | 12.40 | 16.60 | 4.72 | 13.80 | 20.00 | 24.40 | 17.20 | 28.80 | 23.60 | 10.40 |
| FA33 | 11.20 | 17.40 | 9.60 | 13.80 | 4.72 | 11.00 | 17.20 | 21.60 | 14.40 | 26.00 | 20.80 | 7.60 |
| FA34 | 10.00 | 16.20 | 8.40 | 12.60 | 4.72 | 9.80 | 16.00 | 20.40 | 13.20 | 24.80 | 19.60 | 6.40 |
| FB34 | 8.80 | 15.00 | 7.20 | 11.40 | 4.72 | 9.40 | 14.80 | 19.20 | 12.00 | 23.60 | 18.40 | 5.60 |
| FC34 | 7.60 | 13.80 | 6.00 | 10.20 | 4.72 | 8.20 | 13.60 | 18.00 | 10.80 | 22.40 | 17.20 | 4.40 |

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Appendix F. (Continued)

| Farms: | Fertilizer Plants: P15 | P16 | P17 | P18 | P19 | P21 | P22 | P23 | P25 | P26 | P27 | P28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FD34 | 8.80 | 15.00 | 7.20 | 11.40 | 4.72 | 8.60 | 14.80 | 19.20 | 12.00 | 23.60 | 18.40 | 5.20 |
| FA35 | 7.60 | 13.80 | 6.00 | 10.20 | 4.08 | 10.60 | 13.60 | 18.00 | 10.80 | 22.40 | 17.20 | 6.80 |
| FB35 | 6.40 | 12.60 | 4.80 | 9.00 | 3.12 | 11.80 | 12.40 | 16.80 | 10.80 | 21.20 | 16.00 | 8.00 |
| FC35 | 5.20 | 11.40 | 3.60 | 7.80 | 3.12 | 10.60 | 11.20 | 15.60 | 9.60 | 20.00 | 14.80 | 6.80 |
| FD35 | 6.40 | 12.60 | 4.80 | 9.00 | 4.08 | 9.40 | 12.40 | 16.80 | 9.60 | 21.20 | 16.00 | 5.60 |
| FA36 | 5.20 | 11.40 | 5.20 | 7.80 | 2.16 | 13.00 | 11.20 | 15.60 | 12.00 | 20.00 | 14.80 | 9.20 |
| FB36 | 4.00 | 10.20 | 6.40 | 6.60 | 1.20 | 14.20 | 10.00 | 14.40 | 13.20 | 18.80 | 13.60 | 10.40 |
| FC36 | 2.80 | 9.00 | 5.20 | 5.40 | 1.20 | 13.00 | 8.80 | 13.20 | 12.00 | 17.60 | 12.40 | 9.20 |
| FD36 | 4.00 | 10.20 | 4.00 | 6.60 | 2.16 | 11.80 | 10.00 | 14.40 | 10.80 | 18.80 | 13.60 | 8.00 |
| FA37 | 2.80 | 9.00 | 7.60 | 5.40 | 0.88 | 15.40 | 8.80 | 13.20 | 14.40 | 17.60 | 12.40 | 11.60 |
| FB37 | 1.60 | 7.80 | 8.80 | 5.80 | 0.72 | 16.60 | 9.20 | 12.00 | 15.60 | 16.40 | 11.20 | 12.80 |
| FC37 | 0.40 | 6.60 | 7.60 | 4.60 | 0.56 | 15.40 | 8.00 | 10.80 | 14.40 | 15.20 | 10.00 | 11.60 |
| FD37 | 1.60 | 7.80 | 6.40 | 4.20 | 0.24 | 14.20 | 7.60 | 12.00 | 13.20 | 16.40 | 11.20 | 10.40 |
| FA38 | 2.80 | 6.60 | 10.00 | 7.00 | 0.56 | 17.80 | 10.40 | 10.80 | 16.80 | 15.20 | 10.00 | 14.00 |
| FB38 | 4.00 | 5.40 | 11.20 | 8.20 | 1.20 | 19.00 | 11.60 | 9.60 | 18.00 | 14.00 | 8.80 | 15.20 |
| FC38 | 2.80 | 4.20 | 10.00 | 7.00 | 2.16 | 17.80 | 10.40 | 8.40 | 16.80 | 12.80 | 7.60 | 14.00 |
| FD38 | 1.60 | 5.40 | 8.80 | 5.80 | 1.20 | 16.60 | 9.20 | 9.60 | 15.60 | 14.00 | 8.80 | 12.80 |
| FA39 | 5.20 | 4.20 | 12.40 | 9.40 | 2.16 | 20.20 | 12.80 | 8.40 | 19.20 | 12.80 | 7.60 | 16.40 |
| FB39 | 6.40 | 3.00 | 13.60 | 10.60 | 3.12 | 21.40 | 14.00 | 9.60 | 20.40 | 11.60 | 6.40 | 17.60 |
| FC39 | 5.20 | 1.80 | 12.40 | 9.40 | 4.08 | 20.20 | 12.80 | 8.40 | 19.20 | 10.40 | 5.20 | 16.40 |
| FD39 | 4.00 | 3.00 | 11.20 | 8.20 | 3.12 | 19.00 | 11.60 | 7.20 | 18.00 | 11.60 | 6.40 | 15.20 |
| FA42 | 4.40 | 2.60 | 10.00 | 7.00 | 4.08 | 17.80 | 10.40 | 6.00 | 16.80 | 10.40 | 5.20 | 14.00 |
| FB42 | 5.60 | 1.40 | 11.20 | 8.20 | 5.04 | 19.00 | 11.60 | 7.20 | 18.00 | 9.20 | 4.00 | 15.20 |
| FC42 | 6.00 | 1.80 | 10.80 | 7.80 | 5.36 | 18.60 | 11.20 | 6.80 | 17.60 | 8.80 | 3.60 | 14.80 |
| FD42 | 4.80 | 3.00 | 9.60 | 6.60 | 4.40 | 17.40 | 10.00 | 5.60 | 16.40 | 10.00 | 4.80 | 13.60 |
| FA43 | 2.00 | 5.00 | 7.60 | 4.60 | 2.16 | 15.40 | 8.00 | 8.40 | 14.40 | 12.80 | 7.60 | 11.60 |
| FB43 | 3.20 | 3.80 | 8.80 | 5.80 | 3.12 | 16.60 | 9.20 | 7.20 | 15.60 | 11.60 | 6.40 | 12.80 |
| FC43 | 3.60 | 4.20 | 8.40 | 5.40 | 3.44 | 16.20 | 8.80 | 6.80 | 15.20 | 11.20 | 6.00 | 12.40 |
| FD43 | 2.40 | 5.40 | 7.20 | 4.20 | 2.48 | 15.00 | 7.60 | 8.00 | 14.00 | 12.40 | 7.20 | 11.20 |
| FA44 | 2.00 | 7.40 | 5.20 | 3.00 | 1.04 | 13.00 | 6.40 | 10.80 | 12.00 | 15.20 | 10.00 | 9.20 |
| FB44 | 0.80 | 6.20 | 6.40 | 3.40 | 1.20 | 14.20 | 6.80 | 9.60 | 13.20 | 14.00 | 8.80 | 10.40 |
| FC44 | 1.20 | 6.60 | 6.00 | 3.00 | 1.52 | 13.80 | 6.40 | 9.20 | 12.80 | 13.60 | 8.40 | 10.00 |
| FD44 | 2.40 | 7.80 | 4.80 | 2.60 | 1.36 | 12.60 | 6.00 | 10.40 | 11.60 | 14.80 | 9.60 | 8.80 |

(Continued)

Appendix F. (Continued)

| Farms: | Fertilizer Plants: P15 | P16 | P17 | P18 | P19 | P21 | P22 | P23 | P25 | P26 | P27 | P28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FA45 | 4.40 | 9.80 | 2.80 | 5.40 | 2.16 | 10.60 | 8.80 | 13.20 | 9.60 | 17.60 | 12.40 | 6.80 |
| FB45 | 3.20 | 8.60 | 4.00 | 4.20 | 1.20 | 11.80 | 7.60 | 12.00 | 10.80 | 16.40 | 11.20 | 8.00 |
| FC45 | 3.60 | 9.00 | 3.60 | 3.80 | 1.36 | 11.40 | 7.20 | 11.60 | 10.40 | 16.00 | 10.80 | 7.60 |
| FD45 | 4.80 | 10.20 | 2.40 | 5.00 | 2.16 | 10.20 | 8.40 | 12.80 | 9.20 | 17.20 | 12.00 | 6.40 |
| FA46 | 6.80 | 12.20 | 3.60 | 7.80 | 4.08 | 8.20 | 11.20 | 15.60 | 8.40 | 20.00 | 14.80 | 4.40 |
| FB46 | 5.60 | 11.00 | 2.40 | 6.60 | 3.12 | 9.40 | 10.00 | 14.40 | 8.40 | 18.80 | 13.60 | 5.60 |
| FC46 | 6.00 | 11.40 | 2.00 | 6.20 | 3.12 | 9.00 | 9.60 | 14.00 | 8.00 | 18.40 | 13.20 | 5.20 |
| FD46 | 7.20 | 12.60 | 3.20 | 7.40 | 4.08 | 7.80 | 10.80 | 15.20 | 8.00 | 19.60 | 14.40 | 4.00 |
| FA47 | 9.20 | 14.60 | 6.00 | 10.20 | 4.72 | 7.40 | 13.60 | 18.00 | 10.80 | 22.40 | 17.20 | 4.00 |
| FB47 | 8.00 | 13.40 | 4.80 | 9.00 | 4.72 | 7.00 | 12.40 | 16.80 | 9.60 | 21.20 | 16.00 | 3.20 |
| FC47 | 8.40 | 13.80 | 4.40 | 8.60 | 4.72 | 6.60 | 12.00 | 16.40 | 9.20 | 20.80 | 15.60 | 2.80 |
| FD47 | 9.60 | 15.00 | 5.60 | 9.80 | 4.72 | 7.00 | 13.20 | 17.60 | 10.40 | 22.00 | 16.80 | 3.60 |
| FA48 | 11.60 | 17.00 | 7.20 | 11.40 | 4.72 | 8.60 | 14.80 | 19.20 | 12.00 | 23.60 | 18.40 | 5.20 |
| FA49 | 14.00 | 19.40 | 6.80 | 9.80 | 6.16 | 6.20 | 12.40 | 16.80 | 9.60 | 21.20 | 16.00 | 2.80 |
| FA50 | 11.60 | 17.00 | 4.40 | 7.80 | 4.72 | 5.00 | 11.20 | 15.60 | 8.40 | 20.00 | 14.80 | 1.60 |
| FB50 | 10.40 | 15.80 | 3.20 | 6.60 | 4.72 | 4.60 | 10.00 | 14.40 | 7.20 | 18.80 | 13.60 | 0.80 |
| FC50 | 11.60 | 17.00 | 4.40 | 7.40 | 4.72 | 3.40 | 8.80 | 13.20 | 6.00 | 17.60 | 13.60 | 0.80 |
| FD50 | 12.80 | 18.20 | 5.60 | 8.60 | 5.20 | 3.80 | 10.00 | 14.40 | 7.20 | 18.80 | 14.80 | 1.60 |
| FA51 | 9.20 | 14.60 | 2.00 | 5.40 | 4.08 | 5.80 | 8.80 | 13.20 | 6.00 | 17.60 | 12.40 | 2.00 |
| FB51 | 8.00 | 13.40 | 0.80 | 4.20 | 3.12 | 7.00 | 7.60 | 12.00 | 6.00 | 16.40 | 11.20 | 3.20 |
| FC51 | 9.20 | 14.60 | 2.00 | 5.00 | 3.92 | 5.80 | 6.40 | 10.80 | 4.80 | 15.20 | 11.20 | 3.20 |
| FD51 | 10.40 | 15.80 | 3.20 | 6.20 | 4.08 | 4.60 | 7.60 | 12.00 | 4.80 | 16.40 | 12.40 | 2.00 |
| FA52 | 6.80 | 12.20 | 1.20 | 3.00 | 2.96 | 8.20 | 6.40 | 10.80 | 7.20 | 15.20 | 10.00 | 4.40 |
| FB52 | 5.60 | 11.00 | 2.40 | 1.80 | 2.96 | 9.40 | 5.20 | 9.60 | 8.40 | 14.00 | 8.80 | 5.60 |
| FC52 | 6.80 | 12.20 | 3.60 | 2.60 | 3.92 | 8.20 | 4.00 | 8.40 | 7.20 | 12.80 | 8.80 | 5.60 |
| FD52 | 8.00 | 13.40 | 2.40 | 3.80 | 3.92 | 7.00 | 5.20 | 9.60 | 6.00 | 14.00 | 10.00 | 4.40 |
| FA53 | 4.40 | 9.80 | 3.60 | 0.60 | 2.96 | 10.60 | 4.00 | 8.40 | 9.60 | 12.80 | 7.60 | 6.80 |
| FB53 | 3.20 | 8.60 | 4.80 | 1.00 | 3.12 | 11.80 | 4.40 | 7.20 | 10.80 | 11.60 | 6.40 | 8.00 |
| FC53 | 4.40 | 9.80 | 6.00 | 1.80 | 4.08 | 10.60 | 3.20 | 6.00 | 9.60 | 10.40 | 6.40 | 8.00 |
| FD53 | 5.60 | 11.00 | 4.80 | 1.40 | 3.92 | 9.40 | 2.80 | 7.20 | 8.40 | 11.60 | 7.60 | 6.80 |
| FA54 | 4.40 | 7.40 | 6.00 | 2.20 | 4.08 | 13.00 | 5.60 | 6.00 | 12.00 | 10.40 | 5.20 | 9.20 |
| FB54 | 5.60 | 6.20 | 7.20 | 3.40 | 5.04 | 14.20 | 6.80 | 4.80 | 13.20 | 9.20 | 4.00 | 10.40 |
| FC54 | 6.80 | 7.40 | 8.40 | 4.20 | 6.00 | 13.00 | 5.60 | 3.60 | 12.00 | 8.00 | 4.00 | 10.40 |

(Continued)

Appendix F. (Continued)

| Farms: | P15 | P16 | P17 | P18 | P19 | P21 | P22 | P23 | P25 | P26 | P27 | P28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fertilizer Plants: | | | | | | | | | | | |
| FD54 | 5.60 | 8.60 | 7.20 | 3.00 | 5.04 | 11.80 | 4.40 | 4.80 | 10.80 | 9.20 | 5.20 | 9.20 |
| FA55 | 6.80 | 5.00 | 8.40 | 4.60 | 6.00 | 15.40 | 8.00 | 3.60 | 14.40 | 8.00 | 2.80 | 11.60 |
| FB55 | 8.00 | 3.80 | 9.60 | 5.80 | 6.96 | 16.60 | 9.20 | 4.80 | 15.60 | 6.80 | 1.60 | 12.80 |
| FC55 | 9.20 | 5.00 | 10.80 | 6.60 | 7.92 | 15.40 | 8.00 | 3.60 | 14.40 | 5.60 | 1.60 | 12.80 |
| FD55 | 8.00 | 6.20 | 9.60 | 5.40 | 6.96 | 14.20 | 6.80 | 2.40 | 13.20 | 6.80 | 2.80 | 11.60 |
| FA56 | 9.20 | 3.00 | 10.80 | 7.00 | 7.92 | 17.80 | 10.40 | 6.00 | 16.80 | 7.20 | 0.80 | 14.00 |
| FB56 | 10.40 | 4.20 | 12.00 | 8.20 | 8.88 | 19.00 | 11.60 | 7.20 | 18.00 | 8.40 | 2.00 | 15.20 |
| FC56 | 11.60 | 5.40 | 13.20 | 9.00 | 9.84 | 17.80 | 10.40 | 6.00 | 16.80 | 7.20 | 2.00 | 15.20 |
| FD56 | 10.40 | 4.20 | 12.00 | 7.80 | 8.88 | 16.60 | 9.20 | 4.80 | 15.60 | 6.00 | 0.80 | 14.00 |
| FA57 | 11.60 | 5.40 | 13.20 | 9.00 | 9.84 | 15.40 | 8.00 | 3.60 | 14.40 | 4.80 | 2.00 | 15.20 |
| FB57 | 12.80 | 6.60 | 14.40 | 10.20 | 10.80 | 16.60 | 9.20 | 4.80 | 15.60 | 6.00 | 3.20 | 16.40 |
| FC57 | 14.00 | 7.80 | 15.60 | 11.40 | 11.76 | 15.40 | 8.00 | 3.60 | 14.40 | 4.80 | 4.40 | 17.60 |
| FD57 | 12.80 | 6.60 | 14.40 | 10.20 | 10.80 | 14.20 | 6.80 | 2.40 | 13.20 | 3.60 | 3.20 | 16.40 |
| FA58 | 9.20 | 7.40 | 10.80 | 6.60 | 7.92 | 13.00 | 5.60 | 1.20 | 12.00 | 5.60 | 4.00 | 12.80 |
| FB58 | 10.40 | 6.20 | 12.00 | 7.80 | 8.88 | 14.20 | 6.80 | 2.40 | 13.20 | 4.40 | 2.80 | 14.00 |
| FC58 | 11.60 | 7.40 | 13.20 | 9.00 | 9.84 | 13.00 | 5.60 | 1.20 | 12.00 | 3.20 | 4.00 | 15.20 |
| FD58 | 10.40 | 8.60 | 12.00 | 7.80 | 8.88 | 11.80 | 4.40 | 0.00 | 10.80 | 4.40 | 5.20 | 14.00 |
| FA59 | 6.80 | 9.80 | 8.40 | 4.20 | 6.00 | 10.60 | 3.20 | 3.60 | 9.60 | 8.00 | 6.40 | 10.40 |
| FB59 | 8.00 | 8.60 | 9.60 | 5.40 | 6.96 | 11.80 | 4.40 | 2.40 | 10.80 | 6.80 | 5.20 | 11.60 |
| FC59 | 9.20 | 9.80 | 10.80 | 6.60 | 7.92 | 10.60 | 3.20 | 1.20 | 9.60 | 5.60 | 6.40 | 12.80 |
| FD59 | 8.00 | 11.00 | 9.60 | 5.40 | 6.96 | 9.40 | 2.00 | 2.40 | 8.40 | 6.80 | 7.60 | 11.60 |
| FA60 | 6.80 | 12.20 | 6.00 | 2.60 | 4.88 | 8.20 | 1.60 | 6.00 | 7.20 | 10.40 | 8.80 | 8.00 |
| FB60 | 5.60 | 11.00 | 7.20 | 3.00 | 5.04 | 9.40 | 2.00 | 4.80 | 8.40 | 9.20 | 7.60 | 9.20 |
| FC60 | 6.80 | 12.20 | 8.40 | 4.20 | 6.00 | 8.20 | 0.80 | 3.60 | 7.20 | 8.00 | 8.80 | 10.40 |
| FD60 | 8.00 | 13.40 | 7.20 | 3.80 | 5.84 | 7.00 | 0.40 | 4.80 | 6.00 | 9.20 | 10.00 | 9.20 |
| FA61 | 9.20 | 14.60 | 3.60 | 5.00 | 4.88 | 5.80 | 4.00 | 8.40 | 4.80 | 12.80 | 11.20 | 5.60 |
| FB61 | 8.00 | 13.40 | 4.80 | 3.80 | 4.88 | 7.00 | 2.80 | 7.20 | 6.00 | 11.60 | 10.00 | 6.80 |
| FC61 | 9.20 | 14.60 | 6.00 | 5.00 | 5.84 | 5.80 | 1.60 | 6.00 | 4.80 | 10.40 | 11.20 | 8.00 |
| FD61 | 10.40 | 15.80 | 4.80 | 6.20 | 5.84 | 4.60 | 2.80 | 7.20 | 3.60 | 11.60 | 12.40 | 6.80 |
| FA62 | 11.60 | 17.00 | 4.40 | 7.40 | 4.88 | 3.40 | 6.40 | 10.80 | 3.60 | 15.20 | 13.60 | 3.20 |
| FB62 | 10.40 | 15.80 | 3.20 | 6.20 | 4.88 | 4.60 | 5.20 | 9.60 | 3.60 | 14.00 | 12.40 | 4.40 |
| FC62 | 11.60 | 17.00 | 4.40 | 7.40 | 5.84 | 3.40 | 4.00 | 8.40 | 2.40 | 12.80 | 13.60 | 5.60 |
| FD62 | 12.80 | 18.20 | 5.60 | 8.60 | 5.84 | 2.20 | 5.20 | 9.60 | 2.40 | 14.00 | 14.80 | 4.40 |

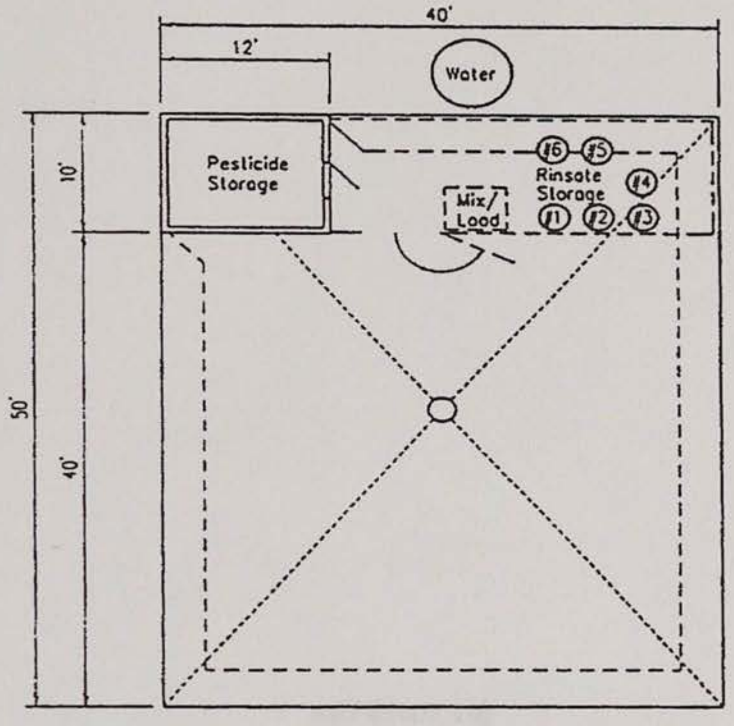
(Continued)

Appendix F. (Continued)

| Farms: | Fertilizer Plants: P15 | P16 | P17 | P18 | P19 | P21 | P22 | P23 | P25 | P26 | P27 | P28 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FA63 | 14.00 | 19.40 | 6.80 | 9.80 | 6.16 | 2.60 | 8.80 | 13.20 | 6.00 | 17.60 | 16.00 | 2.80 |
| FB63 | 12.80 | 18.20 | 5.60 | 8.60 | 5.20 | 2.20 | 7.60 | 12.00 | 4.80 | 16.40 | 14.80 | 2.00 |
| FC63 | 14.00 | 19.40 | 6.80 | 9.80 | 6.16 | 1.00 | 6.40 | 10.80 | 3.60 | 15.20 | 16.00 | 3.20 |
| FD63 | 15.20 | 20.60 | 8.00 | 11.00 | 7.12 | 1.40 | 7.60 | 12.00 | 4.80 | 16.40 | 17.20 | 4.00 |
| FA64 | 16.40 | 21.80 | 9.20 | 12.20 | 8.08 | 3.80 | 10.00 | 14.40 | 7.20 | 18.80 | 18.40 | 5.20 |
| FA65 | 18.40 | 23.80 | 11.20 | 14.20 | 9.68 | 3.40 | 10.80 | 15.20 | 4.40 | 16.00 | 20.40 | 7.20 |
| FA66 | 16.00 | 21.40 | 8.80 | 11.80 | 7.76 | 1.40 | 8.40 | 12.80 | 2.00 | 13.60 | 18.00 | 4.80 |
| FA67 | 13.60 | 19.00 | 6.40 | 9.40 | 7.28 | 3.80 | 6.00 | 10.40 | 0.40 | 11.20 | 15.60 | 7.20 |
| FA68 | 11.20 | 16.60 | 7.60 | 7.00 | 7.28 | 6.20 | 3.60 | 8.00 | 2.80 | 8.80 | 13.20 | 9.60 |
| FA69 | 8.80 | 14.20 | 10.00 | 5.80 | 7.28 | 8.60 | 2.40 | 5.60 | 5.20 | 6.40 | 10.80 | 12.00 |
| FA70 | 10.80 | 11.80 | 12.40 | 8.20 | 9.20 | 11.00 | 4.80 | 3.20 | 7.60 | 4.00 | 8.40 | 14.40 |
| FA71 | 13.20 | 9.40 | 14.80 | 10.60 | 11.12 | 13.40 | 7.20 | 2.80 | 10.00 | 1.60 | 6.00 | 16.80 |
| FA72 | 15.60 | 9.40 | 17.20 | 13.00 | 13.04 | 15.80 | 9.60 | 5.20 | 12.40 | 2.80 | 6.00 | 19.20 |

# APPENDIX G

## Rectangular Single Sump Mixing/Loading Pad with Storage Building and Fenced Security Area

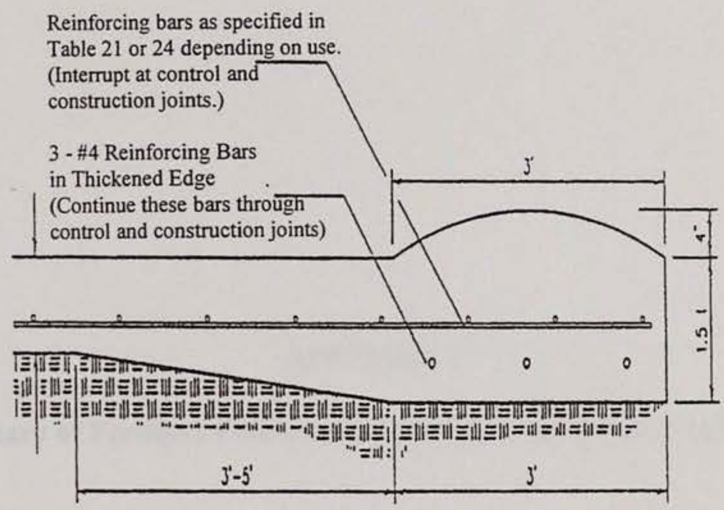



Appendix G. Rectangular single sump mixing/loading pad with storage building and fenced pesticide security area.

Adapted from Figure 38 in Kammel, David W., Ronald T. Noyes, Gerald L. Riskowski, and Vernon L. Hoffman. Designing Facilities for Pesticide and Fertilizer Containment. Ames, IA: Midwest Plan Service, 1991.

## APPENDIX H

**Rounded Drive-Over Curb Construction**




Appendix H. Rounded drive-over curb construction.

Adapted from Figure 67 in Kammel, David W., Ronald T. Noyes, Gerald L. Riskowski, and Vernon L. Hoffman. Designing Facilities for Pesticide and Fertilizer Containment. Ames, IA: Midwest Plan Service, 1991.

# APPENDIX I

## Summary of Fertilizer Plant Annual Storage Capacity in All Scenarios

Appendix I. Summary of Fertilizer Plant Annual Storage Capacity in All Scenarios

| Description | Scenario 1 Full Cost Baseline | Scenario 3 Full Cost with Investment | Scenario 2 Sunk Capital Hypothesis Baseline | Scenario 4 Sunk Capital Hypothesis with Investment |
|---|---|---|---|---|
| Plant Number and Type | | (Tons) | | |
| P01 - Dry | 1,395 | 5,580 | 1,395 | |
| P01 - Liquid | 279 | | 279 | |
| P02 - Dry | 3,627 | 3,627 | 3,627 | 3,627 |
| P02 - Liquid | 279 | 1,395 | 279 | |
| P03 - Dry | 3,627 | 3,627 | 3,627 | 3,627 |
| P03 - Liquid | 1,395 | 1,395 | 1,395 | 1,395 |
| P04 - Dry* | 2,232 | | 2,232 | |
| P05 - Dry | 2,232 | | 2,232 | 2,232 |
| P06 - Dry | 5,580 | 5,580 | 5,580 | 5,580 |
| P06 - Liquid | 5,022 | | 5,022 | 5,022 |
| P07 - Dry | 5,580 | | 5,580 | |
| P10 - Dry | 5,580 | | 5,580 | 5,580 |
| P10 - Liquid | 279 | | 279 | |
| P11 - Dry | 1,395 | 2,232 | 1,395 | 1,395 |
| P12 - Dry* | 2,232 | 2,232 | 2,232 | 2,232 |
| P13 - Dry | 5,580 | | 5,580 | 5,580 |
| P14 - Liquid | 279 | 1,395 | 279 | |
| P15 - Dry | 5,580 | 5,580 | 5,580 | |
| P15 - Liquid | 279 | | 279 | |
| P16 - Dry | 5,580 | 5,580 | 5,580 | 5,580 |
| P16 - Liquid | 279 | | 279 | |
| P17 - Dry | 1,395 | 2,232 | 1,395 | |
| P17 - Liquid | 279 | 1,395 | 279 | |
| P18 - Dry | 5,580 | 5,580 | 5,580 | 5,580 |
| P18 - Liquid | 1,395 | 5,022 | 1,395 | 1,395 |
| P19 - Dry* | 1,395 | | 1,395 | |
| P21 - Dry | 5,580 | | 5,580 | |
| P21 - Liquid | 1,395 | | 1,395 | 1,395 |
| P22 - Dry | 5,580 | | 5,580 | 5,580 |
| P22 - Liquid | 1,395 | | 1,395 | 1,395 |
| P23 - Dry | 5,580 | 5,580 | 5,580 | |
| P23 - Liquid | 1,395 | | 1,395 | |

(Continued)

Appendix I. (Continued)

| Description | Scenario 1<br>Full Cost Baseline | Scenario 3<br>Full Cost with Compliance | Scenario 2<br>Sunk Capital Hypothesis Baseline | Scenario 4<br>Sunk Capital Hypothesis with Compliance |
|---|---|---|---|---|
| Plant Number and Type | | (Tons) | | |
| P25 - Dry | 1,395 | | 1,395 | |
| P26 - Dry | 5,580 | | 5,580 | |
| P27 - Dry | 3,627 | 3,627 | 3,627 | 3,627 |
| P27 - Liquid | 279 | 1,395 | 279 | 1,395 |
| P28 - Dry | 1,395 | | 1,395 | |
| Total Annual Liquid Fertilizer Storage (Tons): | 14,229 | 11,997 | 14,229 | 11,997 |
| Total Annual Dry Fertilizer Storage (Tons): | 87,327 | 51,057 | 87,327 | 50,220 |
| Total Fertilizer Storage (Tons): | 101,556 | 63,054 | 101,556 | 62,217 |

*Dry fertilizer plants P04, P12, and P19 enter the solutions of Scenarios 1 and 2, but they have no sales volume.