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CORN STOVER HARVESTING: GROWER, CUSTOM OPERATOR, AND PROCESSOR ISSUES AND ANSWERS

Report on Corn Stover Harvest Experiences in Iowa and Wisconsin for the 1997-98 and 1998-99 Crop Years

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SCOPE AND PURPOSE

This report documents the experiences of collecting corn stover for the Great Lakes Chemical Corporation and Dickey Environmental in the 1997-1998 and 1998-1999 crop years. These were the first large-scale operations to collect corn stover successfully, with the total area harvested approaching 100,000 acres. The purpose of this report is to provide an understanding of the activities and issues that affected the collection, storage, handling, and transport of corn stover for the two companies. The report documents collection operations from the perspective of grower, custom operator, and processor. Included are descriptions of the following activities:

- advance preparation,
- obtaining grower commitment,
- harvest preparation,
- harvesting operation,
- storage site selection and inventory management,
- transporting the material between farm and processing plant, and
- equipment performance.

INTRODUCTION

Two companies, Great Lakes Chemical Corporation (GLCC), Omaha, Nebraska, and Dickey Environmental Systems Corporation (DES), Sharon, Wisconsin, established large-scale systems to collect corn stover to be used as a raw material for their operations. Corn stover is the surface residue left after the corn kernels are harvested. Stover includes the corn stalk, leaves, husks, and cobs. This report describes experiences encountered while working with the two companies to harvest, collect, and store corn stover during the 1997-1998 and 1998-1999 crop years.

The needs of the two companies were different. GLCC was searching for a lower cost feedstock to replace oat hulls used for furfural production. Corncobs were originally used for furfural production because they contain a large xylan fraction, about 22%. With current combines, the cob is left in the field with the other surface residue. Oat hulls are a satisfactory substitute, but cost $100 or more per ton. GLCC determined they could bale, transport and pelletize stover, containing 18% to 20% xylan, for processing to furfural at about half the cost of oat hulls. Their primary requirement for bales was moisture below 30%.

DES was primarily looking at corn stalks to be used for premium horse bedding. The pith contained in the stalk has superior liquid adsorption properties compared to straw and wood chips. The corn stalks *are* the product, so raw material specifications for collection, storage, and handling were more stringent, with moisture of 15% to 18%. No material discoloration was allowed.

Other differences in the needs of the two companies included bale type, harvesting, storage conditions, and pre-processing steps. GLCC accepted round or square bales of any size. They relied on custom harvesters to provide their own equipment. DES provided most of the harvesting equipment, and only processed large square bales. In the 1998–99 crop year they did contract with some custom operators, but only those with large square balers.

Outside storage was acceptable for GLCC since color was not a factor. Inside storage was required for DES to avoid the surface discoloration of the baled product. Even then, DES rejected a significant portion of baled product due to discoloration or high moisture. GLCC rejected nothing, even waiving the moisture limit during the 1997-98 harvest when wet conditions prevailed.

Preprocessing for GLCC involved tub-grinding and pelletizing to reduce the bulk density enough to fully charge the hydrolysis reactors. Pelletizing also simplified handling and lowered transportation cost from the collection center in Harlan, Iowa, to Omaha, a 60-mile distance.

The DES process also included a size reduction step, using a knife mill to expose the pith and achieve the surface area desired for absorption. The material was then bleached, scented, and packaged in "peat moss" sized bags for distribution to retail outlets.

The operations had a number of similarities. Both companies chose to locate their operations in areas with high corn yields to minimize baling cost. However, they both transported over a relatively wide area to ensure adequate raw material. GLCC requirements were available within a 15-mile radius, yet they contracted over a 50-mile radius. DES established two collection points even more distant, one in Wisconsin and a second in McLean, Illinois and trucking the bales directly from the field.

1. ADVANCE PREPARATION

To be consistently successful, year after year, corn stover collection needs to mirror the grain harvest and have a full-harvest mentality. Operations must be in action regardless of the weather or time of day or night. The majority of corn producers are not equipped for such stover harvesting or for hay harvesting, nor do they have the extra people or management time during the grain harvest. We found that the stover harvests required local producers equipped to harvest hay and custom harvesters from other areas with similar equipment. Arrangements for these resources needed to be made months before the harvest.

Additionally, companies purchasing stover need to keep raw material cost as low as possible to compete with other supplies of their products. Balancing producer profit with the manufacturer's feedstock cost is an age-old dilemma. A successful corn stover harvest needs to be a win–win situation for both producer and manufacturer. Advance planning is essential to achieve this balance. The harvest area must be defined to keep travel time manageable. A capable and committed group of workers must be assembled. Balers must be trained to deal with corn stover. Meeting the multiple individual needs of the participants is most important for success.

1.1 COMPONENTS OF HARVEST

Major cost components include labor, equipment, fuel, bale wrap or twine, moisture requirements, and transportation distances. Each project needs an initial survey to estimate the ranges for these factors and to sense local attitudes toward collecting stover.

1.1.1 Labor

In most rural areas, labor is at a premium in the fall harvest season. Several factors contribute. The younger side of the farm labor pool returns to school before the stover harvest begins (the vast majority of corn stover is harvested after September 1). The senior side of the farm labor pool in rural areas contains many retired farmers with the necessary skills to be of value to a corn stover harvest. However, few of these retired farmers are available as most are helping in their son's or daughter's farm operation during the harvest of the grain and other fall work.

Local truckers are also difficult to obtain because they are busy moving grain. All of this fall farm activity lessens the availability of the normal labor pool. Contract harvesters coming in from other areas of the country may not be familiar with the local fall shortage of labor. Most want to hire rake operators or fill some other positions requiring less skill with local labor.

The harvesting of dry corn stover (20% moisture or less) must be done when Mother Nature allows, which is not necessarily between the hours of 8 a.m. and 5 p.m. Potential workers need to know this prior to hiring in order to minimize absenteeism. Workers also need to know that it is not possible to harvest in the rain. They must be made aware that is it necessary to check frequently with management because rain is often spotty. While it may be raining where they are, harvesting may be possible a few miles down the road.

Although the actual harvest occurs in the field away from traffic, equipment is moved via public roads from field to field. The implements being pulled by the tractors are often wider than half of the road. Pre-harvest safety courses are beneficial and in some states mandatory.

Hourly wages are dictated by labor availability. The corn stover harvest window is small and every hour that is worked when conditions are right is important to the success of the harvest and the company. Dependable people are imperative, so it is wise to pay a few more dollars per hour to encourage a larger number of applicants from which to choose.

1.1.2 Equipment Cost

Cost was calculated for five different equipment operations: baling, staging, loading, hauling, and stacking. Equipment performance is discussed in Chapter 7.

Baling. Three types of balers were considered: round balers, intermediate square balers, and large square balers. All three types can achieve 9 dry lb/ft^3 of bale. The normal price of the large round baler (5 ft × 6 ft) is $10/bale (mesh wrapped) or $15.73/dry ton. Normal price of an intermediate square baler (3 ft × 3 ft × 8 ft 5 in) is $1.00/linear foot or $24.70/dry ton. Normal price of the larger square baler (4 ft × 4 ft × 8 ft 5 in) is based on $1.75/linear foot or $24.25/dry ton. Square balers produce bales of varying length to accommodate the producer's equipment. Typical lengths are 6 ft, 8 ft and 8.5 ft.

Baling for GLCC had advantages over baling for individual farmers. GLCC offered much more volume, allowed higher moisture bales, and offered mesh wrap or twine at wholesale prices. Price for baling was set at $14.60/dry ton. GLCC expected few square balers to participate because of the lack of local availability. The majority of round balers used were John Deere[1] balers using a knife attachment by equipment supplier Heartland Manufacturing to chop the stalks into 4 inch pieces for improved bale density.

In the DES operation, large square bales were preferred because bales were stored indoors. Price was negotiated with each contractor. The 4 ft × 4 ft × 8 ft bales averaged $1.42/linear ft, $11.43/bale, $18.30/wet ton (under 18%). Estimated dry ton cost, assuming 14% moisture was $21.40/dry ton. Baler operators produced bales containing 8 to 9 dry lb/ft^3.

Staging. The staging or road siding of bales was included in the hauling operation in the GLCC project, and was estimated to cost $3.25/dry ton. This was an average cost for a tractor with bale wagon. A calculation was not attempted for DES.

Loading. The loading of bales onto trailers after they had been staged or road-sided cost around $1.70/dry ton in both operations, and was included in the hauler cost with GLCC.

Hauling. GLCC hauling is discussed in subsection 1.1.7 Transportation and Distance. In the DES project, haulers were paid from $45 to $50/hour depending on trailer type.

Stacking. Once loads arrived at the plant they were stacked at an average cost of approximately $1.00/dry ton.

Other optional operation costs included flailing the stalks ($2.50/wet ton) followed by raking (at 95 cents/wet ton) to form a windrow.

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[1]Names are necessary to report factually on available data. The use of a name implies no approval of the product or excludes others that may also be suitable.

1.1.3 Fuel

Fuel was a component of harvest as well as transportation costs. In both the DES and the GLCC projects, buying in volume reduced fuel costs. Storage tanks were purchased or leased that could hold 130% of a single transport's maximum volume or about 10,000 gallons. By using compartmentalized tanks, or two tanks, the transports could deliver both truck fuel and farm fuel. This reduced farm tractor fuel cost by 25% and truck fuel by 15%. Delivering fuel directly from the terminal reduced handling and service charges.

In the GLCC harvest most of the stover was transported to the plant using high-speed (40+ mph) JCB farm-type tractors. Fuel for farm-type tractors is tax exempt. At the end of the first harvest season a comparison was made between 1997 FL80 Freight liner trucks with 275-hp Cummins engines with automatic transmission versus JCB tractors with 185-hp Cummins engines pulling identical bale trailers. The savings favored the JCB tractors by 49 cents/dry ton hauled. This savings reflects the federal over the road diesel fuel tax of 24.4 cents/gallon and the State of Iowa diesel fuel tax of 22.5 cents/gallon incurred by the Freightliners and not by the fuel-tax-exempt JCB farm-type tractors.

The loading and transportation costs for fuel incurred by the JCB units averaged 72 cents/dry ton delivered while the freightliners averaged $1.21/dry ton. The average hauling distance in this comparison was from a 24-mile radius or 48 miles round trip and included fuel used picking up bales as they were placed in the field by the baling operation in addition to travel.

1.1.4 Twine and Wrap Cost

Twine for the large square bales and mesh wrap for the large round bales was purchased in volume by GLCC in order to receive wholesale price discounts. The savings was passed on to the baler operators, with a small handling charge added.

Custom operators were also allowed to purchase twine and wrap for their other needs. The savings to the custom operators were returned to the companies in the form of reduced rates for baling equaling 50 cents/bale. Because at least as many bales would be produced by other baling operations throughout the year, the total benefit to custom balers was $1.00/bale in reduced cost of wrap.

Normal retail cost of three wraps on a large round bale equals $2.10 to $2.30. GLCC's cost of three wraps on a large round bale equaled $1.60 to $1.80. Normal retail twine cost of a 4 ft × 4 ft × 8 ft large square bale is $1.00. The twine cost for a 4 ft × 4 ft × 8 ft large square bale at DES was 72 cents.

1.1.5 Moisture

The acceptable moisture level needs careful consideration. At corn harvest, stover moisture is 35% or more. After 3 days of good weather it usually drops below 20%. Measuring moisture in the field is difficult. The particles are not homogeneous, and windrows result in even wider fluctuation, as the interior moisture levels differ from those at the surface.

DES set an extremely low moisture level of 18%. The low value ensured minimal deterioration in storage, but it reduced the harvest window and added cost. The smaller window required more equipment to meet the harvest goal. More equipment meant higher equipment, labor, and management costs. Starting up and shutting down the harvest took the same amount of time regardless of whether operating time was 2 or 16 hours. Workers wanted a minimum of 4 hours paid each day they showed up for work. Transportation also cost more per delivered ton, and dispatching was made more difficult.

GLCC set an average bale moisture level of 30% or lower. In the 1997–98 harvest, moisture ranged between 11% and 35%, and averaged just under 27%. When the moisture was above 35% the balers experienced too many other problems to continue operations. Most of the higher moisture stover was baled later in the harvest season, and deterioration was minimal during the winter months.

1.1.6 Reducing Partial Loads

The last trip from a producer's field is normally a partial load of bales. To make the best use of the hauler's time, and keep cost low, we opted to complete the load in the nearest available field before proceeding to the plant. Records were kept of the number of bales that belonged to each producer. Net weight on the load was divided by the total number of bales and then multiplied by the number of bales belonging to each producer. Producers were made aware of split load procedures at the time of procurement. Many split loads were delivered and handled without any complaint from producers.

1.1.7 Hauling Rates

At the beginning of the 1997–1998 stover harvest season, GLCC set four fixed transportation brackets, shown in Table 1. Many haulers considered the mileage ranges too broad. In response to their comments, hauling rates in the spring of 1998 were divided into the eleven brackets shown in Table 2. Additional discussion on hauling rates appears in Appendix A, Stover Hauling Considerations and Profitability.

Table 1. GLCC hauling rates for the 1997–1998 crop year

Loaded miles	0–10 miles	11–30 miles	31–50 miles	51–70 miles
Pay, $/dry ton	$6.10	$8.77	$11.44	$14.10

Table 2. GLCC revised hauling rates for the 1998–1999 crop year

Loaded miles	1-5	6-10	11-15	16-20	21-30	31-40	41-50	51-60	61-70	71-90	91-125
Pay, $/dry ton	5.60	6.60	7.85	9.60	12.10	13.10	14.10	15.10	15.60	16.10	17.10

1.2 IDENTIFYING AND EDUCATING STAKEHOLDERS

Because resistance to the GLCC corn stover program could adversely affect producer participation, we decided to contact several organizations directly to provide information about the GLCC program and to request advice. In preparation for these meetings, we collected research articles and other facts about nutrient value, the benefits for the soil, and benefits for the producer. These are shown in Appendix B1.

1.2.1 Soil Conservation Service (SCS)

Meetings were set up with local Soil Conservation Service (SCS) office personnel. The discussion included how stover removal might affect soil conservation compliance, soil compaction, and tillage practices. It was a general consensus among those involved that only with experience could the effects be measured. Harvesting between 40% and 70% of the corn stover was not expected to cause a negative effect. By avoiding slopes steeper than 6% (especially in drought years), reducing the need for tillage, and creating a financial benefit for the producer, stover removal was believed to have positive effects.

1.2.2 Extension Agents

Visits were scheduled to extension offices in each of the counties where producer participation was anticipated. Discussions with extension agents usually revolved around nutrient removal and whether or not producers would be adequately rewarded for the corn stover. Some concern regarding the value of nutrients removed and whether producers farthest from the GLCC Harlan Plant would be adequately rewarded were expressed. Regardless of their personal concerns, all the extension agents provided names of producers they felt would benefit or participate.

1.2.3 Lenders

Lenders had no conflict or contradictory remarks regarding nutrients or soil erosion potential. They generally accepted the research results presented by GLCC. Most were supportive and some enrolled acres they controlled into the GLCC program. Others offered to have GLCC representatives speak to producers at a producer meeting sponsored by the bank. One concern expressed in these meetings was landlords' reactions to the stover harvest.

1.2.4 Landlords

Landlords were a most diverse group. Many were absentees, living in other parts of the country. Most landlords were older, well into their retirement years, and a large portion were women. Some were very receptive, but most had concerns about how a stover harvest would benefit them.

In one scenario presented, the producer demonstrated that harvesting corn stover was a dependable source of income, reduced tillage and chemical expense, and became a part of the producer's business plan. The income and savings derived from the grain and stover harvest dictated affordable rents and land values, which in turn generated additional income for the landlords. This was suggested to producers who were unsure of how to best approach their landlords. Although exact results were not tracked, qualitative feedback indicated this approach had a positive effect.

Some landlord/tenant rental contracts contain a clause that prohibits removal of stover. With most landlords this is negotiable. However, many producers were reluctant to ask the landlord to consider stover removal, fearing it would result in a rent increase or possibly disrupt the relationship.

1.2.5 Producer Meetings

With DES, all meetings with producers were one-on-one. No group producer meetings were held. Several producer meetings were held at the onset of the GLCC program to help in the initial planning. These producer group meetings were kept small, less than 12 producers per meetings to better ensure full discussion. Producer groups from nearby communities initiated some of these meetings while other meetings were sponsored by GLCC.

Meetings in which stover acres were committed came later during one-on-one meetings with producers. In most situations, producers needed to include partners, wives, sons, or others in the decision-making process, and preferred to contract or sign commitments in more private surroundings.

1.3 GROWER ISSUES

Like landlords, growers were diverse. What appeared to be important to one grower might be of little concern to another. An extremely large number of variables needed to be considered. To help speed up the growers' decision-making process, a list of interesting points was prepared along with a worksheet titled "Value of Average Corn Crop." The worksheet was originally based on statistics and data from western Iowa and the GLCC harvest methods. A similar version proved to be equally effective in Wisconsin and Illinois. Appendix B1 has the Iowa version.

The worksheet developed the value for an average corn crop based on the past five years harvest for the particular county using local data. Space was provided for the farmer to enter his or her individual estimate for each factor, including seed, chemicals, equipment, fuel, labor, and land cost. In the example profit without stover harvest was $24.19/acre.

The value added by corn stover harvesting was determined next. Included with the analysis was supporting data that addressed the issues of nutrient value, sustainable removal, effect of crop rotation of the two most likely cases (corn-corn and corn-soybeans), and other factors such as tillage practice and reduced chemicals for weed and pest control. Only the revenue for corn stover was included in determining the bottom line for the producer based on distance from the collection center.

Table 3 summarizes the pricing structure for two cases. Rationale for the differences is described in the remainder of Sect. 1.3 and in Sect. 1.4.

Table 3. GLCC 1997–1998 corn stover pricing summary payments ($/dry ton)

Radius (miles)	0–15	16–30	31–50	51–100
Producers revenue				
1) 1.5 dry ton/acre	15.00	12.33	9.66	7.00
2) >2.5 dry ton/acre	10.90	8.23	5.56	2.90
Baler's revenue	14.60	14.60	14.60	14.60
Hauler's revenue	6.10	8.77	11.44	14.10
Total, Case 1	35.70	35.70	35.70	35.70
Total, Case 2	31.60	31.60	31.60	31.60

The corn stover operating profit example is worked out below:

GLCC pays (11–15 miles) $15/dry ton (1.5/acre) to the producer for providing the windrow	= $22.50/acre
Nutrient replacement	= $10.40/acre
Net additional income	= $12.10/acre
Savings of one field cultivator pass	= $ 7.10/acre
	$19.20/acre for corn stover
Normal profit without stover harvest:	$24.19/acre for corn
Profit with stover $19.20 + $24.19:	$43.39/acre

In this example, operating profit increased form $24.19/acre to $43.39/acre with little or no additional risk using custom operators. With transportation and baling costs excluded, the average producer participating in GLCC programs received $12.90/dry ton and those participating in the DES programs received an estimated $0.0072/lb or $14.40/wet ton (up to 18% moisture). The farmer could increase his revenue and operating profit further by baling and hauling the corn stover. Most chose to leave the collection to others while they concentrated on harvesting the conventional "cash crop."

1.3.1 Residue Value

There are three main considerations when estimating the value of corn stover: nutrients, organic matter, and erosion control. It is difficult to establish a generalized value for nutrients. Nitrogen is perceived to have no value in corn-bean rotations. As indicated in the Appendix B1 worksheet, an average of $10.40 was used for phosphate and potash the first year. Based on extensive sampling it was revised to $4.56/dry ton the second year.

For producers with large livestock operations (usually planting continuous corn), the stover has no nutrient value, especially where hog operations have caused excessive soluble phosphate to become a serious concern in the area's water quality. These producers were anxious to have some nutrients removed.

Few producers raised the issue of soil organic matter. In all cases, more than 30% of the residue was left to cover the soil for erosion control.

1.3.2 Amount Removed

Both GLCC and DES expected to collect 1.5 dry tons/acre of corn stover. GLCC collected 1.25 dry tons per acre. For DES, the estimated result was 1.55 dry tons, based on an average of 3,790 lbs "as is," and 18% moisture. Moisture readings were taken to avoid material exceeding 18%, but records were not kept to determine average moisture.

In all cases more than 30% of the residue covered the surface for erosion control. One farmer in Iowa complained that too much was removed. Several other farmers in Iowa and Wisconsin mentioned more should have been taken. No reaction was received from the Soil Conservation Service in either harvest project. Grain yields were not tracked as part of the record for either harvest. Conversations with producers indicated western Iowa yields varied from 130 to 180 bu/acre. The DES Wisconsin harvest area, yield was 150 to 200 bu/acre.

1.3.3 Timely Harvest

Producers were sometimes frustrated by the harvest crew's ability to be timely. In the DES operation, stalks were flail chopped, and several days elapsed before the moisture reached 18%. Some producers did not wait and proceeded with their fall tillage. However, this occurred less often with no-till producers and those in river bottoms with loess-type soils (a soil with fine silt particles, mostly sand and clay). They were more relaxed and less concerned with a quick harvest, preferring the ground frozen or fairly dry before harvesting the stover. The only exception was one producer on loess soil wanting to V-rip the field to overcome compaction.

To gain a higher degree of satisfaction among producers in future harvests, it is important to decrease the time between combining and corn stover harvest. New methods of harvesting and perhaps drying should be explored to accomplish this.

1.3.4 Removal Method

The GLCC offered two harvest methods in the 1997–1998 year. In one, the producer could shut off the spreader and/or chopper on the combine, making a windrow of cobs, shucks, leaves, and some stalk. The baler then harvested the windrow left by the combine. This method collected 40% to 50% of the stover, depending on combine head size. Predominantly round balers were used. A twelve-row head forms a windrow three times larger than a four-row head. In most situations, the windrow created by a four-row head is too small for the large square balers. The GLCC paid more per ton, but less per acre, for this method, referred to as Case 1 in Table 3. This method was expected to collect more cobs, which had more value for GLCC's furfural extraction process than other stover components.

The second method, Case 2, collected up to 70% of the corn stover by raking the field before baling. Skipping rows was allowed. This method generated more income per acre but paid less per ton since the stover contains a lower percentage of cobs. Operators with square balers normally preferred this type of harvest.

A windrow dries more slowly than stover left in the field until the desired moisture level is reached, and then raked. Tradeoffs to consider when choosing between the two methods include an extra operation, the amount of residue collected, and collection urgency.

Round bales were removed from fields with automated bale pickers and hauled directly to the GLCC plant (Fig. 1). The bales were sampled, weighed and then automatically off loaded at GLCC's plant. Square bales were either collected on an accumulator behind the baler (Fig. 2) or picked up by an automated bale picker and moved to the field's edge where they could be reloaded onto flatbed trailers pulled by semi-tractors (Fig. 3). These loads had to wait for GLCC personnel to off load using spears or squeeze trucks.

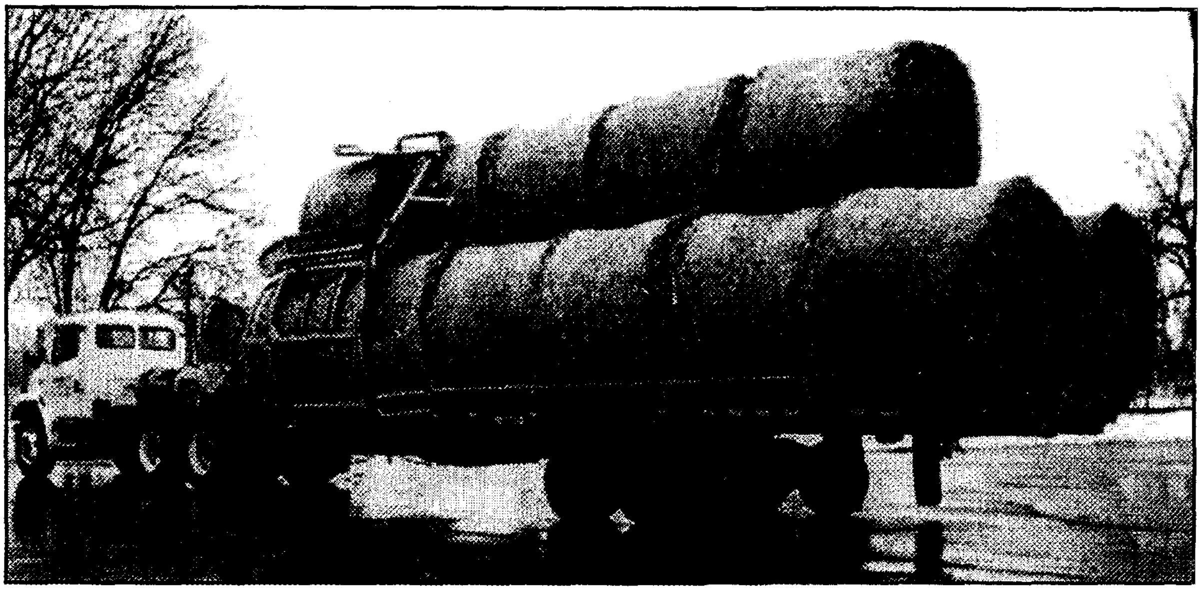


Fig. 1. Round bales transported on an automated bale picker

For DES and some GLCC fields, the stalks were first chopped using a flail stalk chopper. When moisture was judged to be less than 18% (usually requiring 2 to 3 days of favorable weather after combining), V-style rakes were used to form windrows. Within a few hours of the windrow's creation, the balers arrived to harvest the material the same day. If left overnight, dew forms raising the moisture above 18%, delaying the baling until 11 a.m. or later the next day and depended on favorable weather.

No bale picker was available, so after baling, telescopic loaders with bale squeeze attachments gather the bales into groups of 24 or more (Fig. 4). Then semi-tractors with flatbeds would be dispatched to the field near the groups of bales where a loader placed the bales on the trailer. After transport to the final destination, other telescoping loaders off-loaded and stacked the bales in the warehouse.

The GLCC operation was considerably cheaper—about $37.00/dry ton stacked in the open field at the plant. DES costs were nearly $50.00/dry ton stacked at the warehouse. Warehouse storage costs are additional.

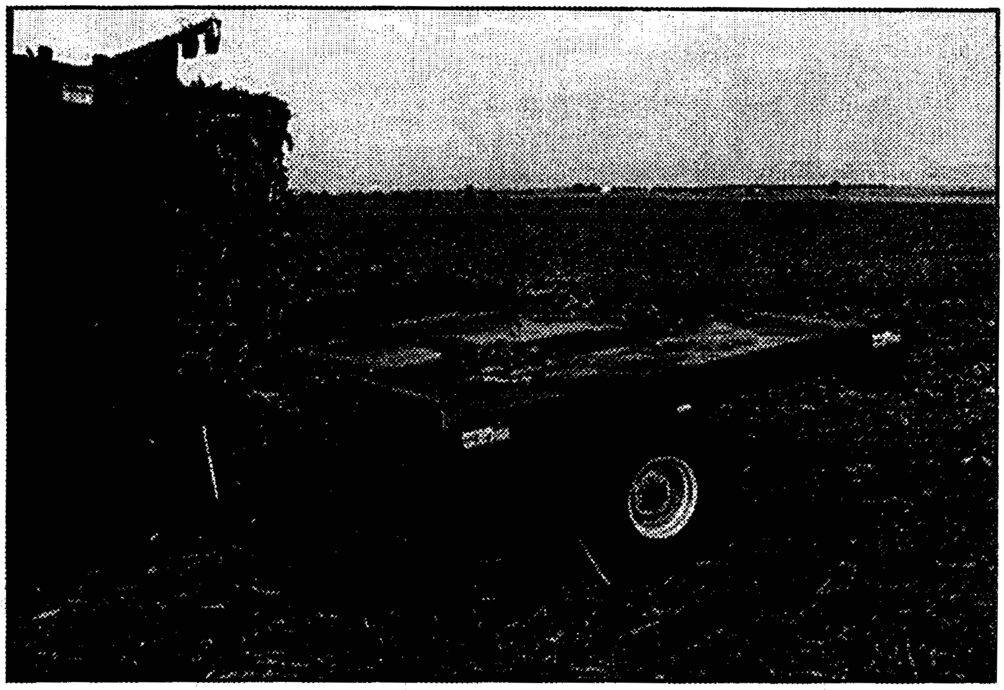


Fig. 2. A bale accumulator pulled behind a large square baler

Fig. 3. Large square bales transported on flatbed trailers pulled by semi-tractors

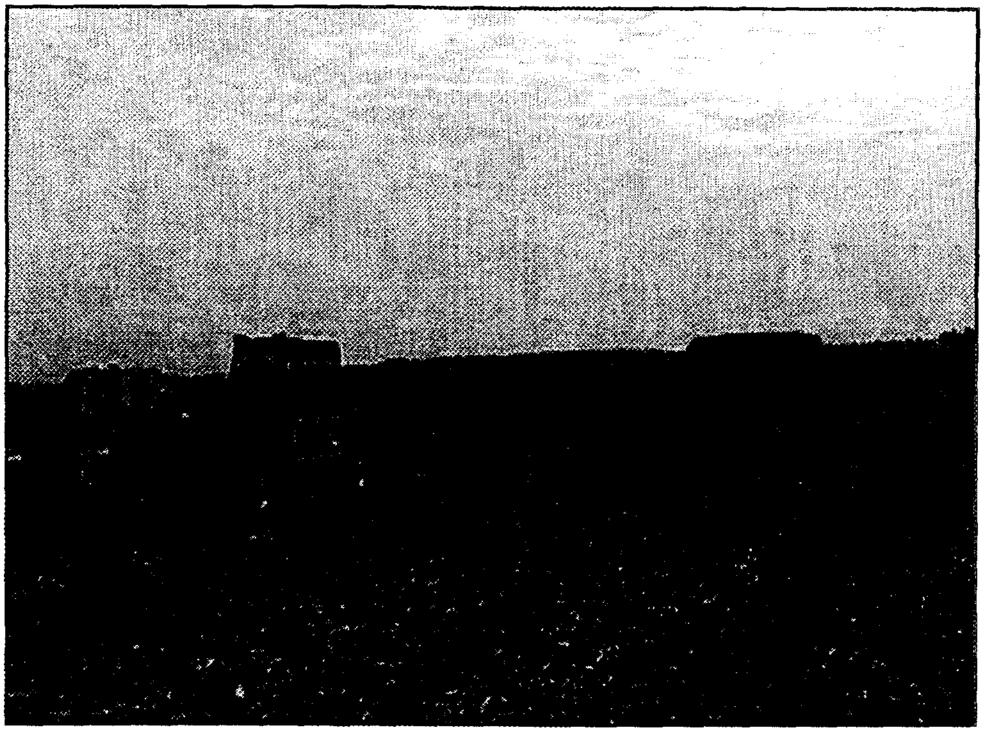


Fig. 4. A telescopic loader with a bale squeeze attachment gathering bales into groups

1.3.5 Broken Bales

The harvest must be consistently clean. Farmers will not accept anything foreign or abnormal left in their fields. Broken bales, plastic twine, or net must be minimal. Twine or surface mesh can wrap around axles and other rotating parts of their equipment. Excess stover and uneven surface cover may adversely affect the next crop by interfering with chemical application and soil warming.

Broken bales can occur when wrapped improperly, equipment or wrap fails, or foreign matter is trapped in the stover. The average number of broken bales was approximately 3%. The percentage varied among baler operators and field situations, such as operator experience and fields containing dirt or soil clods left from cultivation.

If farmers must clean up after baling, they may envision a greater cost or bigger problem than actually exists and therefore reduce producer participation. Better methods of dealing with broken bales need to be addressed.

1.3.6 Windrow Removal

Windrows are always a concern to the producer. If the weather turns against the stover harvest or the company fails to complete the harvest, the producer may have the expense and inconvenience of redistributing the windrow. Most producers do not have the proper equipment to do so, nor can the windrow be redistributed as evenly as if it were never made in the first place. An excess of corn stover where a windrow has been gathered but not harvested can cause slower emergence of the new seedings, more problematic planting or tillage or anhydrous ammonia application, and less uniform weed control. Last, but not least, an excess of corn stover can make a more ideal habitat for cutworm as was experienced by a few producers in both the DES and the GLCC harvests.

1.3.7 Compaction

Compaction is always a concern for producers because it can adversely affect the soil's future productivity. Harvesting of crop residues can again have a positive or negative effect on compaction. In the northern part of the country where frost can break up compacted soil, fall compaction is not quite as big a concern as springtime compaction. However, it can still be a serious problem. After grain is harvested with a combine, the crop residue can be harvested, provided that there is some type of benefit for the producer and that a reasonable effort is made not to compact. The effort not to compact should be similar to or more so than the effort made by the producer in his grain harvest. Removing some of the residue can reduce compaction by exposing the soil to drying by movement of air and the sun. A drier surface when spring planting takes place can reduce compaction. Spring planting is completed within a very short window of opportunity and quite often under wetter than desirable situations.

1.3.8 Post-harvest Tillage

In many areas in the Corn Belt fall tillage is preferred, at least chisel plow or major tillage. Fall plowing is by far the easiest for managing heavy soils. If you plow when the soil is too wet the winter weather will largely correct your mistake. This means the window of opportunity for completing a stover harvest is not only at risk to the onset of winter weather, but also the producer's plow. If producers intend to fall plow they will need to finish before any freeze. In southern Wisconsin and on the river bottoms in western Iowa several fields previously committed to the stover harvest programs were withdrawn so tillage could take place rather than wait any longer for balers to get there and complete their task. This was far less of a problem on fields with slopes.

1.4 ESTABLISH PRICE

1.4.1 Local Existing Prices

It is relatively easy to find current market prices of corn stover and most bedding products including low quality hay, cane hay and sorghum stover. Many agricultural publications list producers and brokers wanting to sell hay and forages. In Iowa, the *Hay and Straw Directory* published by the Iowa Department of Agriculture, is a good source. *The High Plains Journal*, Dodge City, Kansas, also contains many classified ads with corn stover or similar products for sale. Calling the producers and brokers listed can quickly provide a price range. Hay auctions and livestock sale barns are other appropriate sources of information for establishing a range of prices paid to producers for corn stover and similar products.

1.4.2 Setting the Delivery Price

GLCC used the end product value for furfural to establish the delivered price for corn stover they could pay. An example at 40 cents/pound furfural follows:

One dry ton corn stover × 18% furfural potential × 70% GLCC's yield = 252 lbs furfural × 40 cents/pound = $100.80 processed value for each ton of stover. Subtracting processing cost resulted in $31.60/dry ton delivered to the Harlan facility.

The average market price for bedding was higher, $35 to $40 or more per dry ton. Unless a second-tier price was offered it was believe that producer commitment for 50,000 acres would be difficult to obtain within a reasonable transportation radius. Expected participation would only come from producers closest to the Harlan collection point, pork producers with high levels of phosphorus, and a limited number of other producers that for one reason or another felt they had excessive or harmful amounts of corn crop residue on certain fields.

Three possible options to increase the delivered price were considered:

- increase efficiency at the processing facilities and pass savings on to producers;
- increase furfural content in the raw material (corn stover), thereby increasing the value; and
- reduce harvest costs and pass savings on to producers.

While all these options are feasible, option 1 and option 3 occurred over time. Option 2 was immediate if the percentage of cob and shuck could be increased. These portions contain higher xylan and potential furfural: 22% and 20% respectively. The lower leaves and lower stalks contain 16% and 15% respectively.

Stopping the spreader and/or chopper on the combine produces a windrow that contains all of the cobs and most of the shucks, estimated to be 20% xylan. The recalculated price increases 13% to $35.70/dry ton for this scenario. Most important, all the increase went to the producer. Balers and haulers also benefited since the windrow was preformed, which eliminated the raking operation. More cobs also increased bale density, which reduced transportation costs.

After this analysis, GLCC decided to offer two choices:

- harvesting only the windrow left by the combine, paying $35.70/dry ton for the higher fraction of xylan; and
- harvesting up to 70%, paying $31.60/dry ton when the field was raked to bring in more stover, but with a lower xylan composition.

The overall result was a significant increase in the producer's willingness to participate.

1.4.3 Setting the Producer Price

With the GLCC delivered prices now established, the producer could decide on a higher price per ton by choosing to commit just the windrow left by the combine or a higher price per acre by harvesting the entire field. Table 4 summarizes the result.

Table 4. Corn stover revenue and producer net per acre

Harvest choice	GLCC price ($/dry ton)	Harvest (dry tons/acre)	Revenue ($/acre)	Producer net ($/acre)
Combine windrow	35.70	1.5	53.50	10.50-22.50
Rake field	31.60	3.0	94.80	8.70-32.70

The amount of stover per acre collected for only the windrow was 1.5 dry tons maximum, limiting stover payment to $53.55/acre. The producer received $10.50 to $22.50 after baler and transportation costs were subtracted, depending on the distance from the collection center.

If the producer chose to harvest stover from the entire field, about 3 dry tons per acre is expected for a corn yield of 180 bu/acre—collecting 70% of the surface residue. Total revenue increased to $94.80, with the producer potentially receiving more per acre, depending on transportation cost.

1.5 ACCESSIBILITY AND HAZARDS

Collection radius is a general indicator of potential harvest size and cost limits. State regulatory limits, legal restrictions, local soil conditions, highways, bridges, and related conditions must be assessed for each situation.

1.5.1 Regulations and Restrictions

For GLCC to legally harvest corn stover, some Iowa laws were changed to accommodate the wide loads of round bales and the high-speed tractors operated by custom operators. Special wagons designed for picking up the round bales in the field were too wide to comply with existing laws. These wagons and tractors are equipped with air brakes, beacons, and extensive lighting systems. They are fully capable of safely traveling at 45 mph and higher, closer to the speed of regular traffic than traditional tractors and farm wagons. As a result, they fit into traffic flow better while allowing increased productivity in stover harvesting. The changes in Iowa law were:

- increasing the allowable road speed for implements of husbandry,
- allowing custom harvesters the same rights as the farmer in regard to transportation of crops from the farm to a plant, and
- transporting loaded wagons during night hours and on weekends.

In the DES operation, all square bales were utilized, so the width of the load was not a major concern and all loads were hauled with semi-tractors pulling flatbed trailers. However, the cost per dry ton was more than 30% higher than the cost of the GLCC operation with very little difference in price paid to producers.

Wisconsin and Illinois regulatory differences did affect fuel transport. The DES plant was located one mile north of the Illinois State line in Wisconsin. Harvest crews were often moving from one state to another. Transporting fuel in tow tanks to support the baler operations was made difficult by laws regulating fuel movement across state lines and by differences in allowable methods of transporting.

1.5.2 Drainage

When committing to purchase corn stover from producers, a company must consider drainage, slope, and soil type. Some areas drain extremely slowly because of soil type and slope. Many producers with these soils have adapted by using wide tires or tracks and are capable of harvesting the grain even where there are areas of excessive water. Unfortunately, the stover harvest is different. A 4-inch rain in November can eliminate much of the potential stover harvest, at least when conventional stover harvest methods are used. In fields that drain poorly, the stover ends up in the water. With short days and minimal available sun at this time of year, field conditions are unlikely to improve enough to harvest. Also poorly draining sections often contain shorter stalks making harvesting less attractive. To avoid these areas it is often necessary to drive equipment across the rows. This slows the harvest, increases the risk of equipment damage, and can disrupt the field condition for the next crop--all factors to be avoided.

1.5.3 Slopes

Slopes were more prevalent in GLCC's western Iowa operation than in the DES project. Both GLCC and DES wished to avoid refusing farmers offer to contract stover.

Operating on slopes reduces productivity. Normally the steeper the slope the less the potential yield and the greater the need to leave more stover to assure soil conservation compliance. This need reduces baling operation efficiency. When the bales are picked up with an automated bale picker, the risk of mishap also increases as the percent of slope increases. As in fields with poor drainage, slopes may make up a fraction of an otherwise very acceptable field.

A "slope-charge" was developed based on the additional cost the picking and hauling that the contractor incurred. The slope charge was bracketed and increased in each bracket over 8%, 8% to 10%, 11% to 12%, and >12%. Fields suspected of having above 8% slope were checked using software from PMC Map Pro Company or soil topography maps. This was done if requested by the hauler.

By not dictating to producers where to and where not to harvest corn stover, GLCC and DES believed that better relations were maintained. Producers accepted the slope charge, because they are aware of the additional cost of operating equipment on slopes. Slope charges also naturally discourage harvesting stover from fields with slopes greater than 8% by reducing the financial incentives.

1.5.3 Soil Type

Soil type impacts the harvest possibilities.

- Silt loams tend to give the widest harvest window because they have good drainage and aeration.
- Clay and Clay loams can pack badly under wheels when wet. They also tend to stay wet longer than silt loams or sandy soils. Producers are generally more concerned with the potential of compaction and water erosion.
- Sandy soils drain quickly and tend to allow a larger harvest opportunity. Sandy soils tend to cause more wear on equipment, especially balers, but also equipment at the manufacturing plant.

1.5.4 Rocks

The GLCC harvest in western Iowa encountered relatively few field situations where rocks were a problem. However, in the DES harvest in southern Wisconsin and northern Illinois, rocks were often a concern. Rocks are fairly easy to spot in a freshly tilled field in spring, but are difficult to see while the crop is growing or even after the grain is harvested. Most often purchase of the corn stover took place during the period when rocks were most difficult to see. Are rocks expected in the field? What size are the rocks? These are questions that should be answered before committing to a harvest.

A clause addressing the issue of excessive rocks was not included in the GLCC commitment or contract. The DES agreement stated that if rocks were a problem, harvest in that field would not be completed. Flailing high and keeping the rake off of the soil's surface can avoid most small gravel. Harvesters should avoid rocks sized 4 inches or greater. If the producer or contract baler can identify where to expect a pocket of rocks, perhaps most of a field can be harvested.

1.5.5 Cultivation Practices

Although cultivating is not as important of a tool in controlling weeds for most producers today as it was in the past, it is still used. When a shallow scraping is all that has occurred, it is unlikely to affect the corn stover harvest. However, if a deep cultivation or any other method that leaves large clods of soil in the field is used, the baler will have trouble with mud and dirt building up on the belts and rollers, in the case of a round baler, or in lower corners of the large square baler. This additional dirt will cause an increase in missed ties and torn wrap, plus adding more dirt to the bale. It is best to avoid fields that contain large soil clods by checking the fields before commitment.

2. GROWER COMMITMENT

2.1 PURCHASING

2.1.1 What's in it for the producer?

A work sheet entitled "Value of Average Corn Crop" was most beneficial in helping to explain how the producer could financially benefit from the sale of corn stover. A version of this work sheet is described in Chapter 1, Sect.1.3 Grower Issues. Use of this work sheet ensured that all issues were consistently covered. The work sheet developed how the average producer could increase net income 90%. It also provided a basis for the results. An adjacent column allowed the producer to incorporate his own figures, if he chooses. The producers often requested extra copies of the work sheet for partners, sons, or others involved in the decision process.

2.1.2 Farmers as Purchasing Agents

In much of the Corn Belt, there is limited field activity during the period from mid-June to September. Some producers look to supplement their income during this time. GLCC recruited several farmers near their collection center as purchasing agents in the 1997–98 program. By increasing the number of local growers in the stover harvest, the collection radius could be reduced. The program was successful and was expanded for the 1998–99 harvest season. The farmer/purchasing agents were paid approximately 50 cents/acre for acres enrolled in the program. A small problem was experienced when one farmer/purchasing agent made verbal promises not on the GLCC Corn Stover Commitment Contract.

2.1.3 Balers and Haulers as Purchasing Agents

Some contracting balers and/or haulers recruited farmers for supplying stover, with good success. Balers and haulers have more understanding of problems that may arise and were conservative in estimating and scheduling. This eliminated over-expectation by producers in comparison with purchasing by farmer/purchasing agents.

In time, only balers are likely to be needed as purchasing agents. A baler could work for the same company year after year, finding replacements for producers no longer participating.

2.1.4 Producer Meetings (Purchasing Phase)

Meetings with large groups of producers were held initially to introduce the subject. During the purchasing phase, one-on-one meetings were held with producers. The meetings were usually held at the producer's site of operation and involved the purchasing agent and those affiliated with that operation. Questions addressed the individual concerns and promoted understanding.

2.1.5 Advertising

GLCC tried direct mailing the first year, using a mailing list purchased from a farm magazine that included 600 producers with more than 500 acres of corn in specified counties in Iowa. Response to the mailing was 1%, with six producers expressing an interest.

In the DES program, ads in farm periodicals were used. A fair amount of interest was generated, but the coverage area of the publications was far larger than the intended harvest radius. Most of the inquiries came from producers outside of the 25-mile radius of Sharon, Wisconsin.

A booth at the local county fair was also used. The response was not overwhelming, but each lead tended to lead to the next. Posters were put up in farm supply stores, feed and seed dealers, and grain elevators in both the DES and GLCC projects. All of the advertising methods were helpful, but perhaps only necessary the first year.

2.2 PURCHASE CONTRACT OR PURCHASE COMMITMENT

The word "contract" may be a bit strong for the present stage of corn stover harvesting. Such a large-scale harvest had never been attempted before. Until more experience is gained, the word "commitment" makes both parties more comfortable.

2.2.1 Suggested Contents

GLCC and DES were responsible for the harvest crews and set the allowable harvest moisture. This lack of control by the producers, plus the fear of drought, early snow or extended rainy periods increased their concerns with a binding contract. Best-effort commitments rather than binding contracts avoided the negative psychological images that might come into the producer's mind: lawyers, courts, and big companies/versus producer.

From a public relations standpoint, GLCC and DES wanted producers to feel at ease with the idea of a corn stover harvest. The word commitment was selected instead of contract. Legal phrases were avoided. Wording was kept simple and easy to understand. See Appendix B2 for a Sample Corn Stover Harvest Commitment.

Along with the normal name and address information, producers were asked for several phone numbers to increase the harvest crews' ability to make contact with producers, if questions existed.

Location of the field was also important both to save time and to ensure that the wrong field was not harvested. Roads are poorly marked. Therefore, each field was identified and mapped. Often the map provided was not used to locate the field; instead an attached plat map was used. These maps were often better than the sketch provided by the producer. This is addressed further in Sect. 2.4.

2.3 PAYMENT CRITERIA

2.3.1 By Bale

The conventional method of purchasing bales of hay and straw among producers in the past has been by the bale "as is" without specifying moisture. DES used this method, because they had no truck scale. They saw no need to install one and avoided both the labor cost associated with its use and a potential bottleneck in the system.

Producers and contract balers readily accepted the bale "as is" method. They could count the bales in their field or on the loads and know their yield. Pay was based on these "as is" bale weights according to the number of bales. Random loads were checked to verify approximate weights. These check weights averaged more than 1200 lb per 4 ft × 4 ft × 8 ft bale and 1000 lb per 3 ft × 4 ft × 8 ft bale. Truckers were paid by the load, hour, or mile.

2.3.2 By Acre

Purchasing by the acre was avoided, although estimates of the harvest and producer income were made by calculating expected yield per acre. Hybrid, soil type, weather, slope, and many other factors affected the yield within a field. In the DES project, the amount of stover per acre varied from 2.5 to 6 bales when using the same 4 ft × 4 ft × 8 ft baler.

The contract baler often visited the field before harvest to scout for difficulties. Even then, he adjusted to actual conditions as the harvest proceeded regarding wet spots, rocky areas, and excessively weedy areas that needed to be calculated as to acreage and subtracted from original field size.

2.3.3 By Ton

GLCC paid based on delivered dry ton. Their data allows better accounting and control, and they believed such controls were essential for their operation. DES chose to buy "as is" to avoid the additional scale investment and labor cost for moisture analysis. However, the allowable moisture in the bale was limited to 18%. This resulted in some confusion among producers.

This experience illustrated the fact that allowable moisture will be dictated by the application, and the maximum acceptable moisture will vary according to the application. However, it would reduce confusion if corn stover were bought by the dry ton or adjusted to some standard moisture level. Purchasing corn stover on a dry basis appears to be one of the best options. Calculations and comparisons can be made for nutrient removal, actual stover yield, and furfural potential.

Purchasing stover based on a standard moisture level would require adjustments if the stover was either wetter or drier. Using a maximum level would also require adjustments, or the advantage would always be with the buyer and never the seller. All producers not harvesting at exactly the standard level would lose by either being rejected for wet stover or not getting credit for the weight of the allowable amount of water.

2.4 FIELD IDENTIFICATION

2.4.1 Maps

Two types of field maps were used. Township plat maps (Appendix C1) gave very precise locations and shapes of individual properties. The areas where fields were to be harvested were highlighted. Township directories (Appendix C2) do not contain property lines, but do indicate locations of farmhouses, names of the residents, and names of roads. These maps were used as wall maps at company headquarters to show the entire harvest area. The plat maps and directories are extremely useful for harvest and transportation crews as well.

Directory-type maps were preferred when directions were given over the phone or to re-orient confused equipment operators. This was especially necessary in nighttime operations. These maps are normally available for each county in a state, and most rural producers received them free of charge from the publishers.

Some publishers include:

Farm & Home Publishers, LTD P.O. Box 305 Belmond, IA 50421 (515) 444-3508	Directory Service Company, Inc. 950-52 South Sherman Street Longmont, CO 80501 (303) 530-8650

In the GLCC project, four sets of maps were used and one spare set was kept on file. The commitment number and field number ensured correct identification.

- The producer needed a map when calling in to report a field ready for stover harvest.
- The contracted baler and the hauler also had copies of the maps to locate the field.
- The harvest manager used the maps for documenting and following up on potential problems and producer complaints.

The DES project was more complicated, because DES personnel performed a portion of the harvest, the harvest manager was involved, and different crews (flailing, raking, baling, loading, and hauling) performed five separate operations. A large wall map with all fields highlighted was used at plant locations. If someone needed assistance, they would call in and be given directions. Pins, marked with field numbers, were placed on each field and removed when the field was harvested. This practice enabled the company's manager to visualize the progress of the harvest.

2.4.2 Field Signs or Numbers

An additional precaution was taken to avoid using inappropriate driveways. Many of the acreage owners as well as producers had asphalt driveways at the farmstead or house. In most cases the asphalt was not thick enough to support heavy equipment. Corrugated plastic field markers were made for the DES project and were attached to steel posts at the most appropriate field entrance. Reflective field numbers were placed on these signs that corresponded to field numbers on maps. The cost of field signs was much less than the potential cost of repairing damaged driveways and dealing with the associated complaints.

2.5 FIELD CONSIDERATIONS

2.5.1 Rocks

There were many rocky areas within the DES project's harvest radius. Because procurement began in June, the crops concealed rocky areas. As a result, a clause was added to the grower commitment that voided the commitment if rocks were found to be problem.

No clause about rocks was needed in the GLCC project's grower commitment. It was easy to avoid rock concentrations during procurement because of GLCC's familiarity with the area. With few exceptions, rocks are a minor problem within a 50-mile radius of Harlan and are encountered only in the extreme northeast part of this harvest circle.

2.5.2 Drainage

Many of the fields in the DES project had drainage ditches or shallow tile lines that needed to be avoided by heavy equipment. Producers were asked to mark these areas on the commitment map. A written warning was placed on the commitment map, and tile lines were highlighted in orange to draw attention to them. This warning was adequate. No producers complained of tile line damage, and no equipment operators got stuck trying to cross drainage ditches. In western Iowa, the drainage ditches are far more obvious. Tile lines are deep, usually 4 to 6 ft under the surface of the ground, and are not affected by equipment operation.

2.5.3 Field Entrances

Many field entrances are not wide enough to accommodate large hauling units. A tractor-trailer with a 52-ft trailer gives maximum square foot capacity, but will not go through many field entrances in western Iowa. The effective entrance width depends on side grades and the width of the adjoining road. Sloped entrances can cause tractor-trailers to become high-centered and can also stop drop-deck and double-drop-deck trailers.

Many fields have multiple entrances. The best entrance should be selected and noted on the commitment form. If bales are to be temporarily staged near the field entrance for later loading, the staging crew needs to be aware of problem entrances. Some preplanning will reduce the number of mishaps caused by poor decisions on the part of the haulers and stagers. With some advanced planning, most problem entrances can be avoided or resolved.

2.5.4 Producer's Needs (Tillage, Fertilizer Application)

Each field commitment form included a "special instruction from the producer" area. Producers used this area to indicate concerns and needs. Producers often indicated fields that should receive harvest priority to allow early fall tillage or fertilizer application. A clause on the back of the commitment form stated "if baling has not been completed and the producer wishes to do field work or run cows, the producer should do so at his discretion. However, if this is done, this commitment is canceled." This assured producers that they still had control and could begin other field operations when they felt it was necessary.

2.5.5 Field Size, Shape, and Location

Every effort was made to harvest small fields, if the producer desired. Harvesting stover on one field and not others can cause additional management issues or even necessitate additional equipment for the producer, because corn stover harvest affects tillage practices, chemical choices, and other management decisions. Producers have less incentive to participate if these issues are ignored, but the larger square balers have more difficulty working in small or oddly shaped fields. Round balers were assigned to fields, if the practical choice existed.

Special consideration was also made for distant fields. Some fields were harvested 20 miles from the next nearest field, well outside the intended harvest circle. This extreme distance required the baler to travel one hour out and one hour back, towing the associated equipment with a conventional tractor. Although every effort was made to accommodate producers, this one stretched the limits.

3. HARVEST PREPARATION

3.1 IDENTIFY CUSTOM OPERATORS

There are at least three groups of harvest operators: the producers, local custom operators, and large jobbers that primarily work in the western plain states. For the initial corn stover harvest, few producers had the time or resources to participate. Their priority was harvesting the established cash crops, primarily soybeans and corn. Local custom operators were the best source for GLCC, because they had underutilized round balers that were adaptable to corn stover. GLCC relied entirely on the equipment of others. Large jobbers with square balers were the primary source for DES. DES also purchased enough equipment to meet one-third of their requirements and contracted with others to operate it.

3.1.1 Producers

Producers would seem to be the ideal people for the stover harvest, because they could harvest both their own stover and that of nearby producers. Sixty to seventy producers—about 15% of the total that signed commitments to supply stover— attended a baling and hauling conference held in Harlan, Iowa. However, most decided they would not have the extra manpower needed until their own grain harvest was completed. Others decided that their balers were too old, would not make a dense enough bale, or were not equipped with the bale-wrapping device.

Twenty producers did contract to do their own baling and hauling for the GLCC harvest, contracting from 600 to 2500 acres each. Their results were uneven. One-third did well and put forth their best efforts. One-third struggled between their own grain harvest and the unexpected difficulties in baling corn stover. Many of these improved the following year. The final one-third never made a real effort and procrastinated in the belief that they had all winter, which proved to be a mistake.

The lesson learned—have backup balers ready. It is hard to identify the future non-performers. Some risk was removed by setting a maximum of 1500 acres contracted to one baler. Those that finished their contracted acres were offered more acreage from those balers who had yet to complete their contract.

3.1.2 Local Custom Operators

Most local custom operators were an excellent contact for sourcing corn stover balers. Even if they were too busy with present customers to contract for additional business, they were aware of other custom operators and offered referrals. They were also experienced in dealing with producers and persuaded some of their existing hay customers to participate in the corn stover harvest. Although custom operators may have more experience in baling corn stover than producers, their reliability was only a little better. This assignment was too often viewed as a sideline, providing supplemental income, and did not always get the priority needed for timely harvest completion.

3.1.3 Large Jobbers

Jobbers with multiple balers and support equipment harvest large amounts of hay in the western, high-plain states. Their normal harvest occurs between June and September, and their service is available for the corn stover harvest beginning in mid-September through November. They had minimal experience with corn stover but were quick to learn. When they brought their crews into an area they only had one focus—complete the corn stover harvest they were hired to do.

The DES project used crews from Oregon, Idaho, and Illinois. Because some crews were from quite a distance, DES provided some of the preliminary planning for housing, meals, fuel, twine, and equipment parts. These large jobbers were willing to contract all aspects of the harvest from flailing to hauling. Most of these large jobbers do work for large feedlots, hay exporters, and mushroom producers. All of these baling operations were dependable and well organized. Contacts include:

- Rod Phelan, Phelan Inc., Tangent, Oregon, Phone: (541) 967-8195;
- Tom Stevenson, Geneva Enterprises, South Mendota, Illinois, Phone: (815) 539-3040; and
- Dennis Strom, Strom Ranches Inc., Hill City, Idaho, Phone: (208) 764-2596.

3.2 CONTRACTS

3.2.1 Purchasing and Harvesting

Verbal contracts were used with procurement agents. A fee of was $0.50/acre, or the equivalent in mesh wrap when balers were the purchasing agents, was paid for acres committed by producers and submitted by the purchasing agent to GLCC.

Contracts with the custom operators were kept simple, developed without the assistance of lawyers, and avoided legal terminology. This may not be the best method of contracting if one ends up in a legal battle. However, GLCC believed that the effort involved in recovering damages would outweighed any financial settlement, and judged it best to resolve conflicts outside of the court or to disregard them. This made it easier to maintain positive public relations. Individual contracts were relatively small, and for the most part incomplete contracts are often the result of weather conditions or could be blamed on weather.

Field preparation was included in the DES project contract. Most of GLCC field preparation, forming the windrow with the combine, was included in the producer commitments. On occasion, the balers contracted or came to agreements with the producers to form a windrow without GLCC involvement. Reasons included insufficient size windrows left by smaller four-row combines and ridge planting.

In the DES project, balers were contracted to deliver a specific number of bales or harvest a designated number of acres. A sample of the baling contract predominantly used in the GLCC project is provided in Appendix D.

3.2.4 Transportation

In Wisconsin and northern Illinois, DES contracted with trucking companies by the hour for flatbed trailers or double drop-deck trailers, shown in Fig. 5. A double drop-deck trailer is a semi-trailer with three deck heights. The first deck (the first 10 ft or so) is the highest (about 4 ft 6 in from ground to the deck), designed to go over the tandem wheels of the tractor. The center deck is only about 24 in from ground to deck and extends from behind the tractor tires to the front of trailer tires (30 ft or so). The rear deck is about 40 in from the ground, just high enough to clear the trailer tires (normally low-profile tires).

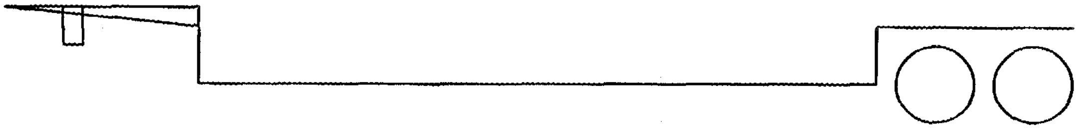


Fig. 5 Double-drop-deck trailer

Contracts varied from $47.50 to $50.00/hr depending on the type of trailer. In the case of Illinois Fiber and Geneva Enterprises, the transportation cost was included in the delivered bale price.

GLCC purchased mostly round bales. Most haulers with conventional equipment did not find the price paid to move round bales attractive. Iron Horse Custom Farming (IHCF) purchased self-contained bale loading and unloading trailers, and as a result, transportation was mostly contracted with them. This type of equipment is desirable because it doe not depend on others for loading and unloading bales. An example is shown in Fig. 1 for round bales.

GLCC contracted a minimum volume of 40,000 tons annually for three years with IHCF. A pre-established penalty amount was held in an escrow account to be paid to IHCF if less than 40,000 tons were available for transport. Without the contract terms, the perceived risk would have been too high for IHCF (or others) to procure this specialized equipment. Other contractors hauled a small amount, mostly square bales). A copy of the hauler commitment can be found in Appendix E.

3.2.5 Loading, Unloading, and Stacking

All loading in the field was the responsibility of the hauler. Efficient round bale handling was a major factor in the limited response by conventional haulers in the GLCC project. The automated bale picking equipment operated by IHCF was able to load and off-load independently, requiring no support.

Delays often occurred in loading and unloading conventional trucks. Conventional flatbed trailer operators were required to wait for fork or squeeze equipment for loading the bales in the field, and for unloading the bales at the collection center. Fork trucks needed to be moved from spot to spot in the field, and no spare fork was available if a breakdown occurred. Fork operators were normally operating another piece of support equipment—the flail or rake—because trucks were loaded intermittently. In some cases the truck drivers had to load their own trucks, not a task most can do well. At the processing center, several trucks would arrive at the same time and the equipment used to off-load could not keep up, which caused another bottleneck in the system.

3.3 AVOIDING PROBLEMS

Advance planning is key to avoiding problems with wet bales, fire, and rodents and ensuring safe operation. Establishing communication systems within the organization, properly training operators, and anticipating potential problems resulted in a successful, incident-free harvest.

3.3.1 Wet Bales

Wet bales are a serious problem. Most damage occurs when bales absorb standing water after harvest. Their weight can damage equipment if they are moved. In cold weather, they can freeze together or to the ground. They can spoil rapidly spoil in warm weather, creating a disposal problem. The best precaution against wet bales is to select the proper site in advance.

Most producers know the areas of the field prone to flooding, slow draining, or standing water. This information is necessary for staging the bales. Optical illusions often make it difficult to identify the best staging location by eye. Bales should never be staged along streams or on the topside of terraces. Sometimes entire fields are at high risk for flooding or standing water. Plans for these fields should include immediate removal of bales after baling in order to reduce risk.

There is a risk of bales freezing to the ground, though this was not experienced in these projects. The slower-draining fields would have higher risk. At the plant, ground should slope away from stacks. Stacking bales on several inches of gravel provides good drainage, but some gravel will stick to the bales when they are moved for processing. This is especially true in winter months.

3.3.2 Fire

Fire, including spontaneous combustion, is always a concern when storing organic material. However, the risks should be kept in perspective. Millions of tons of hay and straw, along with some corn stover, are baled each year with relatively few problems that can be traced to spontaneous combustion. Corn stalks are less homogeneous and vary more in dimension and composition than the other materials, and the heat created in bales of corn stalks dissipates more easily than in a more densely packed bale of alfalfa hay. Risk is reduced when fine particles and dirt are kept to a minimum, because they reduce the air circulation that normally absorbs and exhausts heat.

No spontaneous combustion occurred in the GLCC project, although some stover was baled at 35 to 45% moisture or higher. During the 1997–98 crop year, DES stored tightly packed square bales inside an improperly vented shed—jammed against each other with no aisles or open space. Some bales exceeded 30% moisture, and it literally rained inside the building. Some bales were discolored, but no spontaneous combustion occurred.

Attempts were made to reduce the hazards associated with cigarette smoking in both the GLCC and the DES projects. No smoking signs were posted, and employees were warned that they would be fired for smoking in areas designated non-smoking. Even so, there was evidence that smoking was taking place. Cigarette butts were common in equipment ashtrays, bale storage areas, and elsewhere. The urge to smoke seems to override the fear of job loss. At least one fire was attributed to cigarettes.

Use of spark arrestors was encouraged for exhaust systems of all transport power units. In the DES project, one unit was lost to fire attributed to sparks from the tractor-trailer's exhaust. Hot bearings and other equipment-induced heat sparks caused several fires in both projects. In most cases there was no damage, or very minimal damage, to equipment because safety instructions and means to extinguish fires were provided.

3.3.3 Rodents

Around corn stover, rodents are primarily a health threat to workers rather than a source of contamination and yield loss, as in grain crops. Because a small amount of grain can be expected with the stover, a rodent control program should be in place before harvest begins. Rodent problems can be kept in check with a combination of continuous control, completely using up the raw material, and cleaning up the area at least once per year. In the GLCC project, bait boxes were put in place and maintained weekly by Orkin, a pest control provider. In addition, the inventory plan was generally FILO (first in, last out), with complete cleaning of the area in between each inventory turnover.

3.3.4 Safety

Safety was a major concern in both projects. DES held an in-house tractor safety course for all equipment operators. Individuals involved in management were reminded about safety in discussions at weekly meetings. Safety glasses were mandatory in the plant. Ear protection and hard hats were also suggested and were available.

The GLCC project included safety meetings with all employees on a regular basis. Hard hats and safety glasses were mandatory in the plant. Fire extinguishers, first aid kits, and ear protection were also available.

3.3.5 Training Needs

Most balers had experience in operating their equipment though not all were experienced with baling corn stalks. Training of harvest equipment operators included noting differences between baling corn stover and baling other crops, and equipment maintenance schedules for oil, grease, and air filters.

In the short time DES was in existence, there was little time to develop methods to identify and avoid potential problems. In the GLCC project, balers and haulers did benefit from cooperation among operators, and from direct manufacturer involvement. During the first weeks of harvest, much was learned about baling corn stover. Frequent one-on-one meetings transferred know-how between the harvest manager and the custom operators.

Before the 1998–99 harvest, a baler and hauler conference was held to address problems and share experiences. Representatives of equipment manufacturers and the equipment were on hand to answer questions and help solve problems. Most involved felt the conference was extremely helpful for the manufacturers as well as the operators.

3.4 COMMUNICATIONS AND COORDINATION

Productive deployment of people and equipment is key for successful harvest. More than 200 people were involved in harvesting 50,000 acres: 190 equipment operators and tractor drivers and 45 truck drivers. Total fixed costs during harvest, when the crews were dispatched but unable to work because of high moisture in crops in the field, were more than $5,000/hour. Excellent communication is required for proper coordination of these resources.

3.4.1 Radios and Cell Phones

Private band radios worked well for in field communication. In the GLCC project, some of the balers worked in teams and found radios useful, especially when running at night. When problems with mesh wrap occurred, one baler could inform the other of problems that were hard to see from the tractor pulling the baler. This reduced the number of mis-wrapped bales or tears. Many breakdowns are easier remedied with two people than with one. Teams and radios also reduce the boredom that occurs when individual balers run separately.

In the DES operation, a crew boss normally was in charge of several equipment operators. Private band radios were very useful in directing equipment operators and truck drivers. However, these radios were not reliable enough over distances, and the crew boss also carried a cell phone.

Cell phones were much more dependable than radios for communications between plant traffic managers and equipment operators, but would have been expensive for in-field communication. The combination of radios for in-field communication and cell phones for backup and as first choice between the field and plant worked well.

3.4.2 Satellite Tracking

Global positioning satellites (GPS) could be used during harvest. If the purchasing agent took a reading at the designated location and included the coordinates on the commitment map, harvesters and truckers could use a handheld unit to verify field entrances and other locations. A handheld GPS unit accurate within 50 ft costs around $100.

More elaborate GPS systems could also be used. A system with transmitters on each piece of equipment could be monitored via screen display by the traffic manager. Direction or lack of movement could have been detected, and down time for each operator noted. Isoboard, a large particleboard manufacturer near Elie, Manitoba, used such a system in their straw harvest.

3.4.3 Maps

Field maps are important and were used in both projects. These maps were discussed previously in subsections 2.2 and 2.4.1. Well-drawn maps completed in advance of harvest with details on surrounding crops, street designation, and producer concerns will save a lot of time and confusion during the stover harvest.

3.4.4 In-field Chain of Command

In the GLCC project, contract operators were responsible for completing the harvest in the fields identified in their agreement. The harvest manager monitored each contractor's progress and occasionally gave suggestions about incorporating methods of another contractor that appeared to be more successful. If an individual contractor was falling behind in his harvest and showing little improvement, the harvest manager transferred part of the contracted acres to other operators as they became available.

Working with 30 to 40 baler operators, managing haulers, and responding to producers' concerns placed an enormous initial workload demand on the harvest manager. A more manageable situation was needed, and one evolved with DES.

The DES project was structured so that everyone knew the organization and how they fit in—whom their boss or leader was and which equipment operation they were responsible for:

- Baler operators served as field bosses. They monitored moisture and knew when they could operate. They were also aware of excessive dirt and rocks in the windrow and could instruct rake operators to make necessary adjustments.
- Flail operators were sent to the fields in groups with one operator responsible for monitoring necessary settings and overall field neatness.
- The fork truck "squeeze" operators gathering and loading the trucks worked in a group. A lead operator's job ensured gathering and loading took place in the most ideal areas, and informed the traffic manager how many trucks were needed at a field site. The lead squeeze operator also consulted with the baler operator about when the first truck should arrive at the field.

When the producer informed the harvest manager that a field was ready, a flailing crew was dispatched. At the same time, balers were scheduled to start 48 hours later. This minimized the potential for losing a flailed field to an impatient farmer's plow. Scheduling trucks for loading was not as critical as baling, and 24 to 48 hours were allotted to load and transport the baled stover.

4. HARVEST

4.1 MONITORING

In a large field operation, good monitoring is essential to identify problems that may be overlooked as a result of inexperience or oversight. The short harvest-time window for completion makes early correction of these problems important for overall success.

4.1.1 Foreign Material

The only foreign material that caused a concern in the GLCC project was dirt. Excessive dirt was generally traced back to dirt clods left by the producer's cultivation practices, and this dirt can be best avoided prior to procurement. Some dirt will stick to the corn stover when corn stalks are left lying on the ground and traveled over by equipment, and some root systems tipped out of the ground by harvest equipment end up in the bale. Exact amounts of dirt were not measured, but were thought to be in the 2 to 5% range.

Problems with dirt were similar in the DES project. DES was also concerned about weeds, and on occasion areas of some fields were avoided because of excessive weeds. Some weed types also contributed to additional moisture.

Weeds, moisture, and dirt are thought to be major factors in deterioration and overall shrinkage, and dirt in the process causes severe equipment wear. Grinders, mills, valves, pipes, conveyors, and other associated equipment coming into contact with the dirt fail much sooner, thus increasing maintenance cost and reducing on-stream operating time. Disposal of foreign material at the plant site is another cost to be avoided.

4.1.2 Moisture Measurement

In the GLCC project, corn stover was purchased on a dry basis. At first, attempts were made to establish moisture levels with electronic moisture probes. They were found to be extremely inaccurate for reasons explained in Sect. 4.1.3. Drill-bit-type probes were also tried, but lower parts of the stocks and cobs were pushed out of the way by the probe causing inaccurate sampling.

To measure moisture more accurately, a composite sample was taken from three bales from each load using a chain saw equipped with an approximately 2-ft bar and a specially designed dust-catching system. Round bales were cut from the side. The composite sample was then taken to the scale house where moisture content was determined using the Koster Hay Moisture Testing System. This system involves weighing out a specific amount of material and completely drying it with the electric drying unit. The dry sample is then placed back on the specially constructed scale that shows directly the percentage of dry matter and moisture.

In the DES project, Delmhorst Model FX2000 Hay Moisture Meters were used. These meters have a moisture measurement range of 8 to 40% for hay and stover. Powered by a 9V alkaline battery, a Delmhorst meter can accumulate and average up to one hundred readings. The company mentions that there are many variables associated with measuring moisture content (temperature, crop variety and maturity, cutting, climatic conditions, use of preservatives/drying agents, etc.). These variables must be considered when using a moisture meter. The company's address is: Delmhorst Instrument Co., 51 Indian Lane East, P.O. Box 68, Towaco, NJ 07082.

4.1.3 Effects of Temperature and Density on Moisture Probes

The Delmhorst Hay Moisture Meters were found to be consistent if the bales were either freshly baled—less than one hour out of the baler—or fully cured (occurring in 2 weeks to 1 month after baling). In between those two periods, meter readings would climb up to more than double the actual moisture. Although the cause was not fully understood, it was thought to be the result of wide moisture differences (i.e., 20% in the top of the stalk and 40% in the bottom). A high moisture level causes increased oxidation and thus increases temperature in the bale. Eventually the high moisture areas migrate throughout the bale. When all parts of the bale reach equilibrium, the heating stops and bale temperature is nearer to that of the ambient air.

Example: A bale was tested just out of the baler. Sixteen probes were taken for moisture readings. Moistures ranged from 11 to 36% and averaged 20%. The higher readings occurred when the probe tip stopped in the center of a larger piece of stalk or lower stalk part that carries more moisture. Temperatures were also taken. In the freshly formed bale, temperatures were very near the ambient air temperature of 66 degrees.

The bale was retested for moisture and temperature every few hours until a peak temperature reading was found. This occurred approximately 48 hours after baling, with sixteen readings averaging 149 degrees and 42% moisture. Over the next 3 weeks moisture and temperature readings gradually came back down until ambient air temperature was again achieved 21 days after baling. At this point, moisture migration had occurred.

Sixteen readings indicated 19% moisture, with a range of readings from 15 to 20%. The high heat and humidity that occurs in the curing process evidently caused the 3 weeks in which false readings were recorded. The bale was also weighed at the beginning and again at 21 days. The bale had lost 4 lb or three tenths of 1%.

4.1.4 Bale Weights

The dry-weight bale density is tremendously important to the baling and hauling cost. In the GLCC project, all parties involved were paid based on dry tons. Bale density did not affect the producer. Density does affect baling productivity and wrap cost. Each time the baler stops to wrap a bale, it takes the same amount of time and wrap regardless of the density of the individual bale.

Example: When producing a total of 3000 tons during the harvest season, wrapping 875-lb bales versus 1250-lb bales requires an additional 3000 minutes. This incremental time could have produced an additional $5,000 in revenue from another 344 tons of baled stover. The additional 375 lb per bale also saves 50 cents/bale in wrap cost. For total wrap savings: 3000 ton divided by 1250 lb/bale is $2400 less wrap cost. A baling operation producing 3000 tons per season of 1250-lb bales versus 875-lb bales increases revenue 11.5% while decreasing wrap cost by $2400. Density also affects transportation costs as shown in the Table 5.

Table 5. Hauling revenue and round bale density

Trip distance, miles	Hauling payment per loaded trip* (dollars)			
0 –15	47	57	62	73
16–30	67	82	89	104
31–50	88	107	117	136
Bale weight, dry lb	900	1100	1200	1400

*Normal trailer load is 17 round bales, 6 on the left bottom, 6 on the right bottom, and 5 on top.

4.1.5 Load Weights

The most economically efficient load size is not always equivalent to the maximum legal gross weight allowed on the highway. This is demonstrated in Appendix A, Stover Hauling Considerations and Profitability. Regardless whether hauling with automated bale pickers or tractor-trailers with flatbed trailers, the maximum allowable weight of bales on the load is important and is the main reason for monitoring the weight of loads.

4.1.6 Field Completion and Cleanups

Producers were disturbed about broken bales remaining in the fields after stover harvest. It was difficult to spread out broken bales because most operators lacked proper equipment. Burning the broken bales could alleviate the problem, but negative public perceptions and liability issues occur if fire and smoke get out of control, including the possibility of causing traffic accidents.

Rebaling the material seems to be the best alternative, although it increases baler breakdowns and reduces productivity. Rebaling also leaves some of the remaining residue unevenly distributed where the rebaling took place.

Windrows formed but not removed, because of snow or for some other reason, were also a major concern to producers. Such windrows could cause problems with equipment in future producer operations, reduce the effectiveness of chemical controls, and increase cutworm populations by providing ideal habitat. A penalty clause was included in the Producer Commitment, Appendix B2, which compensates the producer if broken bales and stover residue are not removed. This penalty is detailed in Table 6.

Table 6. GLCC penalty if stover is not removed by agreed upon deadline

Deadline	Apr. 1	Mar. 1	Feb. 1	Jan. 1	Dec. 1
Penalty	$15/acre	$12/acre	$10/acre	$8/acre	$6/acre

4.1.7 Contractor Performance

The most important measure of contractor performance is bale breakage. A high incidence of breakage indicates that the contractor is not applying three full wraps of mesh or, in the case of square balers, missing twine as the result of a knotting problem. Pickups and flails that operate too close to the ground and get into the dirt are also often a cause of breakage.

Bale density was closely monitored, because a hauling operator's profitability suffers if the bales are light. Baler operators also incur additional wrap and twine cost, especially when using round balers and mesh wrap, as detailed in subsection 4.1.4.

In the GLCC project, bell-shaped or egg-shaped bales were difficult to pick up or haul and tended to be more likely to fall off the loads. In many cases it was necessary to drive diagonally from one side of the windrow to the other to keep bales in proper form.

In the DES project, when trucks were hired by the hour, it was necessary to keep an accurate record of loading and off-loading time to track trucker performance. Bale counts, and the operator doing the loading, were recorded for each load. If loads were consistently below the maximum size, the operator was questioned as to the reason. If loads were taking too long to load or off-load, records would indicate where the problem was, and bottlenecks in the system could be discovered and remedied.

4.2 Safety Issues

Operator safety, safe transportation of large bales on public roads, fire prevention, and stable bale stacking are important safety issues.

4.2.1 Payload Containment

It is most important to ensure that bales remain on the load. Straps are needed over each row of bales when bales are positioned lengthwise on trailers. Two straps running from front to back are adequate when square bales are positioned across the trailer. The least time-consuming method was found to be using two straps from front to back if properly installed. Most Department of Transportation (DOT) officers required 4-inch wide straps rather than 2.5-inch wide straps.

The GLCC project used automated containment equipment. The loading arm and side rails fold over the load, securing it in place on the road. Automated bale picker confinement was considered adequate by most DOT officers, although one officer was not sure of compliance. A ticket was issued and not contested by the hauler because of the time and expense involved. Automated containment saves time and, in the GLCC experience, has a better safety record than securing with straps. At some point, a case will need to be made and presented to the DOT, so a ruling can be made.

4.2.2 Field and Transport Fire Protection

Fire extinguishers should be carried on all field and transport equipment. Overheated bearings are the main cause of fires in field operations. One transportation fire was probably caused by a discarded cigarette, either from the operator or from a passing motorist. A spark from a tractor-trailer exhaust system caused one fire. Special exhaust systems with spark inhibitors or resistors are available and work well.

4.2.3 Transport Operations

Driving on the shoulder of the road is often considered a courtesy to other motorists and is practiced by most farmers when a build up of traffic is forming behind slow-moving farm equipment. However, dust kicked up by the equipment can be blown across the roadway and can, at times, reduce visibility for motorists. Unknown to many, driving on the shoulder is illegal in Iowa. The State Highway Patrol has issued several tickets, and farm equipment operators driving on the shoulder have incurred fines.

Roadsides are often rough and occasionally have washed out areas that cause damage to equipment. It is safest to stay on the road with proper warning devices, such as wide-load signs, beacons, flashers, and slow-moving-vehicle signs. DES held a special pre-harvest session to encourage safety, and reminders were issued often for both field operations and highway movement.

4.2.4 In the Bale Yard

Stacking corn stover is different than stacking alfalfa hay, and what works best for hay may not work for corn stover. When stacking large square bales, it is recommended that stacks be no more than six bales high. Round bales are easier to stack. A pyramid style seemed more secure. There was not one incident of a round bale stack toppling over.

A good operator using proper stacking techniques can make very stable stacks of square bales. A less experienced operator can make a stable stack of round bales with less effort. More information needs to be gathered on how to safely stack large square bales and the proper equipment for this operation.

Neither of the operations had fencing around the bale storage area. Fencing is beneficial and necessary in order to maintain safety. Passers-by were often noticed in the vicinity of the bales. The bale storage area should not be readily accessible to unauthorized personnel, including children looking for a place to play.

4.3 HARVEST OPERATION AND MANAGEMENT

Staying informed, setting priorities, and shifting resources to best meet changing circumstances are the basic strategies for managing the harvest operation. Field visits are necessary to gather information. Planning the work and working the plan within the constraints of time, weather, and other conditions is a constant challenge—success often depends on the early preparation that is completed before the start of the harvest.

4.3.1 Quantity or Quality

One of the most difficult decisions for management is to determine which is more important, maximum quantity or best storage quality. Higher moisture can increase mold and deterioration in storage but can substantially increase the time available for harvest. Low allowable moisture limits the harvest day and results in higher harvest cost per ton.

In the DES project, peak production of square bales was around 40 bales/hour/baler. Average production was around 20 bales/hour/baler. Each time the baling operation was started, it would take 30 minutes to 1 hour to get all balers running smoothly. After start-up time, the number of bales produced per machine per hour sharply increases.

For each additional percentage of moisture allowed between 20 and 24%, estimated production time per day increases 30 minutes. Estimated production time increases at an even greater rate above 24% moisture. The impact is shown for October 1998:

- 54 hours available in 12 days when baling at 20% moisture
- 74 hours available in 16 days when baling at 24% moisture
- 150 hours available in 18 days when baling at 30% moisture

Although more moldy bales occurred in bales averaging 24% moisture, shrinkage or deterioration was not as severe. When used within a week of harvest, bales containing moistures of 30% or more created no major problems in the GLCC project. The winter temperatures also reduced oxidation, if bales were allowed to cure before stacking.

In the GLCC project, some bales were harvested with more than 35% moisture. Many of these bales were placed in single stacks. Heat emitting from the stack was noticed all winter. Corn plants sprouted and grew on top of the stacks in the middle of winter. Although the plants were frosted, they still survived. When the bales were finally moved for processing, nearly 18 months later, some heat still existed. Some of the stover was brown (the color of coffee grounds), extremely dry, and crumbled in your hand. Even with this apparent extreme oxidation and heat, no black ash was found.

4.3.2 Grower Field Availability

Often producers neglected to call in and report immediately when their grain harvest had been completed and they were ready for the stover harvest. Better communication as to field availability is needed, especially early in the season when harvest crews are idle and there is no backlog of fields ready for stover harvest. Once under way, the backlog of available fields builds, and fields are scheduled for harvest based on priorities according to a combination of factors, including producer instructions, soil type, location, weather, and crop conditions.

4.3.3 Baler Maintenance and Operating Time

Most often there was plenty of time for routine maintenance before the dew was off in the morning or when rain had stopped the harvest operation. However, on occasion a problem was discovered or occurred when a harvest could be taking place. The harvest continued even if the bales were one or two twines short or the flails were missing a few knives.

As harvest began each day, it would take the first hour or so to get the balers running smoothly. It seemed the precision mechanical parts needed to re-polish themselves before the baler would become dependable. An hour can be a large percentage of the baling day when trying to harvest at 18% moisture. These daily restart problems were far less significant for the round balers.

4.3.4 Grower Harvest Metrics

When making a commitment to purchase stover, the purchaser should give some consideration to the expected harvest date. Some soils warm more quickly in the spring, better weather may allow earlier planting in one area than in another, and different corn hybrids have different maturities. In both the DES and GLCC operations, there were areas in the harvest circle that were normally 2 weeks or more ahead of other areas. Knowing this allows the harvest to start earlier, a tremendous advantage. Larger river bottoms and sandy soils are often candidates for early harvest.

In the GLCC harvest, popcorn was often drier and harvested much earlier than field corn. Producers harvesting high-moisture grain or earlage can also improve harvest success, because this also allows earlier access to stover.

Producers using no-till, or not planning fall tillage, can be of great benefit later in the harvest season. They often prefer to have harvest operations take place after the ground is frozen, and are the only possible option for an early spring harvest. Having a variety of types of fields, including fields that drain quickly, such as coarse sand or the loess-type soils available around Harlan, can also be helpful in scheduling.

4.3.5 Quality Control

Both dirt and moisture increase oxidation, the main cause of discoloring, during storage. The DES harvest manager routinely inspected bales in the field for moisture and dirt. The electronic moisture tester was fairly accurate when stover was freshly baled. Bales exceeding moisture limits were discarded and taken to the compost site at a considerable cost to DES. Bales containing excessive dirt or root systems were also discarded. Quick response is important in keeping these problems under control.

In the GLCC operation, the harvest manager primarily monitored bale density and wrap cost, although there were concerns with dirt and moisture. Novice corn stover balers required more assistance, with emphasis on bale density to reduce raw material and hauling costs.

4.3.6 Weather Monitoring

Local weather information was continually monitored with a Data Transmission Network (DTN) system provided by Data Transmission Network Corporation. Monitoring approaching storm fronts was especially important in the DES project and somewhat effective in minimizing excessive windrow production. The DTN was also helpful in identifying how widespread rain was and where dry areas could be found so harvest could continue. The rainfall amount was also monitored at many locations to identify where operations could be restarted first.

4.3.7 Field Access

The harvest manager checked field access before harvest equipment was dispatched. Occasionally, the original choice for entering the field was not available because the field closest to the entrance had been chisel plowed or had not yet been harvested.

4.3.8 Resource Scheduling

There were not enough personnel to cover all of the equipment needs in the DES baling operations, and the available personnel were shifted where needed. For example, if rain was not an immediate threat to bales in the field, then some or all loading and staging operations were put on hold to ensure that windrow preparation and baling operations had adequate manpower. The opposite was done if rain was threatening. Flailing, possibly raking, and even baling were stopped to maximize the number of bales moved into storage before the rain.

4.3.9 Contingency Plans

The DES operation included two different approaches to contingency planning. One approach was to move operations or to contract with balers in the high plains, western Nebraska, western Kansas, and eastern Colorado, where the humidity is less of a problem. Even when snow falls, it normally melts and evaporates, giving additional late season harvest opportunities. If a spring harvest was necessary in the high plains, lower humidity and slower stalk deterioration offered the best chance of meeting the DES color and quality standards.

The second approach included bringing 27 smaller 3 ft × 3 ft × 8 ft balers into the operation within 150 miles of Sharon, Wisconsin. These balers were ready and could have commenced operation as soon as notified, if weather permitted.

The GLCC contingency plans included a local spring harvest, because color quality was not as important as in the DES harvest. Although far less stover is available in a spring harvest, one could take place if more raw material was needed. The harvest area could be expanded, though transportation costs would increase. Soybean stubble and mature grass hay could also have been harvested before corn stover the following summer and early fall, although furfural potentials would have been lower.

4.3.10 Baler Service and Support

Replacement parts should be available for the equipment at all times. Many times balers broke down during the night or on the weekend. In the GLCC project, some balers were forced to shut down 3 days (over the Thanksgiving holiday) because they had not kept a supply of the more predictable replacement parts on hand. Other baler operators ensured that they had a wide assortment of spare parts readily available, and some operators shared a common and complete replacement part supply. The parts and tools necessary for repairs were kept on a service truck that was readily available in the fieldwork site. Some implement dealers would open at any time in order to accommodate baler operators. The baler operators were given a list of the names and phone numbers of dealerships that were most accommodating.

In the DES project, an extensive parts room was maintained at the plant. A one-day training course was provided to all baler operators. A Heston Baler Technician reviewed the entire baling process with special emphasis given on trouble-shooting and preventative maintenance.

5. STORAGE SITE AND INVENTORY MANAGEMENT

5.1 STORAGE SITE SELECTION

5.1.1 Collection Radius

A large collection radius offers more flexibility in assigning harvest equipment and improves equipment utilization. If fields are wet in one area, another area may be dry and can be harvested. Similarly, if wet weather is threatening in one section, equipment can be assigned to another section. Most importantly, a larger radius better ensures that the desired quantity of material can be obtained.

The collection radius was economically limited to 30 to 50 miles for the GLCC operation, even though some stover was harvested up to 100 miles away. GLCC paid the same price per bale regardless of distance. The farther from the collection point the more the hauler received, which in turn meant less for the producer. Beyond 50 miles, the producer received less than $10/acre for the corn stover. This amount was too small for most producers to commit to a new program.

At the time of procurement, intermediate collection points were arranged with many producers located 20 miles or more from the plant. Their bales could be staged near the entrance to the field for later movement. If the staged bales were moved after the normal planting time, the producer would be paid the current cash rent value of the property involved. The producers' main concerns with temporary storage were losses resulting from bail breakage, shrinkage in storage, and risk of fire and vandalism.

None of these intermediate sites were used. As long as the haulers could get the stover off the fields and delivered to the plant before the spring thaw, there was no point in using off-site collection points and incurring unnecessary costs.

DES took a different approach and leased storage buildings from producers. Stover gathered near these sites incurred additional transportation costs, because nearly half of the stored stover traveled away from the DES processing plant to the storage site, only to retrace some of the same route when returning to the plant.

5.1.2 Infrastructure Requirements

Although all of the desired infrastructure features may not be available at any one site, a storage site should have as many of the following characteristics as possible:

- A well-drained and quick draining graveled site or a large hard surfaced site;
- Away from population centers;
- Located in low traffic area with wide roads and stable shoulders;
- Close to processing plant to minimize handling cost;
- Wet storage bunkers so moisture could be added and stover stored at 50% moisture;
- High corn production area in terms of yields per acre and total acres;
- Conventional corn production, not ridged or furrow irrigated, to facilitate baling;
- Low rainfall area and low humidity; and
- Consistently early fall harvest of corn in the area.

5.2 STORAGE SITE REQUIREMENTS

An off-site collection point requires a well-drained piece of ground with a sod base large enough to place large round bales in single rows. Later this spacing prevents the out-of-shape bales that result from stacking several rows high, and facilitates bale movement. The off-site collection point should be near several fields that will be harvested.

A well-drained, fast draining site is absolutely imperative for bale storage. Without proper drainage, water collecting under or against the stacks will cause deterioration of the lower bales, shrinkage, and will cause the stacks to become unstable. Equipment operation becomes difficult if a site is not well-drained. In the GLCC project, harvest was delayed because of the poor drainage, and problems were encountered when the bales were retrieved for processing.

It is difficult to move round bales after storage and stay within the legal maximum load width, and highway transport should be avoided. Also, the additional handling causes bale breakage, and it is expensive to retrieve broken bales. For these reasons, storage sites in close proximity to the plant are best.

5.2.1 Gravel

DES selected a 10-acre area for composting spent horse bedding that returned from their customers. Part of the site was available for stacking bales. The area drained well and was covered with 6 inches of 1-in crushed limestone. However, some gravel was carried along when bales were moved into the processing plant, causing additional equipment wear.

The 6 in of gravel did not provide a surface solid enough to support the bale handling equipment. The telescopic boom truck would occasionally dig tracks in the surface when the boom was extended to place a bale high on a stack. The uneven surface also caused problems with equipment movement. Frequent maintenance to remove the ruts was helpful. A garden rake was adequate for most situations.

5.2.2 Dirt

A dirt surface is more difficult to maintain and keep free of ruts than a gravel surface, but it is more forgiving because it absorbs shocks better when heavy equipment crosses ruts. Consideration should be given to soil type if bales are stacked on dirt. Some soils drain well, while others do not.

The soil at the Harlan site did not drain well. Severe ruts caused by equipment were an enormous problem. Occasionally, the plant would close to raw material delivery because of the problems with mud. In cold weather, any ruts would freeze solid and impede operations.

5.2.3 Paved Surfaces

GLCC had no exterior paved surfaces. DES had paved entrance roads and parking lots, and all storage was inside on a concrete surface. Smooth paved surfaces are safer and make work easier. Gravel and dirt do not stick to the bottom of the bales. Equipment can be maneuvered regardless of weather, and surfaces can be sloped to enhance drainage.

5.3 ENVIRONMENTAL CONCERNS

5.3.1 Runoff

Runoff from stacks of baled stover is not thought to be a major concern. Uncovered bales tend to absorb rainfall, and to release most of the water through evaporation during drier periods. In the case of covered bales, the water does not travel through the baled stover and no harmful amounts of water-soluble phosphorus, potassium, or nitrates are expected in any water running off of the storage site. However, no tests were made to validate these assumptions.

5.3.2 Department of Natural Resources Regulations

Potential runoff from bale storage yards was not of concern to either the Iowa or Wisconsin Department of Natural Resources (DNR). The bale storage yards were considered agricultural in nature and were not regulated as a point discharge source.

In the DES project, 7000 large square bales rejected because they did not meet quality specifications were taken to an outside storage site adjacent to the composting site for spent horse bedding returned from the customers. These rejected bales were either moldy or discolored. The composting site contained manure, was monitored as a point discharge, and required a permit from the Wisconsin DNR. However, no permit was required for the bale runoff.

5.3.3 Mold Spores

Bales have been stored and used on farms for livestock bedding or left to deteriorate in Iowa cornfields for years. The Omaha GLCC Plant maintained a huge pile of corncobs on the riverfront between the cities of Omaha and Council Bluffs. Neither of these situations raised concerns from adjacent parties.

Mold spores were not originally considered as a potential problem in the GLCC project. However, some residents of the community were concerned. They asked if mold spores could blow from the large bale stacks into the City of Harlan (less than 1 mile to the north) and cause health problems. Discussions with industrial hygienists and toxicologists might be appropriate to address such questions, and a sampling program may be considered.

In the DES project, mold was a major concern because of its relationship to the health of the valuable horses that used the DES product for bedding. Mold, or the conditions allowing its growth, also caused the bedding to become discolored.

5.3.4 Fire and Smoke (Roadways and Population Centers)

Accidental fire is a safety concern for firefighters and others involved. If some of the larger stacks catch on fire, smoke could linger for days. In both projects, the main bale storage was located within city limits. Smoke could reduce visibility for nearby traffic, and could also cause evacuation in the population centers.

Frequent mowing controlled grass and weeds around the bale yard, reducing the chance of fire entering the facility. All smoking on the site was prohibited. Any fires, such as welding, were done with a permit, with full precautions taken to prevent any accidental ignition.

In most cases, it was considered too risky to burn broken bales in the field. An uncontrolled fire in the field could also affect traffic and cause other damage to people, property, and the environment. However, some producers along the Missouri River bottom held little concern for fire and smoke risks. In that area, it is still common to burn stover off entire fields in the fall of the year.

5.3.5 Insects and Rodents

Insects, such as European corn borer, live and overwinter in corn stalks in the Northern Corn Belt. Some of the producers near the GLCC collection point were concerned about whether the large stacks of corn stalk bales might place nearby cornfields at higher risk of infestation. In response to such questions, some of the baled stover was inspected for borers. Only dead borers were found, with the deaths attributed to the heat produced inside the bale during the curing process. No producer in the vicinity of the GLCC plant reported problems with production in the following growing season.

Rodent control practices were in place early at GLCC, to reduce the potential for large rat and mice populations. Rodent problems were minimized by the use of a professional extermination and pest control service and the thorough cleaning up of stover after storage. It was thought that the rodent population would be easier to control in the stover than in ear corn stored in wooden cribs on most producers' farms, because there is little corn in the stover.

5.3.6 Restricting the Area

Both projects overlooked the issue of restricting access to the storage areas. Access should be limited, and fences should be considered around storage areas. Children are attracted to any environment that provides the chance to explore. Serious injury could occur if anyone were to fall off a stack or if a stack collapsed on him or her. Although the incidents of unauthorized people in the storage areas were relatively few at both projects, and no injuries or mishaps occurred, any accident could have been devastating.

5.3.7 Public Perception

A collection site is best located away from major highways and population centers. In Harlan, the GLCC collection stirred much curiosity during the harvest. As the stack of bales grew, so did the public's curiosity. This was a new and unique venture, and most were amazed at the size of the storage area and the large number of bales it contained. Many asked "why?" and "what for?" In this case, earlier communication may have avoided the surprise that initially drew unwanted attention.

By the following summer, the size of the storage area remained relatively unchanged. Progress in processing appeared minimal and bale deterioration was evident. The public concerns grew to include the possibility of mold spores and rodents moving into town. Also, the overall appearance was less appealing as the bales aged and the storage area showed many signs of active work. Overall housekeeping must be kept at a high level, but this is difficult to achieve day-in and day-out under varying weather and operating conditions. Perhaps evidence of more progress in processing would have lessened the negative perception.

5.3.8 Stover and Dust

In the DES project, storage buildings were located very near residences. During any movement of corn stover bales, there is a certain amount of leakage. This constant leakage blowing onto nearby lawns was a source of frustration to residents.

Leakage from loads of corn stover being transported through towns was also a source of public frustration. Wrapping the round bales with netting alleviated some of the leakage problem. Transporting bales wrapped only with string resulted in some bales breaking apart entirely along the roadway—an unacceptable and dangerous situation.

5.4 SCALES AND WEIGHTS

In the DES project, as mentioned, a scale was not routinely used. Stover was purchased by the bale. Although DES had a good idea of what an average bale would weigh, checking weights at a nearby grain elevator often revealed a 25% variation caused by different hybrids, field conditions, and baler operators. The most apparent reason for this was the different baler operators.

5.4.1 Type Consideration

The maximum legal length for tractor-trailer combinations in Iowa is 75 ft. In that situation, an electronic scale with a flat approach and a 75-ft platform is best. Over-the-road tractor-trailers need to use longer trailers (up to 53 ft) or to pull two trailers tandem in order to pull their maximum weight. Using a double-drop-deck trailer is another way to increase area on a trailer for maximum weight, and the low road-to-trailer clearance necessitates a nearly flat approach. A computerized electronic scale is faster than a beam-style scale, and it also provides an integral record of the transactions that can be used for inventory control.

5.4.2 Scale Time and Staffing

Time spent on the scale should not be overlooked. During the average 20-hour day, a JCB unit might deliver 11 loads with a 7.5-minute scale time (3.75 minutes each way—part of this time included the walk to and from the scale house to retrieve the ticket). This 7.5 minutes × 11 loads = 82.5 minutes/day, which can be viewed as about as many dollars in lost revenue. Eliminating the scale wait time at GLCC could have increased gross income about 7% and produced an increase of far greater proportion in net income for the JCB owners.

GLCC found it difficult to keep the scale manned, because loads came in around the clock with up to a half-hour between loads. The absence of manpower lengthened the turnaround time significantly. It was decided that JCB drivers would weigh their own loads, which helped but did not allow average scale times to fall below 7.5 minutes.

Stover can be purchased successfully by the bale as in the DES operation. While this would eliminate scale time, purchasing corn stover by the bale may not be a workable solution for most companies. Understanding of the economic impacts of scale time, and keeping scale time to a minimum, is best for all involved. Locating the sampling operation and a load print out at the scale can also be useful in reducing the turnaround time for drivers.

5.5 METHODS OF STACKING OR PILING

5.5.1 Square Bales

A method of stacking large square bales is shown in Fig. 6. This method is effective when stacking large square bales outside but might not always be practical when storing inside, as discussed in Sect. 5.5.4.

Placing loose stover along the outside edges of the square bale stacks accomplishes two things. First, it helps to make the stack more secure by causing the bales to lean into each. Second, it helps to protect the lower outside perimeter of bales from the deterioration caused by rainwater coming off the tarps covering the stacks.

The lower 18-in space between the outside row of bales and the interior bales helps ensure that the outside bales will continue to lean toward the inside even if interior bales settle and try to lean outward. The single row of bales on the top of the stack creates a slope in the tarp and provides for air movement under the tarp.

5.5.2 Round Bales

In both projects, less time and experience were needed to achieve a stable stack of round bales than of square bales. Round bales stacked in a pyramid shape proved to be very stable (Fig. 7). Because of the overall weight and telescopic tendency of stacked units, a limit of five bales high was set. The round bale stacking equipment would pull in and place the bale when resistance of the bale behind on the preceding stack was felt. The bale was lowered and the stacking unit would retreat. The newly placed bale would then settle into the saddle formed by the opposing curves of the two bales below it.

It required a small additional amount of time to stack each bale as the height of the stack increased. Heavier telescoping equipment could have accomplished the job more easily. When storing bales at remote locations for later transport to the plant, the distorted bales that occur during extended storage in stacks will be more difficult to handle. Single rows of bales are more likely to hold their shape if space between rows is maintained. It would be best if bales were placed on gravel or well-drained soil to minimize deterioration of the bottom of the bale.

5.5.3 Bulk Materials (Silage Model)

Bulk storage was considered, but not used in either project because baling appeared to be the most practical method of harvest. GLCC encouraged consideration of options other than bales, however, and the silage method was thought to warrant exploration. Harvesting in the bulk at a higher moisture, right behind the combine, then grinding and adding additional water at the storage site bringing the average moisture to 50% could have positive effects. Silage has been stored in this manner for decades.

Stover could be packed in a bunker silo using methods similar to the methods used by large cattle feedlots for corn silage and achieve wet weights near 50 lb/cubic foot. Storing as silage might reduce overall storage costs, reduce the risk of spontaneous combustion and other mishaps, require less storage area, and provide easier access and easier control of rodents.

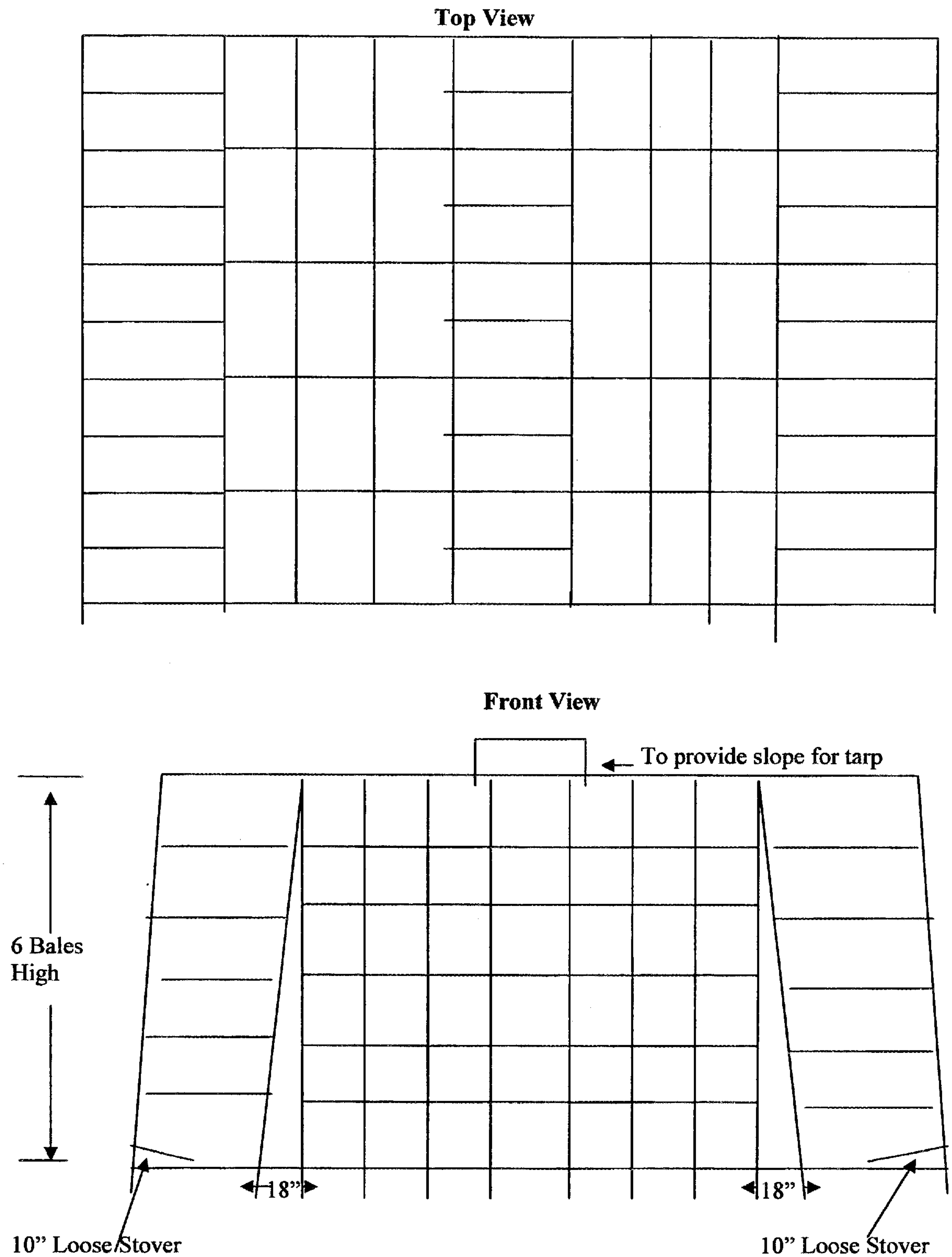


Fig. 6. Recommended square bale stacking plan

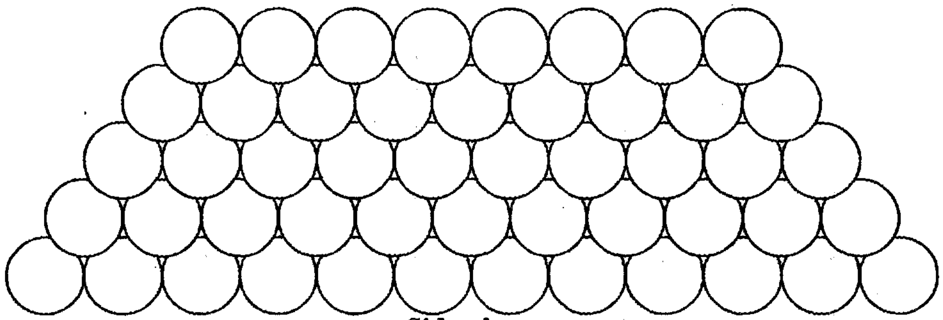


Fig. 7. Recommended round bale stacking plan

5.5.4 Inside Storage

The stacking techniques discussed earlier may not be practical for inside storage. The walls and roof support poles of the storage structures in the DES project were not able to tolerate much pressure from leaning bales. The safest and most secure method of stacking was lengthwise toward the stack with a stair-step method of stacking near the walls (Fig. 8). When bales were stacked or unstacked near the roof support poles, efforts were made to keep the same number of bales on both sides to equalize or support side pressure. Many hollow areas were evident around support poles.

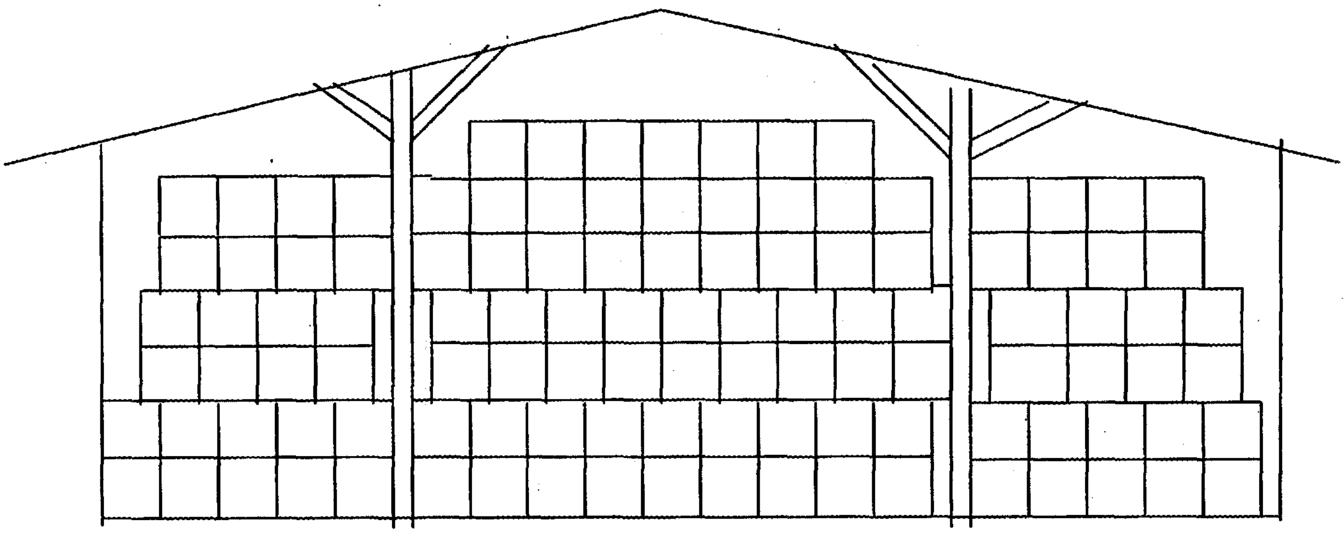


Fig. 8. Inside bale storage

5.5.5 Risk to Employees

Maintaining stack stability is important when stacking, during storage, and when disassembling the stack. Bale movement continues even after a bale has been placed on the stack. Settling first begins at this point and continues until the bales are moved for processing. If bales are soft or improperly stacked, the settling effects cause the stack to lean or move. This movement is gradual and not easily apparent. Workers may get a false sense of security. Once the bales are past the center of balance, the movement is faster and can be seen. But the movement still might not be noticed until a bale is heard hitting the ground. Being taken by surprise by falling bales is a real possibility.

While settling, stacks of square bales, especially low-density bales, can topple over the long way (end over end versus side over side) as well as side ways. Potentially, the most secure stack for square bales is that described in section 5.5.1.

6. TRANSPORT FROM STORAGE TO PROCESSING PLANT

6.1 COST CONTROL

6.1.1 Loading Cycle

Two types of equipment were used: conventional tractor-trailers and a self-loading wagon pulled by a versatile JCB tractor that could operate in the field without difficulty and safely travel at 45 mph on the highway with a full load. The former required a crew to load and unload the cargo, whereas the latter could be loaded and unloaded by the driver.

The loading and unloading of a tractor-trailer with bales can be labor intensive and time consuming. This time should be kept to a minimum, because the charges continue to accumulate regardless. Without effective controls, the cost can spiral up rapidly. In the DES project, two telescopic loaders were used simultaneously to shorten trailer loading times. Both loading and off-loading times were usually satisfactory. Loading in the field often took less than 10 minutes. At the storage site, off-loading times were normally below 7 minutes.

At times bottlenecks occurred. An effort to reduce these costly bottlenecks was in place but was not always effective. Efforts included bringing trucks on duty at different times rather than all at the same time.

In the GLCC project, one man operating an automated bale-picking trailer was often able to load bales in the field in less than 20 minutes, and now with some modifications, loading time became consistently below 15 minutes.

With automated systems, far fewer bottlenecks occurred. One operator consistently working definitely has an advantage over loaders waiting for truckers, truckers waiting to be loaded or waiting to be off-loaded, traffic managers trying to coordinate, and crews gathering bales only to set them back down for loading crews to later pick up and load.

6.1.2 Highway Speed and Overall Efficiency

Trucks were capable of faster speeds on the highway, averaging 52 mph, while the JCB unit averaged around 38 mph. In the GLCC project, a comparison of the travel speed of trucks versus the JCB units was made by IHCF. For a 70-mile round-trip with identical loads, the JCB had a 45-second/mile disadvantage and was 52 minutes longer in transit. However, the ease of loading and unloading JCB tractors resulted in less overall cost, because they averaged considerably better timing in field loading and suffered fewer mishaps in the field.

6.1.3 Load Weight

The total load weight needs to be maximized. However, consideration of other possible constraints (the maximum tons moved per man per day or per piece of equipment per day) is needed.

Field compaction is a concern, and should be kept to a minimum. The load on the soil, in terms of pounds per square inch of tire to soil contact, needs to be considered. Field compaction can reduce the next year's and subsequent crops' yield. A semi-trailer grossing 80,000 lb carries an unacceptable pressure per unit of soil surface. Special tires that spread the weight over more surface area are available. They must be run at a slower highway speed to reduce heat build-up, so the trade-offs need to be evaluated.

The farther the distance traveled with a load, the more important it becomes to carry maximum load weights. Appendix A, "Stover Hauling Consideration and Profitability," contains additional information on this issue.

6.2 REGULATORY ISSUES

6.2.1 License

A Commercial Driver License (CDL) is required in Iowa for drivers of trucks and over-the-road tractor-trailers hauling more than 26,000 lb. Requirements also include that drivers be over 21 years of age, carry a medical card, have travel authority and proof of insurance, and possess a wide load permit.

The numerous DOT regulations at times enforced by an overly zealous law officer make over-the-road trucking a stressful occupation for many of the operators now. Attracting quality drivers to pilot loads of a new and readily obvious load is viewed as especially difficult. For example, if a corn stalk works loose from a bale during transit and extends beyond the legal width or height, the operator is in violation. A court appearance may be required, and a fine in the hundreds of dollars can be expected.

Implements of husbandry involve far fewer regulations. Implements of husbandry are generally defined as all vehicles designed for agricultural purposes and exclusively used by the owner in the conduct of the owner's agricultural operations. There is no logbook to maintain; axle and width limits do not exist. Neither driver's license nor medical card is required. As a result, good drivers are more available and easier to keep when working under the latter requirements.

6.2.2 Insurance

Implements of husbandry can normally be insured under the farm policy umbrella. Insuring a fleet of trucks is much more expensive in comparison. Savings in insurance premiums for IHCF exceeded 25 cents/ton hauled—equivalent to $2.50/trip. This accumulates to $25/day average, easily approaching $1000/vehicle insurance savings over the period of the corn stover harvest.

6.2.3 Speed

Legal traffic speed in Iowa is 55 mph on standard highways and 65 mph on interstates. The legal speed for implements of husbandry, including JCB units, was 30 mph—even though they were fully capable of safely traveling at 80 km/hr, 48 mph with a full load. The Iowa legislature was asked to increase the legal speed for implements of husbandry. The argument was made that travel speeds nearer that of the average traffic flow is safer if implements are properly equipped. In the deliberation, it was determined not all tractors could negotiate this higher speed safely. The legislature, however, did increase the limit by 5 mph, and Iowa law now permits implements of husbandry to travel up to 35 mph legally.

6.2.4 Truck Length

Truck length is important when choosing specialized equipment for moving bales and when contracting with haulers from other areas than Iowa. The legal length of a single vehicle in Iowa is 40 ft. Originally, IHCF planned to use automated bale-picking units similar to that pictured in Fig. 1 but mounted on a truck bed rather than on a trailer as depicted. A single unit has better traction in the field, is easier to operate, and is less expensive to purchase. The reason these units were not used is because their overall length was a few inches over 40 ft.

The truck with the special bed was not in compliance with Iowa DOT laws, and special permits were not available. Even though these units were used in most western states and in Canada, they were not legal in Iowa. This restriction limited GLCC's ability to contract with haulers who already had these truck-mounted units. The units also carried loads higher making it difficult to stay under the legal height limit in Iowa of 13 ft 6 in.

Other restrictions exist in Iowa as well as in other midwestern states. DOT laws need to be examined before purchasing equipment or contracting for hauling with new haulers. Are axles are at least 40 in but not more than 8 ft apart? Axles closer than 40 in apart are restricted to the legal weight of one axle.

These restrictions were not issues when JCB units were used, because JCB-powered units fell under implements of husbandry laws and were exempt from many laws imposed on trucks.

6.2.5 Hours of Operation

In the GLCC project, stover harvesting was planned to take place round the clock—24 hours a day. Hauling a wide load of large round bales, however, had to occur during the day when conventional over-the-road semi-trucks were used. The custom-operated JCB (a farm-type tractor) was also originally restricted. The legislature was again asked to review and make changes that would allow farm tractors to travel at night with wide loads. The changes now allow the stover harvest hauling operations to continue during nighttime hours while using implements of husbandry.

It is important to note that this change in the law only covers farmers and customer operators using implements of husbandry while traveling from the farm to the processing plant. It may not cover situations where movement of stover is from a company-owned or -controlled storage site to the plant.

6.3 PROBLEMS TO CONSIDER

6.3.1 Mud

If the bales are stacked on dry ground during the fall harvest season, the ground under them will be dry when they are moved to the plant even in the spring. The reverse is also true. Some of the bales in the GLCC project were moved one year after being stacked on wet frozen ground. When these bales were moved for processing in the month of July (when the ground is normally firm even if it has recently received rain), the ground was very soft and muddy—unlike nearby ground where there was no stack. Areas that had no stacks were firm even when wet. Why the soil under the bales was so soft is not totally clear.

Moving these bales to the plant was extremely difficult, because equipment became mired in the mud as if following a spring thaw. It is also unclear if gravel under the bales would have solved this soft, early spring-like condition.

6.3.2 Ruts

When stacking or removing bales in the bale yard, ruts caused by equipment movement should be routinely graded level. Water from rain or thawing snow will often fill ruts and make them more difficult to work level later. These ruts can also lead water back to the stacking area. Even small ruts made during a warm winter afternoon can become a problem when they freeze with dropping temperatures at night. These wintertime ruts can be very hard on equipment, and it may be several days or even weeks before the thawing of frozen ground gives another opportunity to repair them.

6.3.3 Snow

Snow did cause problems at times making surfaces slippery, but this was not a major problem. However, plans should be made to deal with the large volumes of snow that can occur. Fire lanes between stacks could fill in after a major snowstorm. Some consideration should be given as to how and what direction the snow will be moved in order to gain access to bales. Most of the snow will blow off the tops of the stacks. This is especially true with square bales.

6.3.4 Bale Distortion

After a large round bale has been in storage with other bales stacked on top, it will tend to change its shape. The severity of this change in shape is determined by bale density, the weight of upper bales, the length of time stored in the stack, moisture content, and the space between stored bales. A dry dense bale placed in a tight stack for a few months will distort far less than a bale carrying high moisture in storage for a year. This distortion can make transport from storage to processing difficult. If there is a need to travel on public roads, these distorted bales will not load or be contained as easily. If travel on public roads is necessary, it might be best not to stack bales but rather to place them in single rows at the storage site.

6.3.5 Breakage

Each time bales are handled, some breakage will occur. This loose material will lose the density that it had in the bale form, making it more costly to load and transport to the processing plant. This is especially true if the bales are transported a long distance.

The longer bales are in storage, the higher the percentage of breakage. The sun gradually breaks down the wrap on large round bales, and rodents gnaw through some of the twine on the square bales. Another problem is how much deterioration has occurred. Grinding at the storage site and pneumatically transferring stover from storage to processing could offer large advantages.

7. EQUIPMENT PERFORMANCE

7.1 RAKES

Raking the field increases the amount collected, but can also add to the cost and increase the amount of foreign materials in the bales. If a windrow is left by the combine, raking is optional. If a rake is mounted on the tractor pulling the baler or in front of the baler itself, the raking and baling operations can be combined.

7.1.1 One-pass Raking and Baling

In the GLCC project, the combine already formed a windrow. These windrows varied in size for several reasons, including combine head size (number of rows), corn hybrids, combine operators, and type of combine.

When gathering more stover was necessary for productivity or desired by the producer, wheel rakes were mounted on the front of balers or on the front of tractors pulling the balers. These rakes normally consisted of a pair of rake wheels on each side of an already existing windrow and collected an additional 20 in of stover on each side of the windrow. A two-wheel rake mounted on a tractor retails for $2200. No additional personnel and a minimum of additional equipment were needed. These rakes also provide easier control of the amount of stover harvested within fields of changing topography. Mounted rakes could be hydraulically raised or lowered depending on the slope in that immediate area, allowing more or less stover to be harvested.

7.1.2 Wheel Rakes (V Formation)

The DES project did not require that the combine leave a windrow, but raking was required. A wheel rake that had an adjustable V was the primary method of forming a windrow. In the GLCC project, operators of large square balers also preferred this type of rake for increasing productivity.

The wheel rake requires an additional man and a power unit, most often a tractor, possibly a pickup. The rakes have seven wheels for gathering stover on each side of the windrow that is formed in the center of the fourteen wheels positioned in a V formation. The maximum working area of the V rake was more than 28 ft, but the rake working area could be reduced according to the size of the desired windrow. Also, the rake height is hydraulically controlled. The list price for a wheel rake is $6500 to $7000.

7.1.3 Dirt and Rocks

Excessive inclusion of dirt and rocks results when rakes are set too low or when root systems are raked into the windrow. The latter occurs when the rake tines pull out the "crown" with the root attached. The crown is the very bottom part of the stalk. When harvesting grain, the combine leaves the lowest, most rigid part of the stalk uncrimped and standing. In especially soft or sandy soils, or when rootworms are present, the tine on the rake wheel hitting the crown can dislodge about a 6-in diameter by 2-in thick root that holds much dirt. The raking process rolls this root with most of the dirt intact into the windrow.

Under some field conditions, excessive dirt is difficult to avoid in harvesting stover. More control can be exercised when a flail chopper is used prior to raking. The chopper cuts the stalk about 4 in above the crown and leaves the crown anchored in the soil. When the stalks are cut off, it is easier for the raking operator to control the height of the rake and avoid pulling out the crown and the roots. The flail, however, can itself place the same root systems in the windrow, if improperly adjusted. The flail's rpm, ground speed, cutting edge, and operating height each have an effect. Excessive dirt within the harvested stover can easily occur. This dirt only adds cost to the baling and causes excessive wear on processing equipment.

7.1.4 Targeted Plant Parts—Leaving the Lower Stalks

Leaving more of the lower stalk in the field can reduce the moisture content of the harvested stover. This is especially true in the earliest part of the harvest season. The stalk dries from the top. A smaller amount of the lower stalk can be harvested by not using the baler-attached flails.

Several crews operating square balers (McLaughlin and Jackson) and round balers (Hines and Shipper) in the GLCC project used this method—raking unflailed fields. The results were anecdotal and warrant more study. An apparent drawback was that small clumps of stover pushed against the corn stalk stumps and resisted the rake, and small bunches of stover remained in the field. Whether this created any problems for producers later, while doubtful, was not confirmed.

7.1.5 Reducing Moisture

Some day hybrids may produce stalks that dry down at the same rate as the grain. However, until then, the flail and rake are the most effective tools for lowering moisture in a corn stover harvest. Flailing the field leaves the smaller stover pieces spread over the entire surface. This better exposes the interior of the stalk to the air and expedites drying. A day or two later, V rakes effectively gather the dried, flailed stover into a large windrow, enabling high baling productivity.

7.2 BALERS

7.2.1 Round Balers

In the GLCC project, John Deere Model 535 and 566 round balers with Model 561 Crop Shredders or Model 669 Crop Processors were mostly used. Balers that did not have the shredder or process attachment made less dense bales. The attachments are an after-market accessory that mounts on the front of the baler and performs as a combination rake, shredder, and flailer. Heartland Manufacturing, Inc., New Vienna, Iowa, manufactures these attachments exclusively for John Deere. The attachments increase the bale density over that of non-chopped stover by 15 to 25%. The denser bale lowers surface wrap cost by $0.50 to $1.00/dry ton and reduces transportation cost significantly.

The power required increases from 80 hp for the baler to 100 hp with the Crop Shredder and 120 hp with the Crop Processor. The shredder operates at around 1400 rpm and is not designed to operate in fields containing excessive foxtail or grass. The Crop Processor operates around 2200 rpm and experienced fewer problems in grassy fields. The Crop Processor and the new version of the Crop Shredder (Model 565) have hydraulic height adjustment for varying the rake/shredder/flailing distance to minimize dirt pick up.

Most round balers used in the GLCC project had surface (mesh) wrapping capabilities. The advantages of mesh over twine are its better ability to shed rainwater in the field, less bale breakage after prolonged storage, and as much as 25% more production capability. The increased production results from less time required for putting on three wraps of mesh on the surface versus twenty plus wraps of twine.

Monitors in many of the balers allowed operators to observe how the bale was forming. Properly formed bales are easier to transport and stack than bell-shaped or other irregularly shaped bales.

Bale diameters between 32 to 72 in could also be set with the monitors. When discharged from the baler, the bale often swelled up to 4 additional inches. This swelling is not as large with alfalfa hay.

The mega-tooth pickup is recommended. It lasts longer than the standard-tooth pickup. Corn stover stumps are hard on pickup teeth, and the bigger, stiffer mega-tooth lasts considerably longer.

High moisture kits for the balers also improve their operation for stover applications. These kits feature roll scrapers, mountings, and anti-wrap spirals to reduce roll wrap and crop build up, a major reason for low productivity when baling corn stover. Other options and after-market products, such as carriers that allow extra or additional rolls of wrap, can increase productivity. Consulting with the local dealers and custom baler operators to benefit from their experience is always a wise activity.

7.2.2 Square Balers

Large, rectangular and square balers were introduced in 1978, but relatively few exist in the Midwest compared with round balers. This is primarily the result of the relatively small share of crops baled and the large capital cost of the balers—retailing near $70,000 compared with under $30,000 for a round baler. Square balers need large acreages to justify this cost. With increased interest in using agricultural crops and residues for fiberboard and other uses, such as biomass processing, large balers are expected to increase in number. Better service and easier access to a service technician can also be expected.

Several brands of large square balers were utilized in the projects. Hesston recommends a minimum of a 135 hp for the application. In the DES project, Case IH 8930 models were used with 180 hp. The Hesston 4900 4 ft × 4 ft baler manufactured by AGCO Corporation, Duluth, Georgia was the primary baler. A few Hesston 4750 3 ft × 3 ft balers and several Freeman 3 ft × 4 ft bales were used along with Hesston and New Holland demonstration models that produce 3 ft × 4 ft bales.

All of these balers are primarily designed and engineered for alfalfa, cereal straw, and grass hay production. Producing quality bales of corn stover or similar crop residues produces problems that exacerbate those that exist in hay and straw baling.

One of the most notorious problems is just keeping the knotters clean. Some operators stopped after every 40 bales to use a gas-powered leaf blower to clean the knotters. Others mounted fans that are supplied as an after-market item by Harold Electric Co. (HECO), Walla Walla, Washington, above the knotters. Hesston offers an air hose attachment to the knotters in an attempt to reduce the problem. None of these devices was completely satisfactory. Fig. 9 shows the knotter cleaning and repair operation.

Fig. 9(a). Knotters after partial cleaning

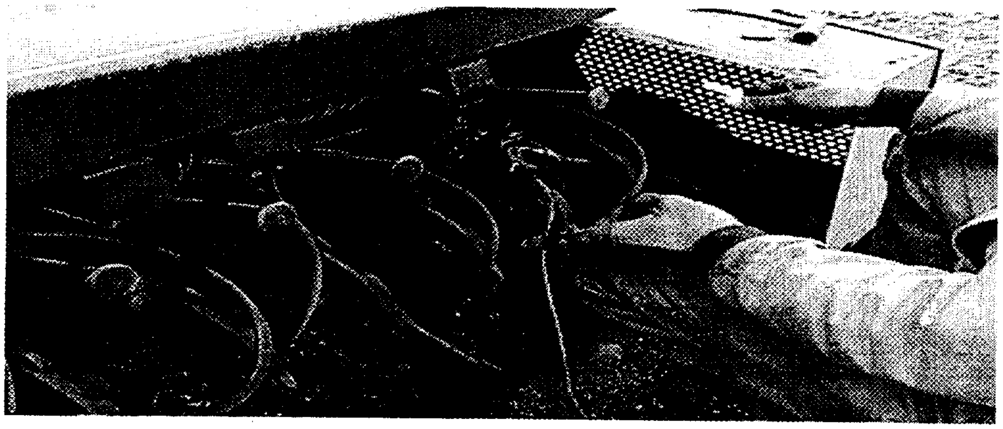


Fig. 9(b). Repairing knotter

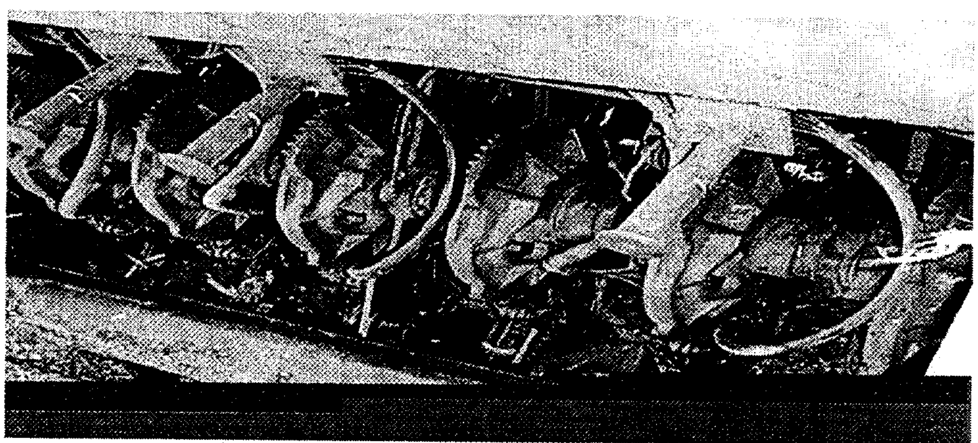


Fig. 9(c). Cleaned and ready for operation

Dirt is a major cause of problems in baling regardless of bale size or shape. Minimizing dirt prevents many problems. Dirt collects in the lower outside corners of the bale chamber, changing bale shape. The best solution is keeping the pickup teeth above the dirt and creating a dirt-free windrow.

The 4 ft × 4 ft bales had inconsistent density. The top third of the bale was less dense than the lower third. Balled corn stover varied more than baled. An attachment offered by the Maise Corporation of Wichita, Kansas [(888) 722-8710] places more fine particles in the top third of the bale to partially offset this variation.

7.2.3 Importance of Size and Weight

Balers are capable of making almost any size bale, round or square. The larger and denser the bale created, the fewer need to be handled for any specific tonnage. Normally, the lowest number of bales to be handled would be synonymous with the lowest cost.

Even though big, heavy bales are normally more cost-effective, local regulation concerning transportation can limit these parameters. Height, length, width, and weight restrictions need to be checked to ensure compliance with transportation regulations.

Example: A trailer with a 54-in. deck height operating under state or local height restrictions of 13 ft 6 in.—as in Iowa—could have bales stacked up to 9 ft high on the deck. If hauling 4 ft × 4 ft × 8 ft bales, 1 ft of potential payload space is not being used. If 3 ft × 4 ft × 8 ft bales were used the full 9 ft of payload space could be used. In a state allowing heights of 14 ft 6 in., 2 ft of payload space can be lost with the 4 ft × 4 ft × 8 ft bales. Knowing the deck height of the trailers intended for use and local and state regulations is necessary in order to utilize the maximum available payload area.

With current balers, a density of approximately 9 dry lb/ft^3 is practical when baling corn stover. Heavier densities can be achieved when baling alfalfa hay.

7.2.4 Effects of Dirt and Moisture

During stover harvest, dirt created baler problems in both projects, especially as moisture content increased. More baler wear caused by dirt should be expected in corn stover harvests than in most haying operations.

For round balers, dirt sticks to the belt and to the belt rollers. This build up can cause the mesh wrap to tear—resulting in a worse problem when the mesh sticks to the mud-coated rollers rather than to the bales. Cutting wrap off of rollers is dangerous and frustrating as well as time consuming. Balers equipped with high moisture kits or silage specials were less troublesome.

In the square balers, moist dirt builds up in the lower outer corners of the bale chamber and, over time, rounds the edges of the bales. Removing this buildup is time consuming. A panel with screen-type perforations is available as an after-market item from Maise Corporation. The panel fits the underside of the charge chambers and filters out some of the dirt, thereby preventing the problem in the bale chamber. Plastic liners for the bale chamber may be another remedy, but they were never installed in this project.

7.2.5 Importance, Consistency, and Density

A dense, consistently formed bale is important to both the transportation and storage operations. Round balers producing bell-shaped or oval-shaped bales should be stopped, pulled from production, and remedied immediately. Irregularly shaped bales are hard to load, troublesome to contain on the load, and difficult to stack properly. They also pose a hazard to people in the stack yard and to the public on the transportation route.

Round balers that utilize crop shredders and processors consistently produce higher quality bales. Large square bales with low-density result in uneven settling that can cause bale stacks to topple over. Monitoring each baler's performance through the harvest season is recommended.

7.2.6 Twine and Net Wraps

Quality plastic twine should be round and have 12 to 14 twists per foot of length. Baler operators should buy newly manufactured twine, watch the use date, look for flat areas and kinks or knots, and store in such a way that rodents cannot gain access. Slight adjustments are often required when changing from one-knot strength or twine manufacturer to another if peak performance is to be maintained.

Only one supplier and knot strength was used for the DES-controlled balers. In the DES project, Donaghys Inc., LTD of Vancouver, British Columbia, Canada, offered a significantly better price and as high a quality as found anywhere. This twine was manufactured in New Zealand and was ordered in amounts that would totally fill large shipping containers in an effort to minimize costs. Thinking ahead allows time for delivery and can result in enormous savings financially as well as saving the time required to adjust balers to accommodate last-minute twine purchases where manufacturers might vary.

Most mesh wrap is produced by only a few manufacturers but marketed through many retailers. Watch for rolls that are not completely round from being smashed by excessive weight during shipping or storage. Also compare lengths, because different retailers order and market different (shorter) lengths in order to gain the perception of lower cost. Lower cost per roll is not necessarily lower cost mesh wrap. Buying wrap with a warning strip that signals operators when it is time for a new roll of wrap will reduce the instances of unwrapped bales released from the baler.

Sunlight and time break down the mesh wrap, and mesh with some UV resistance is desirable. Recently manufactured mesh wrap offers the best potential results. When inserting new rolls of mesh wrap in balers, some operators applied talcum powder to the rollers to reduce the chances of wrap sticking to feed rollers.

Surface wrap for round bales is the fastest wrapping option available. It cuts wrapping time to just a fraction of that of twine; savings of more than 1 minute per bale is normal. When balers are producing 8 to 10 bales/hour, the increased productivity that mesh wrap offers goes a long way toward paying the additional cost of mesh versus twine. The mesh wrap also reduces tramp or loose stover and offers much better rainwater protection than twine wrap.

The twine and mesh wrap were not separated from the stover at GLCC, where the ground wrap and twine were processed with the stover. The plastic and twine were consumed in the process. At DES, plastic twine was not compatible with the horse bedding applications and was removed before processing.

7.3 BALE PICKERS

Bale pickers are available in a wide variety of configurations to meet the needs of different crops and volumes. Costs of industrial bale pickers for relatively high levels of productivity and utilization, such as in Harlan, approach $30,000. Smaller models designed for mostly farm use cost less than $10,000.

7.3.1 For Round Bales

Seventeen different bale pickers were considered by IHCF for use in the GLCC project. All were innovative, and selection was based on the following criteria:

- Automated loading and off-loading,
- Accommodate mesh wrap,
- Carry a minimum payload of 10 ton,
- Strong enough for continuous use, and
- Conform to height and length laws of the Iowa DOT.

Most of these manufacturers offer videos, and many are willing to provide demonstrations. The following is a list of the manufacturers whose equipment was originally considered.

Inland Steel and Forgings, Ltd.
675 Washington Ave.
Winnipeg, MB R2K 1M4
(204) 667-7854
Contact: Henry C. Neufeld

Horst Farm Wagons—sold by:
Westwood Distributors, Ltd.
Contact: Richard Cote
(204) 379-2220

Hay Master
CTS Distributing
Box 47
Ludell, KS 67744
(785) 626-9224

Hecla Industries, LLP
P.O. Box 128
Hecla, SD 57446
(888) 994-9797

Buffalo/Kingsman
Fleischer Manufacturing, Inc.
P.O. Box 848
2281 16th Ave.
Columbus, NE 68602
(402) 564-3244

Wilson Manufacturing, Inc.
312 W. 5th
Cherokee, Oklahoma 73728
(405) 596-3381

Richardton Manufacturing Co.
Box 290
Richardton, ND 58652
(701) 974-3356

Blanchat Manufacturing
P.O. Box 444
Harper, KS 67058
(316) 896-7145

MacDon, Inc.
9700 N.W. Conant Ave.
Kansas City, MO 64153-1832
(816) 891-7313

Stinger Bale Transport
Stinger Ltd.
Haven, KS
(800) 530-5304

881 Series Hay Hiker
Morison Industries Ltd.
Available through distributors

Golden View Fabrication
Box 315
Smoky Lake, Alberta, Canada TOA 3CO
(403) 656-3575

Bale Bandits - (Haulers of straw bales through W. Canada)
Contact: Steve Wince
Alberta, Canada
(403) 843-6502 Evenings

Pronovost
260 Route 159
St. Tite, Quebec, Canada GOX 3HO
(418) 365-7551

Mumby Bale Wagon
Mumby Manufacturing, Ltd.
St. Brieux, Sask., Canada SOK 3VO
(306) 275-4510

Methods that squeezed bales or loading systems that had cleated chains were not suitable for mesh wrap and were excluded. Also excluded were bale pickers that did not conform to Iowa DOT regulations, 40-ft length and 12-ft 6-in. width.

However, as a result of recent changes in the DOT regulations, some bale pickers that were originally rejected should be reconsidered. They are used extensively in the western United States and Canada.

7.3.2 For Square Bales

Six different square bale pickers were considered. The Bale Pro, Stinger, and Haying Mantis approach the bale from the side. They all require crossing the corn rows or ridges, which is not suitable for corn. A bump-and-turn method is also used that does not require crossing the rows. Bumping into one corner of the bale with the bale picker causes it to slide and turn 90 degrees and then meet the picker's loading arm without the unit crossing the rows. Although these pickers are able to work effectively for other applications, the bump-and-turn bale picker may include more dirt in the bale gathered in the sliding or turning process. It was also believed that the number of broken bales would increase slightly.

The Stinger and Mantis are self-contained power units on truck tractors. Both pickers include movement of the bales in front of the truck and over the cab. Additional maintenance results from cleaning stover debris out of the radiator and the truck cab area.

The Freeman, American Eagle, and the Inland 4000 are designed to follow the same path as the baler. The Freeman and the Eagle operate with a self-contained power unit, whereas the Inland 4000 incorporates the use of a farm tractor. Each has their advantages and disadvantages, and decisions on which is best should incorporate the needs of the individual contractor. Iron Horse Custom Farming's decision on purchasing the Inland 4000 was influenced by:

- No need to bump and turn;
- Lower cost when already existing power unit was available;
- Power unit (farm-type JCB tractor) could be more usable for other farm work during the spring planting;

- Positioned bales on their side when stacked, allowing a more stable or predictable stack with twine off the ground; and
- Carried more bales, which allowed direct delivery to the plant.

Some of these units stack the bales with twine on the bottom and top, others stack the bales with the twine on the side. When a baler that produces 3 ft × 4 ft × 8 ft bales is used, stacking so that strings are at the bottom and top might be desirable. Although when stacking 4 ft × 4 ft × 8 ft bales or intermediate bales (basically 3 ft × 3 ft × 8 ft), stacking so that twine is on the side might be preferred.

The main reason for this preference is that the top half of the bale is less dense than the bottom half. When stacked with strings to the top and bottom (as they are when they exit the baler), the bales settle, and in time the bales lean one way or the other unpredictably. When stacked with twine on the side, the direction they might lean is more predictable. The less dense top of the bale (as it exits the baler) will tend to be softer, and the bales will lean in that direction.

Example: If bales are stacked with twine on the side and the top of the bale to the left, then the stack will normally lean to the left. With planning, tiers of bales within a stack can be aligned to lean toward each other and increase stack stability.

Vendors include:

Bale Skoop – Pro Ag Designs, Inc.
1700 Amsterdam Rd.
Belgrade, MT 59714
(406) 388-7799

Inland Steel and Forgings, LLC
675 Washington Ave.
Winnipeg, MB R2K 1M4
(204) 667-7854

Stinger Bale Transport
Stinger Ltd.
8905 Industrial Drive
Haven, KS 67543
(541) 567-2992

American Eagle, Circle C Equipment
333 E. Feedville Rd.
Hermiston, OR 97838
(800) 530-5304

Haying Mantis
Justice Enterprises, Inc.
P.O. Box 563
Sterling, CO 80751
(970) 521-9567

J. A. Freeman & Son Inc.
2034 NW 27th AV
Portland, OR 97210
(503) 222-1971

7.3.3 Auto Off-load

All of the automated bale pickers were able to automatically off-load themselves. Methods involved tipping or dropping off, cleated chains on which the bales traveled, hoist or push off systems, and, in the case of square bales, hoist and stack methods. The cleated chain method rips the mesh wrap. Burrs on the rails on which the bales slide can also cause problems, but these problems were easily remedied in the push off methods. When bales were delivered directly to the plant or collection point, the ability to automatically off-load was a big advantage. These automated pickers did not have to wait in line to be off-loaded by GLCC, but they could simply pull near where stacking was taking place, off-load, and be on their way.

7.3.4 Squeezes and Spears

For placing bales on a carrier's deck, squeezing bales is the method preferred by most of the manufacturers of automated square bale pickers. Pickers that applied the pressure of the squeeze to the side of the bale rather than to the twine side were preferred. Pressure on the twine can increase twine breaks. Missing twine increases the amount of future breakage.

Some automated square bale picker manufacturers used spears or claws, which probe into the bale. This method also causes twine breaks and alters the bale shape, because these claws often remove some corn stover when they are retracted from the bale.

Manufacturers of round bale pickers prefer a system of loading bales onto the carrier deck that uses lift arms hinged to the carrier deck. These lift arms enter under the wide area of the round bale and then lift upward while cradling the wider area of the bale until bale rolls onto the carrier deck. Differing lift arm configurations exist among manufacturers, and all are effective even though some may be better than others.

7.3.5 Compaction Concerns

The larger the load, the more producers were concerned with compaction. Heavy wheeled loads are believed to be the cause of most deep soil compaction. The volume of soil compacted by a wheel pass varies with soil type, soil moisture, tire size, pressure, and total load size. Therefore, concerns can be reduced if the tire area in contact with the soil is increased in the same proportion that the load weight is increased.

Suggestions:

- Consider soil type and compaction issues and discuss them at the time of stover procurement.
- The pounds of pressure per square inch of tire in contact with the soil should be similar to or less than the pressure of the producer's combine and grain wagons. Add more axles and tires, or increase tire size if wheel pressure exceeds that of the equipment of most area producers.
- Complete bale removal from fields before spring thaw.
- Stay out of wet fields or at least receive permission from the producer, if fields are in question and work needs to be completed.

7.4 TRANSPORTS

7.4.1 Automatic Containment

Automated bale-picking and off-loading trailers were used in the GLCC project. Fig. 1 shows the side rail on the trailers up along the side of the bales, approximately 24 inches higher than the lower portion of the bales. The top row of bales is similarly contained by the opposing curves of the two bales below. A hydraulically controlled tailgate comes up 18 inches on the back of the load and keeps bales from sliding off the back of the trailer.

A safety indicator light inside the power unit cab shows if the tailgate is not in its full upright position. This bale containment system was time efficient and reliable. Automated trailers hauled approximately 90% of the bales, whereas conventional semi-trailers hauled the other 10%, utilizing 4-in-wide nylon straps for containment. Mishaps occurred with both methods.

- Two incidents occurred with the automated containment systems when the tailgate was not in the full upright position because of a failed cable connection or broken cable and the failure of the driver to respond to or notice the warning light.
- Ten incidents occurred with the conventional containment systems using straps. The most frequent cause was loose straps resulting from bales settling as they jogged along the road.

The savings in time offered by automated containment should be recognized as a major advantage and should be improved upon. With these improvements automated containment should become the primary method. Laws and legal definitions for containment may need to be reexamined.

7.4.2 Methods of Strapping or Tying Down

Two different methods of strapping or securing bales prior to movement were used. The most common method for strapping from side to side is illustrated in Fig. 10.

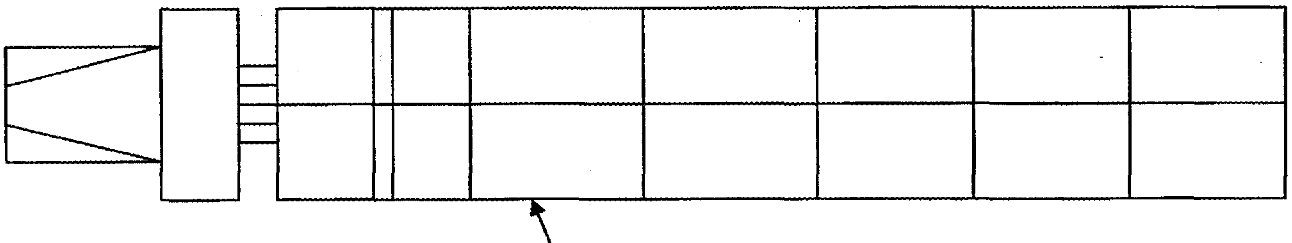


Fig. 10. The 4-in-wide nylon straps over the center of each group of four bales

The second method (Fig. 11) is less commonly used but is believed less time consuming to apply, although no actual comparison was made.

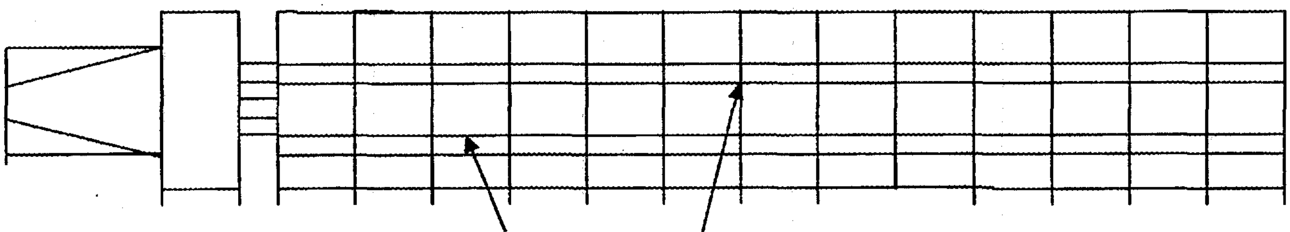


Fig. 11. Two 4-in-wide nylon straps lengthwise over the entire trailer

Four-in-wide straps are preferred to 2.5-in-wide straps.

7.4.3 Regulations

In Iowa, drivers hauling more than 26,000 pounds must have a CDL (Commercial Driver's License). Special endorsements or restrictions to a CDL are required for double/triple trailers or for units that are equipped with air brakes.

Transport units that haul for hire, which includes most stover haulers using semi-trailer combinations, need travel authority. Owners of trucks and semi-trailers hauling for hire or compensated in any way also are required to carry insurance for public liability and cargo insurance [$100,000/$300,000/$10,000 (injury per person/injury per accident/property damage)].

The maximum dimensions and weights allowed on Iowa highways are:

Length: 40 ft — single vehicle
53 ft — maximum semi-trailer (loaded or empty)
28 ft 6 in — maximum semi-trailer used in a double bottom combination
65 ft — combinations of a power unit and trailer
75 ft — Stinger Steer maximum length (similar to a car carrier)
Width: 8 ft 6 in
Height: 13 ft 6 in
Gross weight: 80,000 lb

Weight must be properly distributed over the axles. For a maximum load with a single axle, the limit is 20,000 lb; for a tandem axle, 34,000 lb. Special annual permits from the state are available and cost $25 for loads exceeding widths of 8 ft 6 in of up to 12 ft 5 in, for lengths exceeding length limits of up to 75 ft, and for heights exceeding height limits of up to 14 ft. Some county and city permits must be obtained separately. Crossing into another state may require fuel permits and quarterly reports. Wide loads may not be allowed on certain days of the week.

Safety regulations also include a maximum drive time of 10 hours on and 8 hours off (a maximum of 60 hours/week), on-duty time limits, and an annual unit inspection. Drivers must be 21 years old and carry a doctor's certification that they are physically qualified to drive. Most states have similar complicated regulations covering trucks, semi-trailers, and their drivers. Those operating implements of husbandry (farm-type tractors pulling trailers, which include JCB's and Unimogs) are exempt from most of these regulations and not subject to their fee.

7.4.4 Field Entrances

Currently many field entrances are not wide enough, are too steep, or for some other reason do not allow easy and safe entrance to the field. This is especially true for the longer transportation equipment necessary in a stover harvest. It is reasonable to believe that producers will improve these entrances with very little expense incurred, if they are motivated by the economic incentive of the stover harvest.

7.4.5 Flatbed (Drops and Double Drops)

Drop-deck trailers can increase the payload area, but they can also create problems entering and exiting the fields because of their lower ground clearance. Double drops are excellent units for maximizing payload but often offer as little as 10 inches of ground clearance (Fig. 5).

7.4.6 Producers

In the Midwest, producers' equipment for moving round bales is designed for on-farm use and does not include options that improve road safety, such as extended mirrors, lights, and proper containment. Most is designed to haul 4 to 8 large round bales. Although there are more roadworthy units available with a larger load capacity, most producers have no need for them. In the case of large square bales, most producers do not possess efficient handling and loading systems, but flat-deck semi-trailers and trucks are not unusual.

7.4.7 Semi-tractor Off Road

The harvest season for corn stover in the northern corn belt means short days in terms of sunlight. Damp, muddy field conditions normally exist. Operations of semi-tractors in the field are hampered by these conditions. This equipment should be equipped with additional or wider tires that apply fewer pounds of weight per square inch of soil surface to avoid soil compaction. Bales should be staged near the road to keep field travel to a minimum. The operator should be prepared to occasionally assist other units back on to the road with a farm tractor and tow chain, better enabling them to remain a viable option.

7.4.8 Conventional Farm-type Tractor

Tractors provide the chief source of power on most farms. They are differentiated from over-the-road semi-tractors by their ability to provide power for other farm machines. These features include a drawbar, a hydraulic system, and a power take-off. In the United States, farm-type tractors normally are designed for traveling between 17 to 24 mph. They typically travel on large lugged tires. The legal definition of a farm tractor does not limit their speed. However, state Implements of Husbandry laws may restrict their speed on the road.

Faster traveling farm-type tractors are emerging that can operate safely at speeds up to 50 mph. Implements of Husbandry regulations in Iowa were recently revised and now allow 35 mph, 5 mph faster speed than was previously allowed.

7.4.9 Farm-type Tractors with High Road Speed Capabilities

In the GLCC project, it was decided that considerable savings in the cost of transporting corn stover was potentially available through the use of the much faster European style tractors: the JCB Fastrac 185 manufactured in the United Kingdom and the Unimogs manufactured by Mercedes-Benz in Germany.

The JCBs offer air over hydraulic brakes that give excellent braking ability, similar to that of an over-the-road truck. A combination air over hydraulic and coil spring suspension provide a smooth ride even when crossing rows in the field. These features reduce driver fatigue and provide a safer working environment. Better control, shorter turning radius, and additional traction of the gooseneck trailer are especially helpful when entering narrow field entrances. The JCB is able to safely travel at speeds over 40 mph.

The Unimog is capable of a more than 50-mph road speed. The Unimog sits lower and has less visibility. Unimogs are more expensive than similarly powered JCB units. Both are better able to increase the productivity of harvest crews and reduce the cost of transportation and handling compared to conventional tractors. They also offer improved traction in the cornfield compared with over-the-road trucks.

7.4.10 Safety, Breaking, and Traffic Flow

When transport units move from the field onto the road, their wheels often will deposit a certain amount of mud. This mud can become a safety issue, and scraping off or some amount of clean up may be necessary.

The power unit pulling a load should be heavy enough to stop the load when the brakes are applied, or brakes should also be added to the trailer wheels. Currently, many farm trailers, which some producers might use, are not equipped with trailer brakes, and their safety should be examined.

Tractors capable of the higher speeds used in the GLCC project were equipped with air over hydraulic brakes along with electric trailer brakes. (Note: Air brakes on trailers might be an improvement.) These JCB-Inland units were also equipped with trailer lights, extended mirrors, mud flaps, and reflectors. Traveling nearer the speed of normal traffic reduces the overall time spent on the road in traffic. The use of faster traveling tractors also reduces the amount and frequency of traffic backing up behind these transports as it backs up behind slower moving farm tractors.

7.5 STACKING AND STAGING EQUIPMENT

7.5.1 Forks and Platinums

Picking bales up in the field and loading them onto trucks with a forklift equipped with forks or platinums is not recommended. Large chunks of dirt are pressed into the bottom of most bales (Fig. 12). Investigation showed that the dirt was caused by the angle of the platinum when it picked up the bales in the field for loading onto trucks.

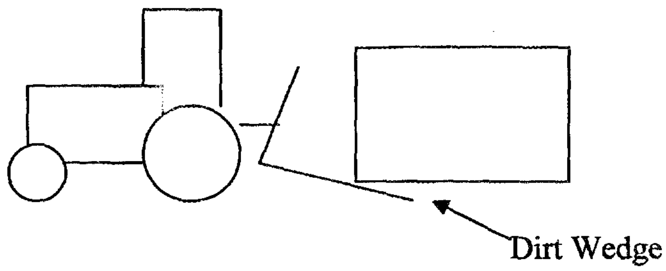


Fig. 12. The angle of the platinum results in inclusion of dirt

7.5.2 Squeeze Arms and Spears

For loading and stacking with a squeeze attachment, one arm movement is best, preferably to the driver's right side of the squeeze when moving from the closed to the open position. A squeeze attachment on telescopic handlers was preferred over spears or forks when handling square bales in the DES project. Squeeze systems tended to rupture the mesh wrap on the round mesh-wrapped bales.

The squeeze attachment was under-designed for this application. Broken welds occurred after handling a few hundred bales. The manufacturer offered to repair them under their warranty if returned to the factory, but needed several weeks for the repair to take place. This was unacceptable, because the harvest was already under way when the problem was discovered. The squeeze attachment was strengthened in this area by DES personnel at DES's expense. The manufacturer voided any further warranty. This DES repaired version lasted considerably longer, but welds and metal fatigue still required too frequent repair. It was decided that a revised hydraulic pressure regulator with pressure relief valve was most likely required to correct the problem. This revision should reduce the frequency of repair.

Spears were preferred in the GLCC project, because most bales were large round and mesh wrapped. Many different types of spears exist. A forged tapered spear was preferred over the pointed-shaft type. This tapered spear saved labor and improved the integrity of the stacks. Resistance to the non-tapered, pointed shaft was a problem especially in the higher density bales. This resistance occasionally made it difficult for the spear to enter and exit the bales. The wiggling required to remove the spear often caused the bale's placement to become somewhat precarious within the stack. The forged tapered spear offered insertion and removal of the spear with little resistance. The forged steel spear resisted bending unlike the shaft-type spears.

7.5.3 Telebooms

Telebooms, also known as telescopic handlers and load-alls, combine the attributes of forklifts and wheel loaders. These units are highly functional for loading bales on trailers at the field site or stacking them at the yard. The smaller-lift-capacity units normally offer the best maneuverability. The heavier units provide more stability and safety when equipment is most extended to place a bale toward the top of the stack.

When choosing the best unit for the job, stack height and cab visibility are major considerations. Lift capacity is dependent on extended height. With an experienced operator in the proper unit, two to four large bales can be handled per minute. Near the ground, the time is a bit less; higher than 40 feet, the time will be greater. As described in Sect. 7.5.2, DES used squeeze attachments and GLCC used spears. Teleboom units are available through most agricultural implement or construction equipment dealers.

7.5.4 Road Runners

A Road Runner is a type of forklift that can work in field conditions and move down the road at high speeds. It can utilize a squeeze system rather than forks exclusively. Road Runners can improve loading operations from one field to another. Road Runners, as they are called in the northwest part of the country, are common in the straw and hay harvest. They are also used at the plant sites for off-loading, etc., at companies like Anderson Hay of Ellensburg, Washington; Aurora, Oregon; and Brawley, California.

These units are themselves heavy and are capable of moving several bales at once. These units were not used in either the DES or GLCC projects but deserve consideration in the future. Some testing to better evaluate their operability in the cornfields of the Midwest is suggested. Wetter, softer fields might cause excess compaction or could cause problematic operations. A few different companies manufacture versions of the Road Runner. However, one of the primary manufacturers is the Road Runner Company of Manteca, California [(209)-823-5261].

7.6 FUELING AND SERVICE EQUIPMENT

7.6.1 Safety and Regulations

In the DES project, diesel fuel was transported to the field operations using tow tanks with an approximately 500-gallon capacity each. Some tanks had a series of baffles within the tank that kept fuel in a partially filled tank from rushing forward inside the tank when the truck stopped at an intersection. The tanks without baffles caused the pickup truck pulling the tank to jerk back and forth with the fuel movement inside the tank. The fuel movement was minimal when the tank was completely full or empty. Baffled tanks were considered safer and could be pulled at faster speeds.

Regulations restricted the movement of fuel in these tow tanks to diesel and did not allow gasoline to be moved in this manner.

Maintaining a supply of fuel is essential, because operations continue around the clock, on holidays and weekends. Bulk delivery trucks are extremely busy during the harvest season. Often they cannot be scheduled for a specific time or location. Even when a harvest company has its own fuel delivery truck, it is difficult to coordinate deliveries. Harvest equipment is continually moving from one field to the next. Exact delivery times are not possible to predict.

7.6.2 Diesel Versus Gasoline

Power units that use diesel are preferred, especially on hauling units and those working in the bale yard. Even though exhaust from diesel engines can produce sparks; they do so far less frequently than the exhaust from a gasoline engine. The use of exhaust system spark resistors or inhibitors further reduces the risk of sparks from the exhaust.

Regulations on the transport of fuel to field operations vary from state to state and are constantly changing. Potential liability could be devastating to any company if the laws are not followed. Complete understanding of and compliance with the current regulations are essential.

Fire codes also regulate the amount of gasoline storage that is allowed, and these regulations are more stringent than those for diesel storage.

7.6.3 Contracting

At the onset of the DES project, fuel prices were at or below a 20-year historical low. Management believed that protecting the cost of the harvest by locking a firm fuel price for the entire season was in order. Three options were considered.

- Hedging fuel position — using home heating oil required approximately $2,500 up front.
- Contracting with Downing Fuel Delivery Service Company.
- Contracting with the fuel terminal for direct delivery (which meant having to accept delivery in semi-transport-load amounts).

Contracting with Downing was the final choice. A 4-cent per gallon premium was paid to Downing. For the service, DES received free usage of six tow tanks, a total maximum capacity of 3000 gallons not considering tractor and equipment tank capacities. A 24-hour notice was required by Downing, and all tanks were to be filled at one location near the DES plant.

This contract saved renting or purchasing tow tanks for the field operations as well as eliminated the need for advance payments, margin calls, or up-front money. Downing presented a bill after filling tanks and allowed 30 days for payment. The price on 42,000 gallons was set during the summer prior to harvest at 64 cents/gallon for off-road diesel.

8. SUMMARY AND CONCLUSIONS

8.1 COMMUNICATION

Establishing a successful corn stover harvest operation requires wide communication and much advance planning. All growers are potential suppliers. Properly identifying those to closely communicate and work with helps lay the foundation for recruitment of producers to supply adequate material for harvest.

Open communication is the best tool for overcoming concerns and opposition: using the media, public meetings, and individual meetings with key people to reach as many people as possible. The benefits to be derived from removing excess stover are substantial. Providing facts related to sustainable harvest in many forms—in simple terms to communicate to the average person and in economic and technical terms for those requesting a more comprehensive understanding—helps recalibrate traditional value judgments. While public meetings are necessary, one-on-one meetings to address the individual's concerns are the most important. Gaining an understanding of the reasons for the other perspectives is essential for effective discussion.

8.2 PLANNING

Planning every detail of the harvest ensures proper preparation. No one likes to be surprised. Because this was the first harvest, more time and attention was required. Allowing for adequate time in advance of the harvest to meet with the producers at their sites, map locations, and document directions and instructions results in an organized harvest and better ensures happy customers with no complaints.

8.3 SELECTION OF CUSTOM OPERATORS

Selection of skilled contract harvesters with the right equipment for the first stover harvest builds another platform for success. Additional time is needed in the initial year to match contract harvesters with producers, adapt their methods and equipment to a different harvest, and follow their performance, managing by exception, and rapidly correcting any problem.

8.4 COORDINATION OF HARVEST

Coordinating the harvest operation with the producer and custom operators is key to keeping the baling equipment fully utilized and the producer satisfied. Prompt clean up of broken bales is required. Anticipating problems and prompt response to new conditions and incidents all require coordinating activities at a high level of performance.

8.5 HARVEST EQUIPMENT

For the actual harvest, the most proven, lowest cost collection method for corn stover processed to chemicals, fuels, and other fermentation products is baling the windrow with a round baler that has a height-adjustable flailing attachment. Adding a wheel rake in front of the tractor can increase the harvest, if desired. Surface wrapping the bales with three layers of a UV-resistant plastic mesh minimizes breaks as the bales are collected, transported, unloaded, staked, and retrieved for processing.

Large square balers may be adapted to equal the round baler's cost performance with more experience, especially when harvesting large, relatively regularly shaped fields as in Central Illinois. The cost of the separate flailing and raking operation may be offset by greater baling productivity.

Load-and-go wagons pulled by high-speed tractors that permit one operator to load the bales in the field, safely travel to the storage site at normal road speeds, and self-unload offer the lowest cost within a 50-mile collection radius. For greater distances, square bales on flatbed trailers usually offer an advantage.

Outside storage of surface-wrapped round bales is less likely to offer stack problems than storing square bales under tarpaulins or other types of wrap. The inherent variation in square bale density may result in stack shifting and tearing the wrap with resultant bale spoilage. In any event, both round and square bales should be stored on a raised, easily drained surface to avoid excessive loss of the bottom bales.

Purchasing the bales on a dry basis offers more control than on an "as is" basis. Incoming shipments are best weighed, sampled, analyzed for moisture, and possibly coded for inventory control.

8.6 OUTLOOK

In following years, the contract harvester and producer should generally work directly without the need for additional coordination. As experience is gained, it is expected that more producers will favorably consider including harvest, collection, and transportation roles within their farmgate operation. The degree this occurs is likely to depend on confidence in an ongoing market for the harvested material and the margins that can be expected.

Transportation regulations are expected to evolve, better allowing inter-state and cross-border—Canada/United States—equipment operation consistency.

Creating the infrastructure for corn stover processing reduces economic barriers for the collection of other residues and dedicated energy crops. Timing of harvest varies, and improved equipment utilization results. Other feedstocks increase the comfort of the potential processor, reducing the risk of a one-crop disruption.

Agricultural machinery and equipment suppliers can anticipate a large market for corn stover collection. While there are many underutilized balers, the opportunity for expanding sales is expected to drive innovations that will better serve this market. Present possibilities are expected to reduce the baling cost 20%, to less than $30/dry ton without reducing the growers' and custom operators' margins.

APPENDIX A

STOVER HAULING CONSIDERATIONS 1998 GLCC PROGRAM AND PROFITABILITY

APPENDIX A: STOVER HAULING CONSIDERATIONS AND PROFITABILITY 1998 GLCC PROGRAM

This appendix provides an explanation and example calculations of the economics for hauling corn stover.

Short-haul trucking companies generally believe that more than $350 per day, five days a week, 260 days a year of revenue is needed just to stay in business. This is not a perfect rule; because it depends on variable costs, which are affected by fuel usage, tire wear, and differing risks of breakdown or other mishaps, such as getting stuck. Always operating on hard-surface roads minimizes breakdowns and mishaps, but this type of haul normally is very competitive. When hauling stover from farmers' fields, mud and narrow field entrances increase the risk of mishaps.

For all types of hauling, strategies to increase profits need to be considered. For example, running more hours can increase profits, because fixed costs remain fairly constant whether the truck runs 4 hours or 24 hours per day. Using longer trailers to carry more tonnage is another possibility: 53 ft trailers or 30 ft flatbed trucks with a 28 ft pup has the longest load carrying area (58 ft) and the most flexibility when turning into field entrances. The 3 ft × 4 ft bales can be stacked 3 high on a 54-in high flat trailer and the total height still only be 13 ft 6 in.

Dollars per loaded mile is another common method of determining whether a load will be profitable. In the Midwest, $2.00 per loaded mile is acceptable for a normal haul–$1.85 for longer distances and $2.40 for shorter hauls. If back hauls are available, lower prices can be profitable.

Table A-1 includes estimated dollars generated per hour. The truck sitting still while being loaded or off-loaded still needs to generate revenue to cover fixed costs. One strategy to help reduce the dollars needed while the truck is sitting is to have the driver operate the equipment that transfers the corn stover. An example calculation follows:

$1.70 per ton × 16.8 ton on a load = $28.56 in 40 minutes or $42.84 per hour savings. The cost of the loading equipment is $13.00 per operating hour, if enough hours were put on per month. As an example, a rental charge is $2,000 per month for up to 160 operating hours. If it were used to load 6 loads per day, 6 days a week, for 4 weeks at one-half hour on tachometer per load, it would equal 72 hours on the tachometer at a cost of $27.78 per hour. If the equipment were used for the full 160 hours, it would cost $12.50 per tachometer hour (some repair costs may also be necessary, such as tires). This again demonstrates the advantages of shift hauling to the efficiency of the total operation.

- Pay per dry ton: these numbers include staging at $3.25 and loading at $1.70 per dry ton.
- Semi hauling: the $3.25 per ton for staging and $1.70 per ton for reloading have been subtracted, so that hauling and the different ways of looking at it could be more accurately reflected. As an average, 16.8 ton per load is used.
- Estimated loads per hour: this column is based on figures from 1997 deliveries of intermediate square bales (3 ft × 3 ft) with travel speeds averaging 50 mph. The 1998 loads per hour have the potential of being significantly increased.
- Range of $ per hour and $ per loaded mile: calculated using the high mile and low mile in that bracket of loaded mile.

- Average $ per loaded mile: calculated by using the average miles in the bracket.
- Estimated per 10-hour day: calculated by using estimated loads per hour times semi-hauling load of 16.8 tons of dry matter times 10 hours.

Table A-1. 1998 hauling calculations – semi-tractor trailers

Loaded miles	Pay per dry ton* ($)	Semi hauling 16.8 ton* ($)	Est. loads per hour*	Range of $ per hour*	Range of $ per loaded mile*	Avg $ per loaded mile*	Est. $ per 10-hr. day*
1 – 5	5.60	10.92	0.73-0.65	7.97-7.10	10.25-2.18	6.55	75.35
6 – 10	6.60	27.72	0.64-0.58	17.78-16.11	4.63-2.78	3.70	169.45
11 – 15	7.85	48.72	0.56-0.52	27.78-25.33	4.43-3.25	3.84	219.45
16 – 20	9.60	78.12	0.50-0.47	39.06-36.72	4.88-3.90	4.39	378.50
21 – 30	12.10	120.12	0.46-0.39	55.26-46.85	5.72-4.00	4.86	510.50
31 – 40	13.10	136.92	0.39-0.34	53.40-46.55	4.42-3.42	3.92	499.75
41 – 50	14.10	153.72	0.34-0.30	52.26-46.12	3.75-3.07	3.41	491.90
51 – 60	15.10	170.52	0.30-0.27	51.16-46.04	3.34-2.84	3.09	486.00
61 – 70	15.60	178.92	0.27-0.24	48.32-42.95	2.93-2.56	2.74	456.35
71 – 90	16.10	187.32	0.24-0.20	44.96-37.46	2.64-2.08	2.36	412.10
91 – 125	17.10	204.12	0.20-0.16	40.82-32.66	2.24-1.63	1.94	367.40

*See definitions in the bulleted list on pp. 73–74.

Since the 125-mile radius haulers travel is broken into 11 brackets, there will be a difference of pay-per-mile within each bracket. These different brackets also affect loads per hour. A 40-minute load time and 40-minute off-load time (total load and off-load time = 80 minutes) for intermediate bales was used in the calculations. An average road speed of 50 mph was used. Load and off load times will be greatly improved with 4 ft × 4 ft bales verses the 3 ft × 3 ft bales, perhaps as much as 30%, which means considerably more loads per day.

As Tables A-1 and A-2 indicate, hauling with semis is not economical within the first 20 miles. For example, within that distance, a JCB (i.e., a fast traveling farm-type tractor) pulling a unit capable of picking up the bales as they were randomly placed in the field by the baler would receive the $3.25 per dry ton otherwise reserved for the stager.

When the bales are hauled in directly to the plant, there is no reloading charge. A self-picker can receive the entire pay per dry ton. However, to avoid excess compacting, these units are only able to haul about 60% of the normal payload of a semi or truck and pup. Most often they will need more traction than an over-the-road truck offers. This type of unit needs to generate $50 to $60 per hour to enable a reasonable profit for drivers and equipment owners and can be economical up to 40 miles. Table A-2 below gives an idea of how JCB hauling with self-pickers might pay based on the 1997 corn stover harvest. Strategies for increasing profits with JCB and self-pickers would include equipment mounted on the front of the JCB with the ability to carry an additional bale or breakage and the ability to operate 24 hours a day.

Table A-2. 1998 hauling calculations – JCB tractors with self picker

Loaded miles	Pay per dry ton* ($)	JCB hauling 10.2 ton total revenue* ($)	Estimated loads per hour*	Estimated $ per hour*	Estimated $ per 10-hr. day*
1 – 5	5.60	57.12	1.7	97.10	971.04
6 – 10	6.60	67.32	1.07	72.03	720.32
11 – 15	7.85	80.07	0.79	63.26	632.55
16 – 20	9.60	97.92	0.62	60.71	607.10
21 – 30	12.10	123.42	0.48	59.24	592.42
31 – 40	13.10	133.62	0.36	48.10	481.03
41 – 50	14.10	143.82	0.295	42.43	424.27
51 – 60	15.10	154.02	0.245	37.73	377.35
61 – 70	15.60	159.12	0.21	33.42	334.15
71 – 90	16.10	164.22	0.175	28.74	287.39
91 – 125	17.10	174.42	0.13	22.67	226.75

*See definitions in the bulleted list on pp. 73–74.

APPENDIX B

SAMPLE AGREEMENTS

APPENDIX B1

SAMPLE WORKSHEET FOR THE POTENTIAL STOVER HARVESTER

VALUE OF AVERAGE CORN CROP

Average Yields for Shelby County over the past five years:

Year	Avg. bu/acre	
1992	144.8	Considering high quality land vs. average,
1993	85.0	we added 15% to the average.
1994	148.4	
1995	113.8	
1996	135.1	Yield 144.2 Bu/acre
5-yr avg.	125.4	

Selling Price based on Iowa Farm Business Association Data collected as of March 21, 1997, for Southwest Iowa.

Year	Avg. Selling Price $/bu
1992	$2.11
1993	$2.02
1994	$2.22
1995	$2.38
1996	$3.30
5-yr avg.	$2.41

Value of corn crop: (144.2 bu/acre) ($2.41/bu) = $347.52

Cost of a Corn Crop

Cost Item	Published Number $/acre	Estimate Your Farm $/acre
Land value	$126.00	________
Equipment, fuel, labor	$ 74.25	________
Seed, chemicals, etc.	$123.08	________
Total	$323.33	________

Note: This figure does not include cost for drying, storage, or shipping.

Land Value: Whether you own land or not, it is a cost. It could be rented for the above amount. We used the rental rates for high-quality land. The range was from $110 to $145/acre as shown in Iowa State University (ISU) 1996 Cropland Survey for Shelby County (Extension Publication FM1851).

Equipment, Fuel and Labor: Custom farm rates were used as shown in 1997 Iowa Farm Custom Rate Survey (Extension Publication FM1698). Rates varied from $51 to $100 depending on field shape, size and topography.

Seed, Chemicals, Etc.: The cost for corn following soybeans was used. It was felt that producers following with soybeans would more likely benefit from stover removal. The figure is based on 1997 issue of the ISU Estimated Cost of Crop Production and Iowa Farm Business Association Record Summaries (Extension Publication FM1712).

Seed 26,000K	$ 25.48	________
Nitrogen at $0.22 X 177 lb	$ 25.74	________
Phosphate at $0.31 X 51 lb	$ 15.81	________
Potash at $0.13 X 41 lb	$ 5.33	________
Lime (year cost)	$ 6.00	________
Herbicide	$ 25.75	________
Crop insurance	$ 4.20	________
Interest on pre-harvest variable cost	$ 7.77	________
Miscellaneous	$ 7.00	________
Total	$123.08	________

PROFIT FROM CORN CROP

Value	$347.52/acre	Yes, there still are government subsidies, but they are shrinking each year and will be gone in 5 years. For the purpose of this evaluation, we did not include any.
Costs	$323.33/acre	
Net profit	$ 24.19/acre	

Profit per acre from Corn for the High-Quality Land: $24.19/acre
Your #: ________.

Now Let's Look At Value-Added Corn Stover Harvesting

- For each pound of corn produced there is over a pound of corn stover (approximately 56% of total). (Modern Corn Production, 3rd ed. 1986. S.R. Aldrich, W.O. Scott, and R.G. Hoeft. A&L Publications, Inc., Champaign, Illinois.)

  The yield used before of 144.2 bu/acre would result in 144.2 bu/acre (56 lb/bu) = 8,075 pounds of corn. There would be 8,560 pounds of stover produced. Even if you attempted to strip the field entirely, you could obtain only 75% or about 6,400 pounds.

- The GLCC Plan is to deactivate the chopper and/or spreader on the combine, thus producing a windrow of cobs, shucks, leaves, and stalks. The baler will then bale this up along with the two rows of stalks in the windrow. We can expect about 3,000 lb/acre depending upon the following factors: corn yield, plant population, hybrid, combine head size, how long after corn harvest, and row width.

- For example, we will use 3,000 lb or 1.5 tons per acre. This leaves more than 60% for soil conservation, fertilizer, humus, etc.

- Before the combine arrived, we removed all the cobs along with the corn. After shelling, these were burned, used as bedding, or sold to the Furfural Plant in Omaha. The cobs make up as much as 20% of the total corn stover. In addition, corn yields have increased more than 1 bu/acre per year, which means stover has also increased. Even after harvesting corn stover, today's producers have more stover remaining than most producers did just a few decades ago.

Nutrients

- Many studies and papers have been done on what nutrients are being removed by harvesting corn stover. Variation will exist on individual fields for all sorts of reasons. In 1997, two composite samples from over 50,000 bales of corn stover collected from hundreds of fields all over western Iowa. The samples were split and sent to two Laboratories (Woodson-Tenent Laboratories Inc. of Des Moines, Iowa, and A & L Heartland Laboratories of Atlantic, Iowa). There were some expected variations among the four analyses. However, the average of the four is what we will use in the example. We are fairly comfortable with the average by analysis because it is also backed up by analyses of corn stover "ash" - a by-product of Great Lakes Chemical Corporation furfural extraction.

Corn to Soybeans (1.5 ton stover removed)	$/acre
Nitrogen (not required if going to soybeans)	$ 0.00
Phosphate (7 lb*1.5) ($0.29/lb)	$ 3.05
Potash (35 lb*1.5) ($.014/lb)	$ 7.35
	$10.40

Corn to Corn	
Add nitrogen (20 lb) ($.016/lb)	$ 4.80

- It is important to note that many things can reduce the need to add these nutrients; but for this analysis, none of these were included.
  - If you spread manure, you probably need very little of N, P, or K.
  - If a field's soil tests in the high or very high range, the P and K will not have to be replaced (Dr. Regis Voss, Iowa State University).

OTHER SAVINGS

- Total or partial stover harvest most often will enable fewer tillage passes and make no till or minimum till more attractive. Normal tillage equipment is listed below along with average per acre rates for 1997 according to ISU's Iowa Farm Custom Rate Survey.

		GLCC	Your estimate
Shredding corn stalks	$6.50	________	________
Disking--tandem	$7.15	________	________
--offset	$9.00	________	________
Harrowing	$3.75	________	________
Soil finishing	$8.05	________	________
Field cultivating	$7.10	________	________
Add to no-till planter cost			
over planter w/attachments	$1.79	________	________
over planter w/o attachments	$2.75	________	________

- Removal of corn stover lessens the carryover of insects and disease that live in the decaying residue.

- Large quantities of residue left in no-till, or minimum till, fields retard soil warming and thus germination in the spring. Some say they can plant as much as three weeks earlier in areas where the residue has been removed. This has more importance today and in the future than it did in the past. Reduction in numbers of producers is expected to continue, leaving the number of acres tended by a producer to increase.

- Even if it is a bad crop year, corn stover can still be harvested.

- Some of the herbicides applied are intercepted by the residue. Eventually most of this will be washed off by the rain and reach the ground, but removal of the residue should result in a more uniform application of herbicide and thus more consistent performance.

- Harvesting of stover can take place from shortly after harvest until the following spring. The tons per acre harvested will likely decrease as time from harvest passes. Compaction when soils are not frozen or are wet warrants serious consideration.

- The corn stover program can compare favorably with other value-added corn and bean programs in net return with little or no additional risk.

BOTTOM LINE

GLCC pays (11–15 miles) $15.00/ton (1.5/tons acre) to the producer for providing the windrow	=	$22.50/acre
Nutrient replacement	=	$10.40/acre
Net additional income	=	$12.10/acre
Savings of one field cultivator pass	=	$ 7.10/acre
		$19.20/acre
Normal profit without stover harvest	=	$24.19/acre
Profit with stover $19.20 + $24.19	=	**$43.39**/acre

To prosper, the producer must steadily increase net profit.
Corn stover is an opportunity to make a significant impact.

In the above example, profit is increased from $24.19/acre to $43.39/acre, or 80%, with little or no additional risk.

Interesting Points

Note: Although there are slightly different variations among soil scientists and nutrient experts, the "Interesting Points" listed below are intended to be middle of the road. They could be legitimately debated, but we believe at the end of the discussion most would still be intact.

- Based on present inputs from farmers, soil scientists, and ISU agronomists, in many situations a partial corn stover harvest can provide a significant increase in the net return per acre with little or no additional risk.
- A 144.2 bu yield would result in approximately 8,560 lb of corn stover, but would also produce a like amount of residue in the root systems (17,120 lb total stover and root residue). If 3,000 lb of stover were harvested per acre, it would equal 17.5 % of the total post-harvest corn plant.
- Nitrogen removed by harvesting corn stover may be of little if any value, when the next crop being planted in that field is soybeans or any other legume. These plants, unlike the corn plant, are able to take nitrogen from the air for their own growth and production and store even more for the crop that follows.
- There is approximately 33,000 tons of nitrogen in the air over every acre.
- If weather permits, harvesting of stover can take place from shortly after harvest until the following spring. The tonnage per acre will likely decrease as the time from harvest passes. Also, with the passage of time, rain will decrease potassium levels left in the residue by rinsing it from the stover.

- One ton of dry stover will create about 100 lb of humus that contains 5% nitrogen. A partial stover harvest may allow reduced tillage. Reducing tillage will increase humus near the soil surface by increasing its longevity. Reducing tillage will have a greater positive effect on humus accumulation than the negative result from partial stover harvest.

- In the past, corn pickers removed ear corn from the field. This ear corn was later shelled, and most often the cobs were sold for other uses like furfural. The five-year period (1992 to 1996) estimated 144.2 bu corn crop yield on the high-quality land in Shelby County would have had 2,018 lb of corn cobs per acre removed (1 bushel of ear corn = 70 lb, 56 lb of grain and 14 lb of cob).

- Each year technology, management, and improved breeding increases the yield per acre. It has been estimated that corn yields have increased at a rate of over one additional bushel per acre per year for the past forty years. Along with each additional bushel of grain comes fifty-six pounds of additional stover. That is an addition of over one ton.

- Large quantities of residue left in no-till or minimum-till fields retard soil warming and thus germination in the spring. This is especially true in situations with corn following corn and hybrids with low cold tolerance. Some say they can plant as much as three weeks earlier in fields where residue has been removed.

- Some of the herbicides applied are intercepted by residue. Eventually most of it will be washed off by the rain and reach the ground. Harvesting residue may result in more uniform application and more consistent herbicide performance.

- Harvesting stover from your field does not eliminate the potential of running cattle or sheep to glean dropped ears of corn after stover is partially harvested. The weight of the full ear is often heavy enough to escape stover harvesting methods, and GLCC prefers not having the ears of corn as the grain contains very little furfural. Most often livestock are placed in fields to pick up the otherwise lost ears of corn. The livestock consume less than 1,000 lb of actual stover per acre.

- 95% of plant food is taken from the air. The remaining 5% is taken from the soil.

- Bales from stover harvested when windrows are left behind the combine are most often heavier than bales taken from a total stover harvest. An eight-row head on the combine will produce heavier bales taken from the windrow than a four-row head.

- It has been calculated from a nutrients-removed standpoint that selling stalks for $35.60/per dry ton would be similar to selling alfalfa hay in large round bales at near $100/per ton.

- Root carbon contributes more to organic matter than does the stover [C.A.V.O. Biederbeck, R.P. Zenter, and B.P. Lafend, Effect of crop rotations and cultural practices on soil organic matter, microbial biomass and respiration in thin Black Cherrozem. Canadian Journal of Soil Science 71(3):363–376 (August 1991)].

- It is Great Lakes' goal to make corn stover a viable raw material supply for the Omaha plant while adding to the income of the corn producer. "IT MUST BE A WINNER FOR BOTH."

APPENDIX B2

SAMPLE CORN STOVER HARVEST COMMITMENT

Contract__________

Producer____
First Middle Last

Address: ____
Street Address City State Zip Code

Phone: (___)_____________(___)______________(___)_____________
Home Shop/Business Cellular

Field No.	State	County	Township	Section	Removal Deadline	# of Acres	Harvest method		Done By		Est. Mi. to Harlan Plant	Bales for own use
							W	E	S	G		

W= WINDROW, E=ENTIRE FIELD, S= SELF, G= GLCC

MAP

Please draw a detailed map of the farm.

- Describe location, surrounding crops, road names or numbers, waterways and other landmarks.
- Identify by number each cornfield where stover is to be harvested.
- This map represents one section of land and each small box is 40 acres.
- Use an * to recommend a bale staging location.
- Identify entrances to the field.

Additional maps may be attached for fields located in other sections but operated by the same producer.

S

Producer:____________________________GLCC:_______________________________
Signature Date Signature Date

Checks will be made out to one Producer only

Sample of 1997–98 Corn Stover Harvest Commitment (back of form)

NOTE: Early sign up is necessary to allow GLCC time to arrange for balers, stagers and haulers and be ready as soon as the corn harvest begins.

- GLCC penalty if stover is not removed by agreed upon deadline:

Deadline	Penalty
Apr 1st	$15/acre
Mar 1st	$12/acre
Feb 1st	$10/acre
Jan 1st	$ 8/acre
Dec 1st	$ 6/acre

- If producer wishes to keep some bales for himself, GLCC must be notified prior to harvest. The producer's account will be charged $9 per round or large square bales and $6 per intermediate square bale. The producer is responsible for staging these and for informing the haulers so that they do not remove those bales wanted by the producer.

- If producer has a preferred baler, every effort will be made to use them.

- Producer must call GLCC with Contract No. and Field No. when grain harvest is completed in each committed field. GLCC, baler, producer and trucker must communicate to coordinate efforts.

- Cows should not be in the field with bales, nor should field work be done around bales. If it is necessary to run your cattle or do fieldwork in advance of hauling, the producer should call GLCC and make arrangements or stage the bales.

- If baling has not been completed and the producer wishes to do field work or run cows, he should do so at his discretion. However, if this is done, this commitment is canceled.

- Payments to the producers may vary. Yields and payments depend on the amount of stover available. Yield and payment variations are as follows: Hybrid, Population, Yield, Ridges, Cultivation Practice, Baler Operator and Distance.

- We pay on a dry ton (100% dry matter) basis.

- Special instructions from the producer.

____

____

____

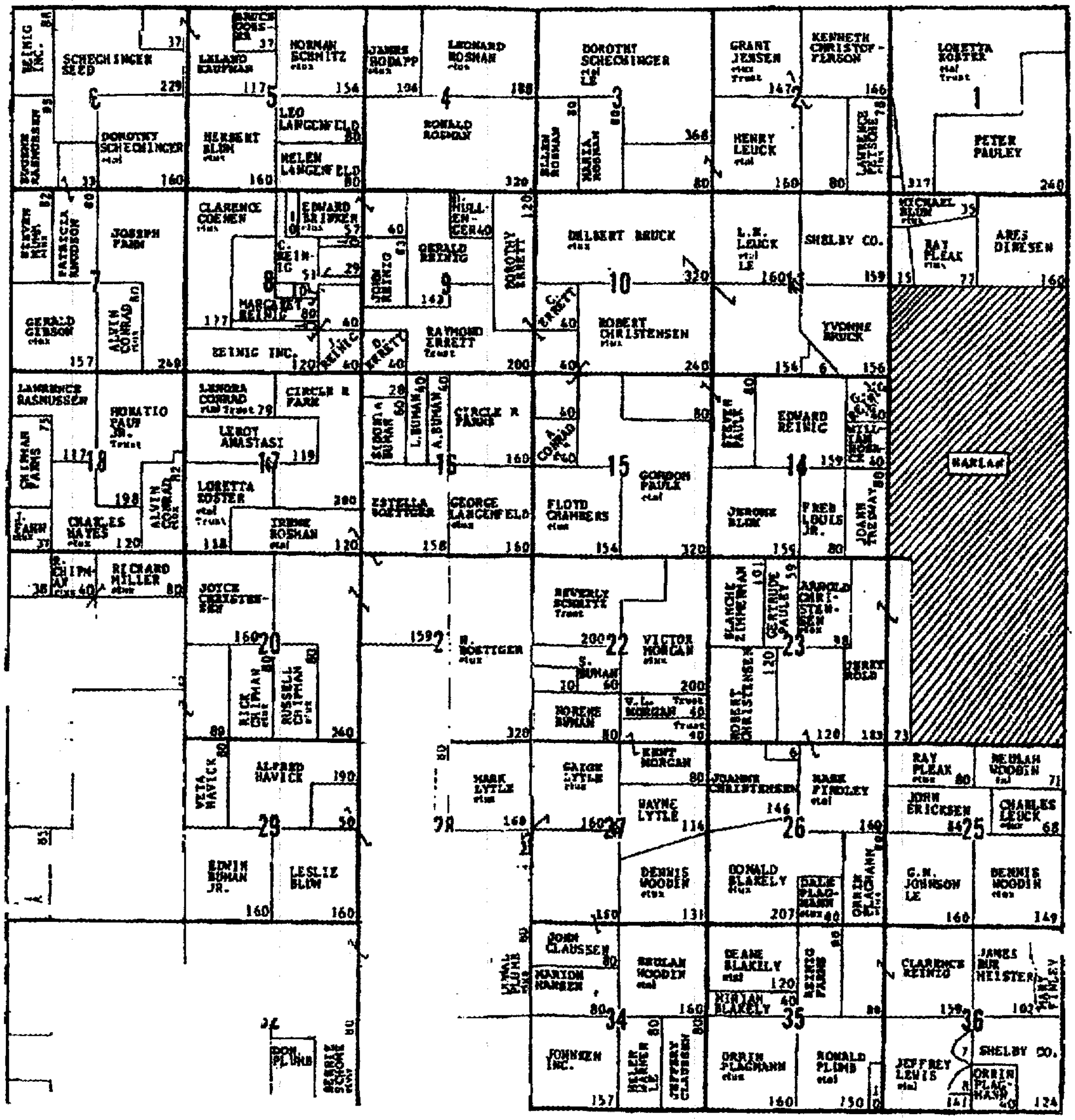
APPENDIX C

SAMPLE FIELD PLAT MAP AND DIRECTORY

APPENDIX C1

FIELD PLAT MAP

LINCOLN PLAT

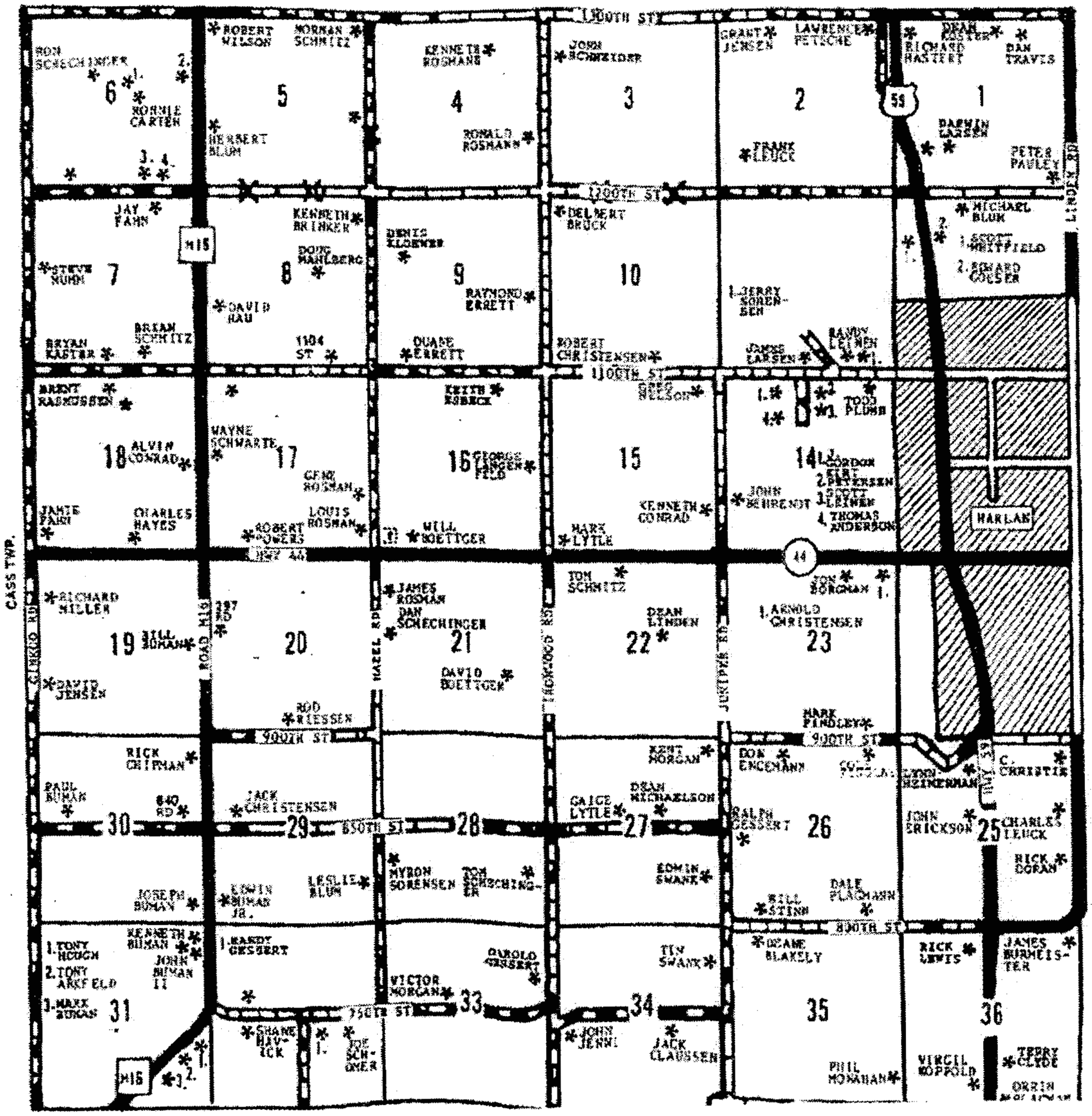


APPENDIX C2

DIRECTORY EXAMPLE

LINCOLN DIRECTORY

WESTPHALIA TWP.



APPENDIX D

BALING CONTRACT

APPENDIX D: BALING CONTRACT

BALER AGREES TO:

- Bale in accordance with the producer commitment. In most cases this will be a windrow left behind the combine.
- Attempt to finish baling at least 10 days before the deadline date on the Producer's Commitment to allow time for removal from the field and trucking.
- Make a genuine effort to bale accepted acres, giving top priority to GLCC during the stover harvest, and not allowing other work to interfere.
- Wrap round bales with 3 wraps minimum of plastic mesh. Rectangular bales to use GLCC twine or equivalent: 380# knot strength for 3 ft × 3 ft × 8 ft and 500# knot strength for 4 ft × 4 ft × 8 ft.
- Work closely with GLCC and the Producer. The producer's satisfaction is of prime importance. A cell phone would be desirable. Communications with GLCC and Producer is extremely important. Any changes in plans or any delays should be communicated.
- Not to bale if the moisture is above 30% or the producer does not want you in the field.
- Assume responsibility for bales broken during baling (especially if excessive).
- Assume responsibility to meet the producer's deadline date, <u>if applicable</u>.

GLCC AGREES TO:

- GLCC will pay baler an interim pay upon completion of fields based on 1,000 pounds of dry matter per bale for large round and large 4 ft × 4 ft square bales, and 500 pounds for intermediate 3 ft × 3 ft. The remainder of the amount due will be paid after delivery to the GLCC plant is completed.
- Provide plastic wrap and twine at wholesale.
- Assign acres to each baling machine. The baler will decide how much he wants to be responsible for.
- If a baler does not have his assigned acres completed when other balers complete their assignments, they may be instructed to complete those acres not yet completed.
- Every effort will be made to schedule in advance so balers can plan ahead.
- Provide copies of the producer commitment to the baler – complete with maps and description.

Total acres requested and accepted ______________________________
Baler

Great Lakes Chemical Corporation ______________________________

(continued on reverse)

Baler agrees that in the event he does not make a sincere effort to complete the baling for the following commitment(s):

Cont..# & Field# Initial	Cont..# & Field# Initial	Cont..# & Field# Initial	Cont..# & Field# Initial	Cont..# & Field# Initial

Baler will cause damage to Great Lakes Chemical Corporation in the amount of:____________________ and agrees to reimburse GLCC for said damages. However, it is understood by GLCC that delays in baling due to weather or illness (with doctor's release) will not be assessed any damage.

GLCC reserves the right to reassign commitments to other balers, if it is felt by GLCC that the baling is not being completed in a timely fashion.

Signature of Baler________________________________

Signature of GLCC Representative________________________________

Print Name ________________________________

Address________________________________

City/State/Zip________________________________

Phone________________________________

Cell Phone________________________________

APPENDIX E

HAULER'S COMMITMENT

APPENDIX E: HAULER'S COMMITMENT

HAULER AGREES:

- Work closely with GLCC and the Producers. The Producer's satisfaction is of prime importance. Always treat producers respectfully.
- To pick-up and haul stover bales from the producer's fields as designated by GLCC in a timely manner.
- Maintain frequent communications with GLCC concerning the status of the hauling. A cellular phone would be desirable. Any changes in plans or any delays should be communicated.
- To minimize ruts or field tracking (communicate with the producer if there are any question).
- Note potential problems in producer's field or breakage not removed and report it to GLCC immediately, so when possible the problem can be solved or avoided.
- Help solve and prevent problems.
- Hauler requests ________________ number of loads containing an estimated __________tons per load and plans the following number of loads in ________ October, __________November, __________ December, ____________ After Dec.

The above request by hauler for this number of loads is not to be a guarantee by GLCC, but rather a guide to help GLCC establish the number of haulers needed to complete the task.

GLCC AGREES:

- Assign the hauling to the various haulers in accordance with the producer commitments and this hauling agreement.
- To provide copies of the needed information to the hauler, complete with maps and location descriptions.
- To reserve the right to bring in additional haulers if GLCC feels hauling by present haulers is not progressing in a timely fashion.

NAME______________________________________

ADDRESS___________________________________

PHONE_____________________________________

CELL PHONE________________________________

_______________________________ _______________________________

GLCC REPRESENTATIVE HAULER

INTERNAL DISTRIBUTION

1. M. Downing
2. R. Graham
3-7. R. Perlack
8. S. Sokhansanj
9-10. A. Turhollow
11-12. ESD Library
13. Central Research Library
14. ORNL Laboratory Records – RC
15. ORNL Laboratory Records – OSTI

EXTERNAL DISTRIBUTION

16. Phillip Badger, General Bioenergy, Inc., 3115 Northington Ct, Florence, AL 35631
17. Richard Bain, National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, CO 80401
18. Jim Easterly, 9200 Santayana Dr, Suite 400, Fairfax, VA 22031
19. John Ferrell, U.S. Department of Energy, EE-2E, Room 6A-116, Forrestal Building, 1000 Independence Ave., SW, Washington, DC 20585
20. Thomas Foust, Idaho National Engineering and Environmental Laboratory, PO Box 1625, Idaho Falls, ID 83415
21. Richard Glass, National Corn Growers Association, 632 Cepi Dr, Chesterfield MO 63005
22. David Glassner, Cargill-Dow LLC, 15305 Minnetonka Blvd, Minnetonka MN 55345-1512
23. Susan Hennessey, DuPont Central Research & Development Experiment Station, Building 304/C329, PO Box 80304, Wilmington, DE 19880-0304
24. J. Richard Hess, Idaho National Engineering and Environmental Laboratory, PO Box 1625, Idaho Falls, ID 83415
25. James Hettenhaus, CEA, 3211 Trefoil Dr, Charlotte, NC 28226
26. Maurice Hladik, Marketing Director, Iogen Energy, 8 Colonnade Rd, Ottawa, Ontario, K2E 7M6, Canada
27. Reed Hoskinson, Idaho National Engineering and Environmental Laboratory, PO Box 1625, Idaho Falls, ID 83415
28. Kelly Ibsen, National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, CO 80401-3393
29. Douglas Kaempf, U.S. Department of Energy, EE-2E, Forrestal Building, 1000 Independence Ave., SW, Washington, DC 20585
30. Jim McMillan, National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, CO 80401
31. Michael Pacheco, National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, CO 80401
32. Cindy Riley, National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, CO 80401
33. Donald Richardson, U.S. Department of Energy, EE-2E, Forrestal Building, 1000 Independence Ave., SW, Washington, DC 20585
34. Gerson Santos-Leon, Abengoa Bioenergy R&D, 1400 Elbridge RD, Suite 212, Chesterfield, MO 60317
35. Tom Schechinger IronHorse Farms/Biomass Agri-Prod., LLC 816 Ironwood Road Harlan IA 51537 USA
36. Sam Tagore, U.S. Department of Energy, EE-2E, Forrestal Building, 1000 Independence Ave., SW, Washington, DC 20585
37. David Thompson, Idaho National Engineering and Environmental Laboratory, PO Box 1625, Idaho Falls, ID 83415
38. Robert Wallace, National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, CO 80401
39. Marie Walsh, 128 Orchard Lane, Oak Ridge, TN 37830