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Feldspar and Quartz from the Dunes of Kankakee, Illinois:
A Preliminary Feasibility Study

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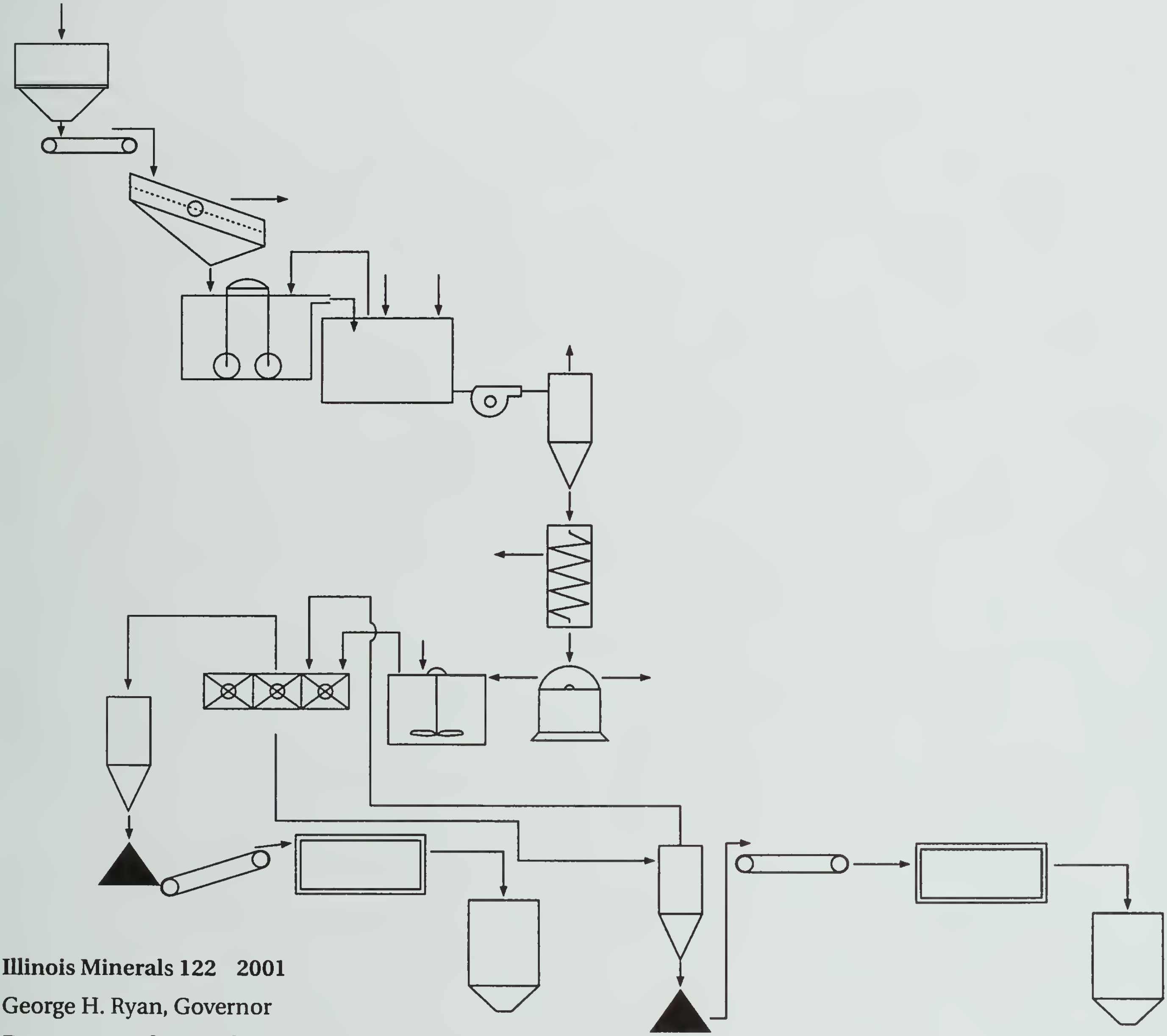

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Foreword

Crushed stone and sand and gravel have fundamental importance for the construction industries of Illinois. However, other industrial minerals, such as silica sand, feldspar, tripoli, and clays, play important roles in the state's economy because they are used in industrial processes of high economic value or processed into higher value products. Such minerals are used in making glass, ceramics, pottery, and brick and serve as fillers in paints, detergents, paper, and chemicals.

Most industrial minerals remain as local commodities because they are usually consumed near their origin. In several Illinois counties, they are an important source of employment, tax revenues, and economic stability.

In 1997, the staff of the Industrial Minerals and Resource Economics Section of the Illinois State Geological Survey (ISGS) responded to a request from the Kankakee County Economic Development Council to investigate the economic feasibility of extracting feldspar, glass sand, and foundry sand from dune deposits in the underdeveloped southeastern part of Kankakee County.

A team of ISGS geologists had studied the dunes there in 1974 and found deposits of potential economic interest. This present study investigated whether extraction of one or more products would be economically feasible. The study confirms the occurrence of feldspar and silica (quartz) sand in amounts that would be extracted at a significantly lower cost than the current market prices for the commodities. The markets for feldspar in particular should be studied further because feldspar is a vital ingredient in the manufacture of glass and ceramics. Although silica sand is abundantly available in the upper midwestern United States, the closest feldspar sources are in North Carolina and Ontario, Canada. Several million dollars in transportation costs could be saved annually if feldspar were produced locally. This study suggests that local production of feldspar and silica sand would generate jobs in the area southeast of Kankakee that suffers from very high unemployment. A potential for more new jobs, beyond those that would result from the mining and processing alone, exists if user industries could be attracted to the area.

Bill Shilts

William W. Shilts, Chief

Illinois State Geological Survey

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Executive Summary

This study was undertaken upon a request from the Kankakee County Economic Development Council (1) to verify the mineralogical analyses of the dune sands conducted by ISGS geologists in 1974 near Kankakee, and (2) to conduct a preliminary economic analysis of the feasibility of extracting and marketing feldspar, foundry sand (quartz [or silica] sand), and amber glass sand (feldspar and quartz sand) from the dunes. On the basis of the recommendations of this study, Kankakee County may decide whether to invest in more detailed characterization, processing, and market studies as well as a more comprehensive economic feasibility assessment.

Samples were collected from five boreholes drilled in fall 1997. Twenty-one subsamples from three boreholes were analyzed for their chemical and mineralogical contents and were compared with the results of the 1974 study. The results confirmed that the dune sands contain about 74% quartz (silica sand), 21% feldspar, and 5% other minerals; these percentages are in the same range as those reported in the 1974 study. The only difference between the two studies consists in the types of mineral grains reported. For example, the 1974 study identified both feldspathic rock materials and grains containing both feldspar and quartz; the present study did not separately identify these multi-mineral intergrowths. The samples in the 1974 study were primarily taken from road cuts, whereas the new samples came from boreholes drilled from the tops of the dunes or as near to the tops as possible. The different sample locations did not reveal differences in the mineral composition of the sand; however, grain size of the sand may be different at different positions on the dunes. The feldspar content of the sands is of more economic importance than the quartz (silica) sand content because of the higher market price of feldspar and a lack of feldspar production in the midwestern United States. Although the sands contain 17% to 21% feldspar, extraction inefficiencies had to be considered. Therefore, we have provided two economic scenarios for the sand processing plant, one assuming a feldspar yield of 17% and the other a yield of 15%.

In their 1974 study, Ehrlinger and Masters conducted tests that indicated feldspar could be separated from quartz sand using the flotation technique. Laboratory tests indicated that classification of the dune sand into different size fractions with or without separation of feldspar could permit its use as foundry sand and also produce a mix of quartz sand and feldspar that could be used in the manufacture of amber glass and ceramic products.

This study tested process flow designs to produce four product alternatives: (I) amber glass sand, (II) foundry sand and amber glass sand, (III) feldspar and amber glass sand, and (IV) feldspar alone. The amber glass sand in the first two alternatives contains feldspar in the same percentages as in the original sand; in the third and fourth alternatives, the feldspar has been separated. In the third alternative, feldspar must be added back for glass making, or the sand fraction with low-feldspar content can be marketed as foundry sand. Flow diagram IV assumes that only the feldspar is marketable and that the remaining material can be returned to the mine or sold as common construction sand.

The proposed processing plant was designed for an annual capacity of 112,000 tons raw input or 100,000 tons of production. The basic operating conditions assumed two shifts per day and 200 working days per year. Commercially available data were used to estimate the initial mining and processing plant investments and the operating and maintenance costs. Initial depreciable investments including the equipment, transport and installation, and auxiliaries ranged from $1.67 million to $2.41 million; the operating and maintenance costs ranged from $85 to $111 per hour of operation. A discount rate of 18% was used in the calculation of break-even product prices. The feasibility estimates indicate that the undertaking can be economically viable under certain conditions. Profitability increases significantly if the plant is assumed to be operable for three shifts per day and 250 days per year, as recommended by experienced operators.

Markets for silica (quartz) sand and feldspar in the Upper Midwest differ significantly from one another. Illinois ranks first among the states producing silica sand; Illinois' annual production is 5 million tons (of the U.S. total of about 31 million tons). Illinois, Wisconsin, Michigan, and Ohio account for 36% of the national production. Silica sand in the Upper Midwest is a low-cost material, about $9.50 per ton for glass making and $11 per ton as foundry sand. That price rapidly increases with the distance the sand is transported. Therefore, many small producers are scattered throughout the country, relatively close to consumers. The 10 largest companies in the United States own 58 operations and produce 71% of the sand. The concentration of foundry sand production in the Midwest is especially high (74% of the U.S. total) because of the availability of inexpensively mined, high-quality sand in the region.

Nationally, about 37% of the silica sand is utilized by the glass industry. Among non-glass uses, foundry users are the dominant market. For small producers, such as the proposed Kankakee undertaking, other uses for silica sand should be carefully studied. Some of these uses are for specialty glasses, abrasives, hydraulic fracturing of rocks in crude oil production, fiberglass, filtration, chemicals, and ceramic materials. New sand producers in the Midwest face a market that is highly competitive in both quality and price. The search for a market niche should be based on a combination of product specialty and delivered price in the nearby industrial areas of Illinois, Indiana, Michigan, and Wisconsin. Glass production from silica sand requires the addition of feldspar or nepheline syenite as a source of alumina. Because the dunes of Kankakee County contain feldspar, they offer an advantage over conventional silica sand sources, especially in the amber glass market.

The market prospects for feldspar are better than those for glass making or foundry sand, primarily because most U.S. feldspar (about 1 million tons per

year) is produced in states distant from the midwestern industrial areas, and feldspar's mineral substitute, nepheline syenite, is imported (about 275,000 tons a year) from Ontario, Canada. North Carolina accounts for 54% of the total U.S. feldspar production. Feldspar is also produced in California, Virginia, Georgia, Idaho, and South Dakota. About 70% of U.S. feldspar production is used by the glass-making industry. The other 30% is consumed for ceramic products, pottery, and tiles, among many other uses. Available information indicates that at least 50,000 tons of feldspar are consumed in Illinois and Indiana each year, all of which is imported from North Carolina and Canada. Feldspar production in Kankakee County would be a source close to these industrial markets.

Introduction

The ISGS first studied the Kankakee dune sands in 1942 (Willman 1942). Further studies were performed by Hunter (1965), Ehrlinger et al. (1969), Ehrlinger and Jackman (1970), and Ehrlinger and Masters (1974). The last ISGS publication in 1974 dealt with mineralogical, chemical, and particle size distribution analyses of the Kankakee dune sands that were important to understand how the sand could be used for saleable products. In 1997, the Kankakee County Economic Development Council requested help from the ISGS in determining the economic feasibility of mining and processing the Kankakee sands. The objective was to assess whether the council or a private concern would be justified in investing in further detailed geological, engineering, economic, and market studies.

During fall 1997, ISGS geologists and technicians drilled five boreholes at selected sites and sampled the sand from three of the holes for analysis. The new samples and analyses were (1) to confirm the results of the 1974 study, (2) to take into account advances in analytical as well as minerals processing technology, (3) to propose one or more alternative flow diagrams for sand processing, and (4) to conduct a preliminary economic feasibility analysis to determine the profitability potential of a future venture. This document reports the preliminary results of the samples analyzed for this study, summarizes the mineralogical and size distribution results from the 1974 study, and presents the projected economic feasibility of producing four sand product combinations.

Sampling and Analysis in 1997

Figure 1 shows the distribution of dune fields in Illinois that contain more than 20% feldspar. The large dune field in southeastern Kankakee County is one of the more promising deposits for commercial feldspar production in Illinois because of its size and proximity to the industrial complex of northeastern Illinois, northwestern Indiana, southwestern Michigan, and southeastern Wisconsin. The dune field is a prominent feature on the St. Anne and Leesville 7.5-minute topographic Quadrangles.

Figure 2 shows the configuration of part of the dune field on the Momence 15-minute Quadrangle. The K numbers mark the locations of channel samples taken from road cuts and blowouts for the feldspar study reported by Ehrlinger and Masters (1974). Locations B-1, B-3, and B-5 are the collection sites for the continuous core holes sampled and analyzed for this study. The locations were chosen to position the rig as high as possible on a dune. The cores were taken through the dune sand into underlying bedded fluvial-lacustrine pebbly sands and silts. Coring was terminated when material began to flow into the drill hole. In all five holes, the water table was encountered near the base of the dune sand, which is also about where the sand's carbonate contents increase and its color becomes more gray than brown. The new samples add to the knowledge of the deposits because they were taken from boreholes drilled through the dunes, whereas the 1974 samples were taken from road cuts on the edges of the dunes. Together, the samples of both studies present a reasonably complete picture of the material.

Geologic Origin

The origin of the dune field can be traced to the latter part of the most recent ice age, about 13,000 to 15,000 years ago, when the outer edge of the Lake Michigan lobe of glacial ice was just north of the Kankakee River valley (Ehrlinger and Masters 1974). Enormous amounts of sediment-laden meltwater were released to the valley at that time, and floods spread over all but the highest land in the area. When the glacier and the floods finally receded, large areas of fine-grained sediment were exposed to wind erosion, resulting in the migration of the dune field to roughly its present position. However, subsequent events, such as droughts and fires, have probably caused smaller migrations to occur, just as blowouts and sand migration occur today wherever the vegetation cover on a dune is broken.

Mineral Content

The Kankakee dune sands are composed primarily of silica (quartz), plagioclase feldspars (albite [Na-plag] and anorthite [Ca-plag]), K-feldspar, illite and mica, chlorite, hornblende, pyrite and marcasite, and, in some samples, trace amounts of calcite and dolomite. The mineralogical content of the sand was determined by x-ray fluorescence (XRF) chemical analysis and x-ray diffraction (XRD) mineralogical analysis. XRF chemical analysis was preferred for the calculation of the quartz and feldspar contents because XRF is more accurate than XRD.

Table 1 presents the summary of mineral content analysis of the Kankakee dune sands (for details of the mineralogical analysis see appendix A). Table 1 contains three data sets. The first two

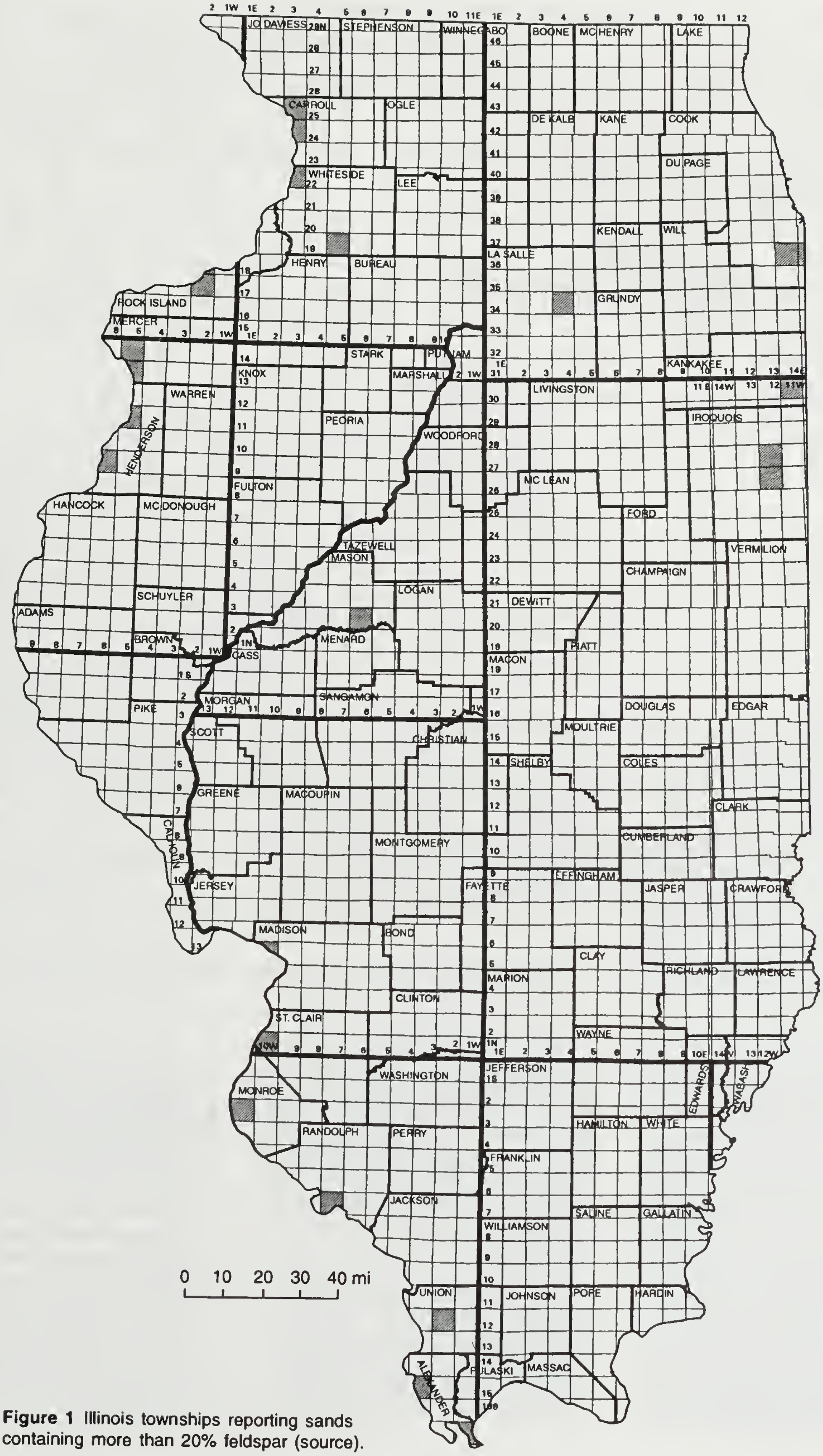

Figure 1 Illinois townships reporting sands containing more than 20% feldspar (source).

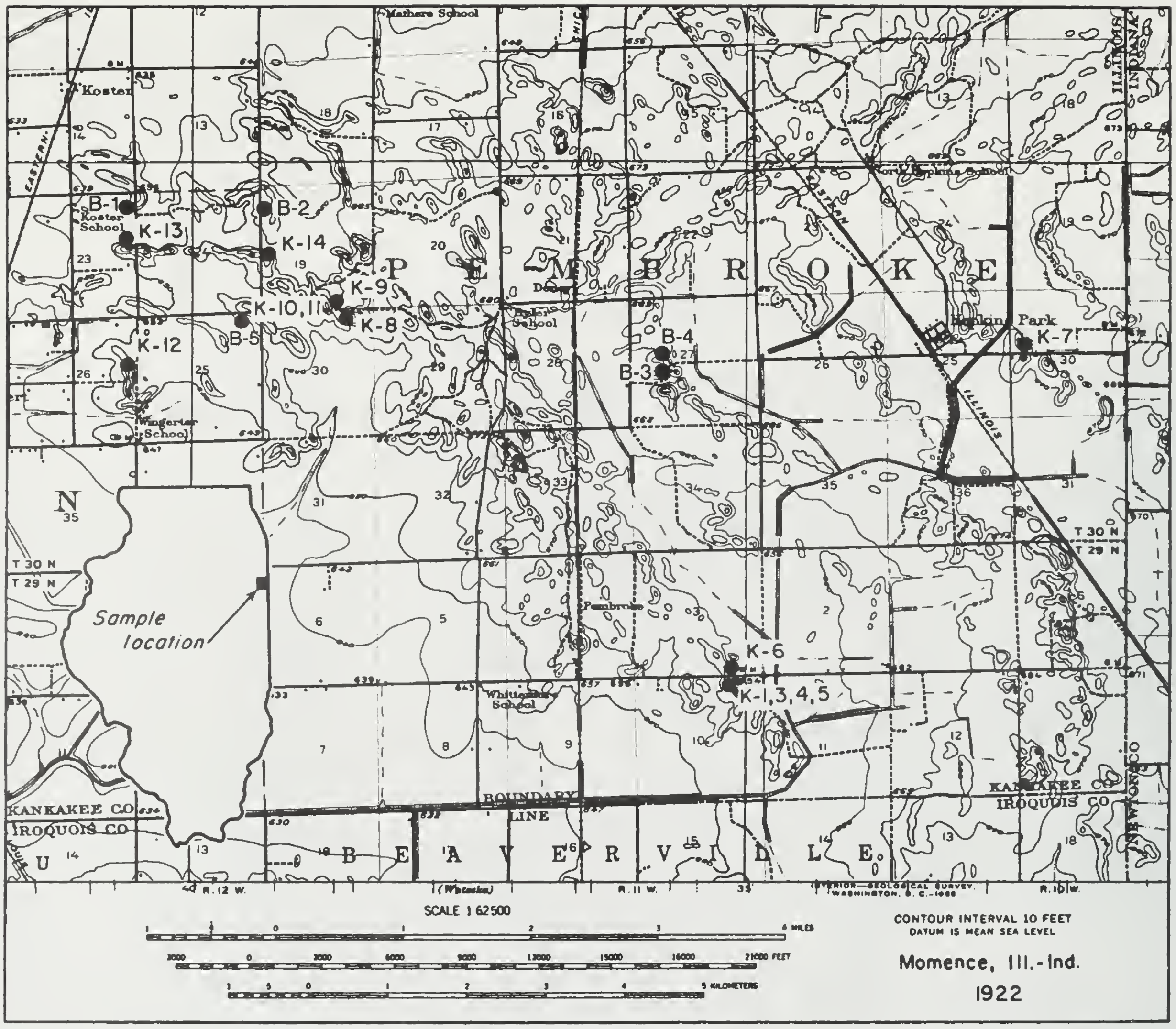

Figure 2 Locations of samples. B-1 to B-5 are drill holes for this study. K-8 to K-14 are nearby sample sites used in the study of Ehrlinger and Masters (1974).

sets of three samples each are from the borings, and the last set of one sample is from the Ehrlinger and Masters (1974) study, re-analyzed using XRF. The first set of samples consisted of material screened to the size <1 mm to >63 µm. The second set of data consists of unscreened bulk samples. The results of the last sample (Ehrlinger and Masters 1974) differ from the newer samples because the older sample was taken at a road cut whereas the newer ones were from boreholes on top the dunes. Weathering at the road cuts affects the mineral content.

The numbers in the "percent feldspar" column of table 1 are the sums of the three preceding columns. Table 1 also presents, in the last three columns, the ratios of each type of feldspar in the total feldspar content. These ratios are significant in certain applications and uses of feldspar.

The average quartz content of the Kankakee dune sands is 73.5% ± 1.5% and the average feldspar content is 20.6% ± 1.6%. The economic analysis considers both the data of Ehrlinger and Masters (1974) (17% feldspar content) and the results from this study (21% feldspar content) for the sands; appropriate adjustments in yield have been made to account for inefficiencies of separation.

All available information indicates that three products are possible from these sands: (1) a relatively fine-grained foundry sand, (2) an amber glass sand containing feldspar, or (3) a flotation product of nearly pure feldspar containing approximately 18% Al_2O_3 and a quartz by-product with traces of remaining feldspar.

Table 1 Nonclay mineral content calculated (as percentages) from XRF chemical analyses (see table A7).

Sample	K-spar	Na-plag	Ca-plag	Feldspar[1,2]	Quartz[1]	K-spar ratio[3]	Na-plag ratio[4]	Ca-plag ratio[5]
3706A[6]	9.6	7.4	6.5	24	72	0.41	0.53	0.47
3706B[6]	10	6.3	3.9	21	76	0.51	0.62	0.38
3706C[6]	11	7.1	4.9	23	73	0.47	0.59	0.41
Mean[6]	10	6.9	5.1	22	74	0.46	0.58	0.42
Std dev[6]	0.48	0.46	1.1	1.3	1.7	0.04	0.04	0.04
3706A[7]	7.0	6.8	5.0	19	74	0.37	0.58	0.42
3706B[7]	9.5	6.5	4.1	20	75	0.47	0.61	0.39
3706C[7]	9.9	7.4	5.5	23	71	0.44	0.57	0.43
Mean[7]	8.8	6.9	4.9	21	73	0.43	0.59	0.41
Std dev[7]	1.3	0.36	0.57	1.6	1.5	0.04	0.02	0.02
3669A[8]	9.2	7.8	18	35	62	0.27	0.31	0.69

[1] Feldspar and quartz percentages are calculated by subtracting the chemical oxides in clay minerals, hornblende, and pyrite/marcasite (as calculated from XRD data) from the bulk chemical analyses.

[2] Sum of %K-spar, %Na-plag, and %Ca-plag.

[3] Ratio of %K-spar to K-spar + plagioclase feldspars.

[4] Ratio of %Na-plag to %Na-plag + %Ca-plag.

[5] Ratio of %Ca-plag to %Na-plag + %Ca-plag.

[6] Samples screened <1 mm >65 μm.

[7] Bulk samples.

[8] Ratios for sample 3669A are in error because of calcite and dolomite in the sample.

Market Indicators for Product Choice

Silica (Quartz) Sand

Illinois ranks first among the states in production of silica (quartz) sand. About 31 million tons of silica sand are produced in the United States, of which 5 million tons are produced in Illinois. Illinois, Wisconsin, Michigan, and Ohio together account for 36% of the national production. Another 28% is produced in California, New Jersey, North Carolina, Oklahoma, and Texas. Although silica sand is produced in almost all of the states, the top five states account for 44% of production. The states in the Upper Midwest have large production, which is why silica sand in this region is a low-priced material (about $9.50 per ton for glass making and $11 per ton as foundry sand). That price rapidly increases with the distance the sand is transported. Therefore, many small producers are scattered throughout the country relatively close to their customers. The 10 largest companies in the United States own 58 operations and produce 71% of the sand. Because of the availability of inexpensive and high-quality sand in the region, foundry sand production in the Midwest (74% of the U.S. total) is especially concentrated. The finer fractions of the Kankakee dune sands may serve a special market niche in the foundry industry because of the angularity of the sand grains.

Although competition from plastic containers and the rise in recycling have affected some glass markets, the container market still dominates the glass-making industry. Flat glass production has been increasing steadily as a result of rising demand in the building and automobile markets. About 37% of the silica sand produced is consumed by the glass industry. Among non-glass uses, foundry users are the dominant market. For small producers, such as the proposed Kankakee undertaking, other uses for silica sand should be carefully studied. Some of these uses are for specialty glasses, abrasives, ceramics, hydraulic fracturing of rocks in crude oil production, fiberglass, filtration, and chemicals.

New sand producers in the Midwest face a highly competitive market with lower-than-average prices in major consumer sectors, such as glass manufacture and foundry applications. Therefore, if a silica sand is to be produced near Kankakee, it is essential that a market niche exists for it. The search for the market niche should be based on a combination of product specialty and delivered price in nearby industrial areas.

Glass production from conventional silica sand requires the addition of feldspar or nepheline syenite as a source of alumina. The dunes of Kankakee County contain feldspar and thus offer an advantage over conventional silica sand, especially in the markets for amber glass and selected markets for ceramics.

Feldspar

The market prospects for feldspar appear to be better than for foundry or glass sand, primarily because (1) most U.S. feldspar is produced in states distant from the northern industrial areas,

(2) feldspar commands a relatively high free-on-board (f.o.b.) price, and (3) feldspar's mineral substitute, nepheline syenite, is imported at similarly high prices from Ontario, Canada. Feldspar is produced in North Carolina, California, Virginia, Georgia, Idaho, and South Dakota. North Carolina alone accounts for 54% of the total U.S. feldspar production. Of the 14 producing operations in the United States in 1996, five were in North Carolina, four in California, and one each in the other five states.

Feldspar supplies essential alumina, alkalis, and alkaline earths in glass manufacture and imparts hardness, durability, and resistance to chemical corrosion to the glass. The feldspar content in glass varies from about 8% to 18%, depending upon the type of glass produced. The United States annually produces about 1 million tons of feldspar and imports about 275,000 tons of nepheline syenite annually. About 70% of U.S. feldspar production is used by the glass-making industry. The other 30% is utilized in the manufacture of ceramic products, pottery, and many other products. State-by-state consumption data for feldspar are no longer available. However, the most recent data from 1990 indicate that at least 50,000 tons of feldspar were consumed in Illinois and Indiana that year, all of which was imported from North Carolina and Canada. Feldspar production in Kankakee County would be a source of this raw material close to its industrial markets. Feldspar's market price ranges from $45 to $80 per ton f.o.b. mine. Typically, the glass marketing industry pays lower prices for feldspar, and the ceramic industries pay higher prices. Transportation from traditional producer states to midwestern customers typically double these prices.

Suggested Processing of Kankakee Dune Sand

The results of the 1974 study by Ehrlinger and Masters and the analyses of samples collected for the present study indicate that three or more sand products can be processed from the Kankakee dune sand using drag classifiers, screens, spirals, magnetic separators, air classifiers, and froth flotation. The three products that can be produced from the Kankakee sand are amber glass sand, foundry sand, and feldspar.

Four process flow diagrams were studied:

I: Amber glass sand (fig. 3)

II: Foundry sand and amber glass sand (fig. 4)

III: Feldspar and amber glass sand (fig. 5)

IV: Feldspar (fig. 6)

Flow diagram III can be refined further by adding a classification step to separate foundry sand from amber glass sand fractions, depending upon market conditions. The carbonate content, if found to be more significant than in current samples, may require the addition of a flotation step before the desliming steps in flow diagrams I and II. Flow diagram IV assumes that feldspar would be the main marketable product. The quartz sand left after feldspar recovery could be either returned to the mine or could be sold as foundry or glass sand for construction purposes. In every case, the products are likely to contain material other than the desired main mineral. That is, the feldspar may contain some quartz and vice versa. Therefore, the mass flows have been adjusted to reduce the product yield compared with the sample compositions. Although laboratory analyses have estimated the feldspar content to average about 17% in the 1974 study and about 21% in the present study, the recovery of feldspar may be somewhat lower. How much lower the recovery will actually be is unclear at this time. Therefore, we have prepared the economic analyses with several scenarios. For the same reason, we recommend follow-up processing experiments.

Preliminary Cost Estimates

Estimates of necessary plant investments, equipment operating costs, wages, and salaries were made for a production unit of 100,000 to 102,000 tons per year for each proposed process flow diagram, based on 1997 databases purchased from Western Mine Engineering Inc. of Spokane, Washington, and the 1982 equipment and capital cost estimation guide published by the Canadian Institute of Mining and Metallurgy (Mular 1982). To account for losses during processing caused by removal of ultra-fine material (slimes), heavy minerals, and magnetic minerals, the required plant input capacity was set at 112,000 tons per year. The plant was designed to operate for two shifts a day for 200 days per year.

The initial investments in mining and processing plant equipment and the hourly plant operating costs (including maintenance labor, parts, fuel, lubricants, tires and electricity, but excluding the wages and salaries of the work force that runs the plant) are presented in appendix B for each of the four flow diagrams. Initial investment in plant equipment was estimated to be about $1.165 million for flow diagram I, $1.322 million for flow diagram II, $1.685 million for flow diagram III, and $1.304 million for flow diagram IV. These estimates include mining and hauling equipment but not land purchase or cost of the building. We recognize the possible need for investment for the treatment and disposal of waste water, as well as the cost of land reclamation, but, at this preliminary stage of the study, we have chosen to postpone the consideration of these costs because we assume maximum recycling of water and limited reclamation work (grading and revegetation) because sand mining will be limited to dunes above groundwater level. Furthermore, investment data acquired from Western Mine Engineering (2000) are manufacturers' suggested list prices; actual prices are expected to include discounts common in the industry.

Operation and maintenance of equipment, excluding the wages and salaries of regular operating staff, are estimated to cost about $85 per hour for flow diagram I, $88 for flow diagram II, $111 per hour for flow diagram III, and $57 for flow diagram IV. We assume plant operation of 16 hours per day for 200 days per year. Winter weather and other down-time are assumed to restrict operations to an average of 5 days per week for 40 weeks. Any in-

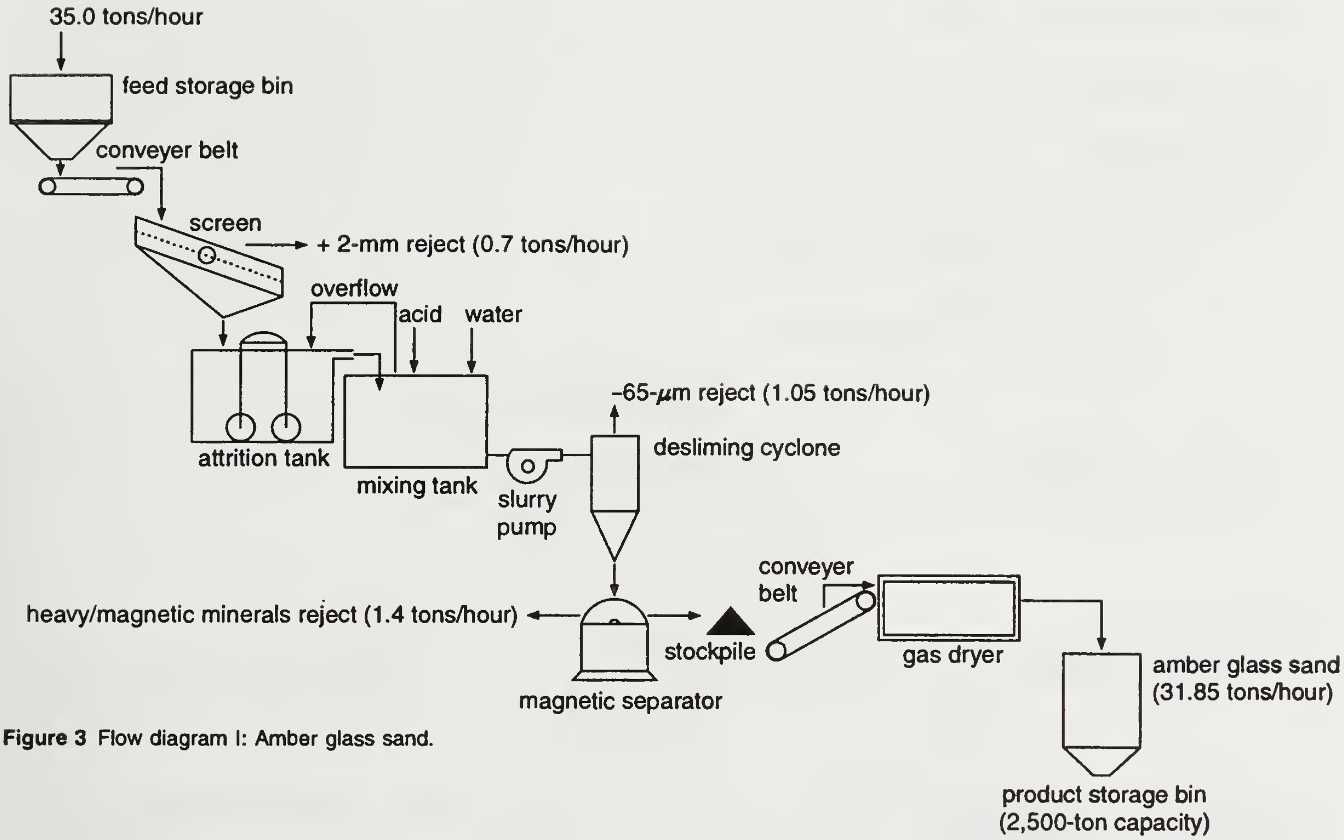

Figure 3 Flow diagram I: Amber glass sand.

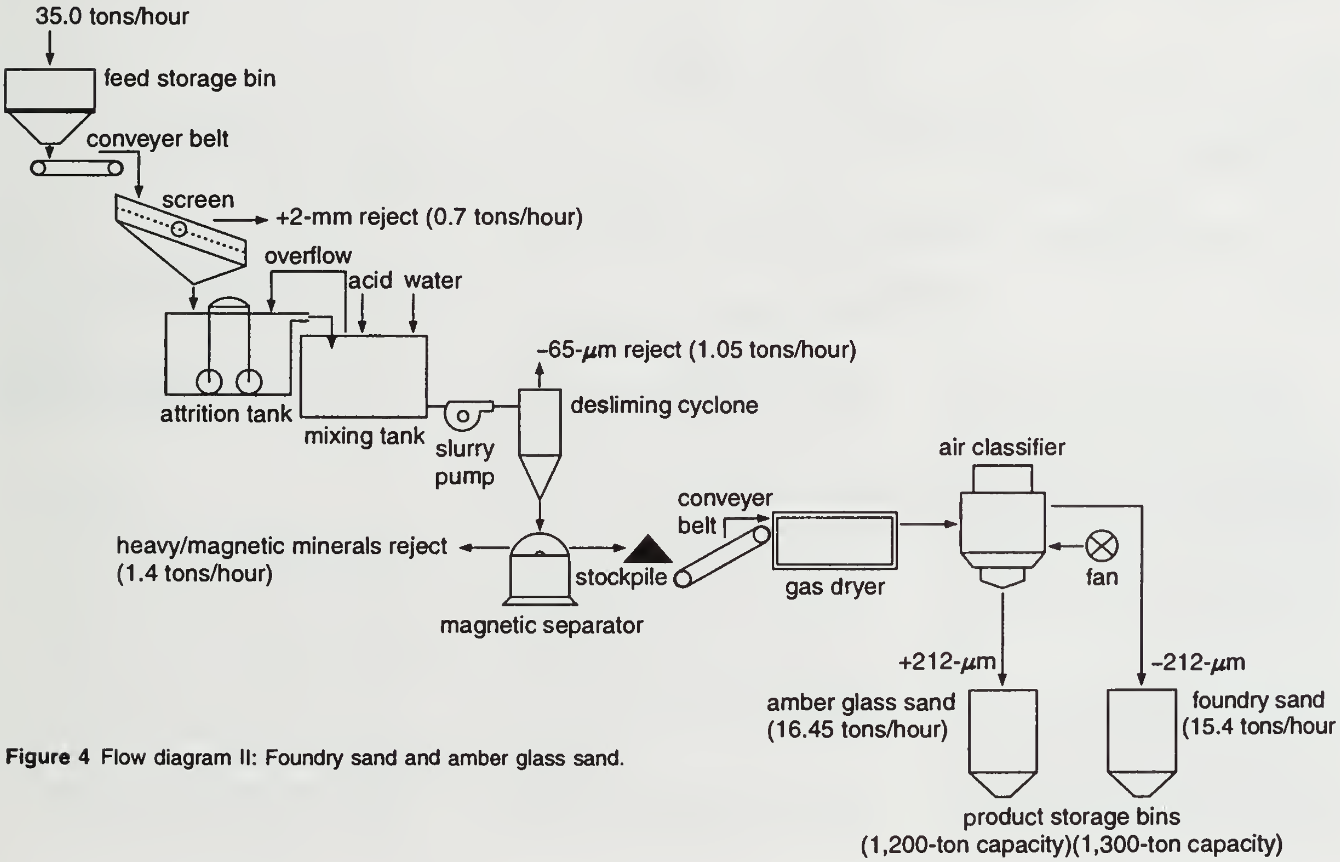

Figure 4 Flow diagram II: Foundry sand and amber glass sand.

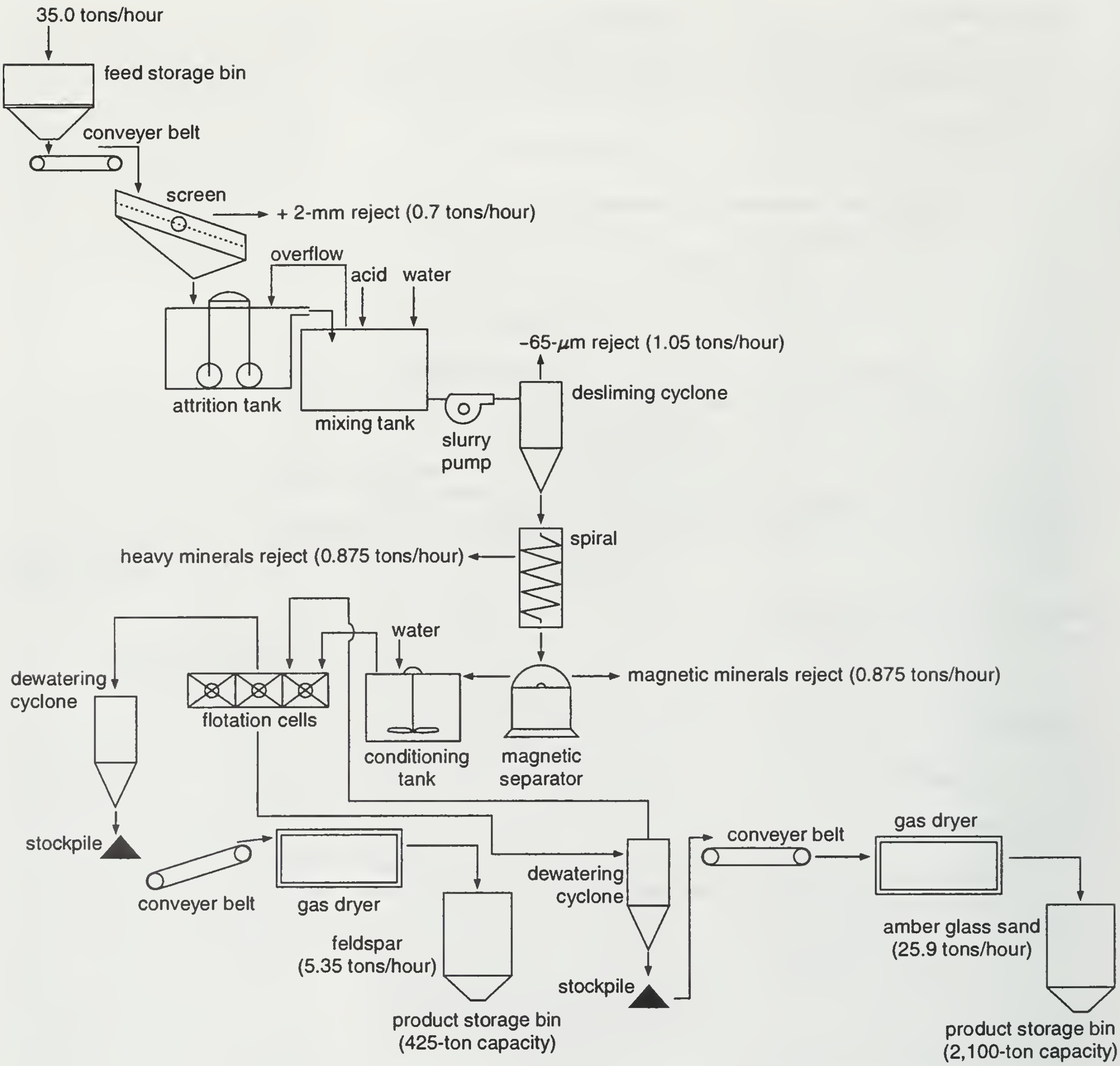

Figure 5 Flow diagram III: Feldspar and amber glass sand.

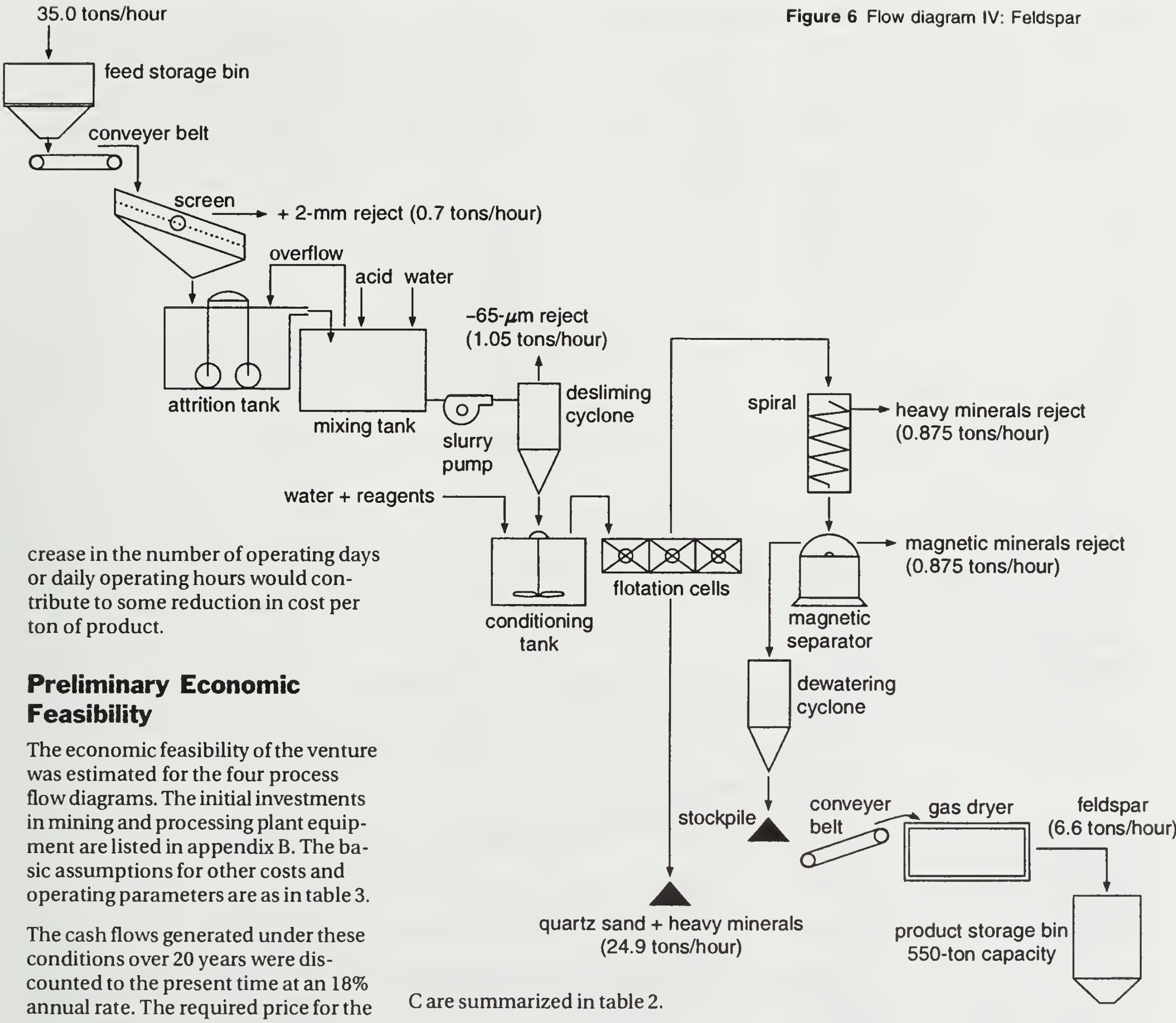

Figure 6 Flow diagram IV: Feldspar

crease in the number of operating days or daily operating hours would contribute to some reduction in cost per ton of product.

Preliminary Economic Feasibility

The economic feasibility of the venture was estimated for the four process flow diagrams. The initial investments in mining and processing plant equipment are listed in appendix B. The basic assumptions for other costs and operating parameters are as in table 3.

The cash flows generated under these conditions over 20 years were discounted to the present time at an 18% annual rate. The required price for the product mix was varied until the net present value of the discounted cash flow was zero or very nearly zero.

Results

The results of the net present value analysis estimates, presented in detail in appendix C, indicate that the undertaking can be economically viable in all scenarios if the tonnage and price conditions presented in table 2 are met in the first year of full operation. Note that in flow diagrams IV (C) and IV (D), the process is designed to separate amber glass sand but assumes the final product will be sold as construction sand. The results detailed in appendix C are summarized in table 2.

Discussion

The current f.o.b. market price for glass sand in the Midwest is about $9.50 per ton. However, to make glass, feldspar must be added to the sand (8% to 18% feldspar and 82% to 92% silica sand). Feldspar produced in North Carolina costs $90 to $110 per ton in the Midwest because of additional transportation costs. Thus, 1 ton of material for glass making in the Midwest costs at least $17.55 if its feldspar content is 10%.

Amber glass sand produced from the Kankakee sand dunes at a cost of $8.00 to $12.17 per ton already contains more feldspar than needed for glass making and would, therefore, be economically attractive. At high-capacity utilization of the plant, glass sand could be produced for $6.60 per ton; feldspar would have to be added, however, thus raising total cost to about $10.00, which is still favorable compared with out-of-state feldspar purchased for the purpose.

Foundry sand produced at a cost of $11.00 per ton is as expensive as its current market price. The price of foundry sand is influenced by the fineness of sand, other characteristics remaining unchanged. Finer sand makes

Table 2 Summary of economic results detailed in appendix C.

	Amber glass sand		Foundry sand		Feldspar		Construction sand		
Flow diagram (scenario)	Production (tons/yr)	Price[1] ($/ton)	Production (tons/yr)	Price[1] ($/ton)	Production (tons/yr)	Price[1] ($/ton)	Production (tons/yr)	Price[1] ($/ton)	Material loss (tons/yr)
I	101,920	11.01	10,080						
II	52,640	12.17	49,280	11.00					10,080
III (A)	81,200	8.00			19,040	41.69			11,760
III (B)	76,720	7.66			23,520	36.40			11,760
III (C)	83,440	8.00			16,800	46.18			11,760
IV (A)					19,040	60.16			92,960
IV (B)					16,800	68.20			95,200
IV (C)					16,800	53.20	83,440	3.00	11,760
IV (D)					19,040	47.37	81,200	3.00	11,760
III (HCU)[2]	156,450	6.60			31,500	35.40			22,050

[1] Price is f.o.b. at plant.
[2] High-capacity utilization (HCU) version of III (C), with three shifts per day and 250 days per year of operation.

Table 3 Basic assumptions for costs and operating parameters (see also appendix B).

Parameter	Cost assumptions
Land purchase	$100,000
Building	$20,000
Other investments	43% of equipment cost to be added for transportation of equipment, installation, pumps, pipes, and instrumentation.
Manpower	Five persons per shift are needed for flow diagrams I and II, and six persons per shift are needed for flow diagrams III and IV.
Working capital	Equivalent to 3 months of production at break-even cost per ton of production.
Cost/price escalation	All costs were increased at 3% per year; product prices were increased at 2% per year.
Discount rate	18%, based on the capital asset pricing model and an above-average market risk.
Taxes	40% of taxable income to account for federal, state, and local taxes. Domestic feldspar and industrial sand production is entitled to a 14% depletion allowance not included in the tax rate estimate.

better quality foundry molds, which require less finishing work on the foundry output. With the estimated cost of foundry sand production being equal to the current market price, marketing and innovative pricing would assume a bigger role in selling the foundry sand product. The finer size, greater angularity of dune sands, and the proximity of the mining site to the industrial areas in northeastern Illinois and northwestern Indiana may offer an opportunity for niche markets, despite competition from traditional foundry sand sources.

Feldspar recovery rate is critical to the overall economics of the plant. Three alternative feldspar recovery scenarios have been calculated for flow diagram III: 17%, 21%, and 15%. The remaining material, after accounting for the removal of heavy and magnetic minerals, can be used for glass making, as foundry sand, or for other purposes. The production cost for feldspar ranges from $41.69 to $46.18 per ton and is well below the market price of North Carolina feldspar sold in the Midwest. The production cost of silica sand (containing small quantities of feldspar) in all scenarios is below the current market price for silica sand.

High production of silica sand in the Midwest results in lower-than-average prices. Therefore, flow diagram IV was designed for the recovery of feldspar only. The feldspar recovery rates were assumed to be 17% and 15%. As a secondary variation, the remaining sand after feldspar recovery was assumed to be either returned to the mine unsold (scenarios A and B) or sold as common construction sand without further processing (scenarios C and D). If sand material is not sold, the feldspar would have to be sold for $60.16 to $68.20 per ton. Although this price range would be substantially higher than in flow diagram III, it remains significantly below the midwestern market price of North Carolina feldspar and Canadian nepheline syenite. If sand material left over after feldspar recovery is sold as common construction sand for $3 per ton, the recovered feldspar could be sold at a much lower price of $47.37 to $53.30 per ton.

All estimates thus far have been based on two operating assumptions: (1) two daily working shifts and (2) 200 annual operating days. Practical experience suggests that mineral processing plants run most efficiently when operated round-the-clock (three shifts daily) and at least 250 days per year. There is a good possibility that, in the Kankakee area, the plant could be operated 300 days or more per year. Such a change would increase plant utilization and raise the production capacity by about 80%, without additional investment. It would increase employment because of the added third shift, proportionately increase operation and maintenance expenses, but lower the cost per ton of the products. The costs of flow diagram III under the revised, high-capacity utilization assumptions are listed in the last row of table 2, and the details are given in appendix table C10. The economic break-even point under this scenario is attained if the feldspar is sold at $35.40 per ton and the sand product is sold at $6.60 per ton. This result is a considerable improvement over all previous scenarios. The other scenarios show similar cost reductions if the plant operations are extended to three shifts and 250 days per year.

Economic analyses of all scenarios suggest that the processing of Kankakee dune sand deserves the attention of investors. However, despite the encouraging results, this study must be treated as a preliminary feasibility study subject to limitations.

Limitations

The primary caveat for the investor is the unknown demand situation in northern Illinois, southeastern Wisconsin, southwestern Michigan, and northern Indiana. We recommend that a detailed survey be made of potential customers in these areas. We also recommend that extensive sampling and analysis of the dunes be undertaken in order to determine the variations in feldspar content and the separability of feldspar and quartz, as well as the particle size of the sand—the former because feldspar is the more valuable component, and the latter because particle size of sand used in foundries can significantly influence its price. Sand processing tests in the laboratory are also recommended to determine more precisely the recovery rates for all products, but especially feldspar.

The strongest selling point for the venture would be that a local source of sand containing up to 21% feldspar for the manufacture of amber glass and ceramics would be made available. Potential also exists for manufacturers of glass, ceramic wares, or metal castings to locate in the area to take advantage of raw materials near their source. Jobs created by any such ventures would require skilled personnel. Training the work force for the jobs would require additional investment in the future of the area.

Environmental and Land Use Impacts

If extraction took place at a scale of 100,000 tons per year, fewer than 3 acres would be affected annually, assuming an average mining depth of 15 feet. According to the Illinois Department of Natural Resource's Office of Mines and Minerals, a mining permit is not needed unless at least 10 acres of land are affected annually. The scale of mining considered in this study could thus result in reduction of dune size in up to 3 acres of land annually. If more than 15 feet of sand are mined, the acreage affected annually would be reduced further, but the dunes in the affected areas would be eliminated. If only feldspar is mined and marketed, almost 80% of the material would be returned to the mine site, considerably reducing the impact on the landscape. Over the 20 years of operating life, of several thousand acres of dune landscape in southeastern Kankakee County, only about 60 acres would be affected. However, we have made no environmental assessments for this study, and we assume that such assessments would be one of the prerequisites before investments would be made in land and plant.

The dunes of Kankakee County are quite permeable. Their carbonate contents and other minerals have been subject to rainwater percolation for centuries. The groundwater table in the area is quite close to the dune base. Although the pH of groundwater shows no apparent effect from either the carbonates or other chemical substances, the issue of groundwater needs to be assessed before any investment decisions are made.

Dust created during mining and processing would have to be monitored and suppressed with appropriate measures such as spraying, provision of proper enclosures, and vacuum collection. Dust emissions from the mine, plant, and transport trucks may require Environmental Protection Agency and Mine Safety and Health Act permits. Experience in a similar plant in central Illinois indicates that effective dust control is feasible.

Future Work

The ISGS could be of assistance in further investigations on a contractual basis. Such assistance could be provided in several areas, including (1) collection of drill hole and surface samples, (2) chemical and mineralogical analyses, (3) particle-size and optical microscope analyses, and (4) environmental and hydrologic assessment. Mineral processing experiments should involve testing with a variety of equipment, which may require industrial involvement. However, ISGS staff can be of assistance in coordinating the effort and, in some cases, may be able to perform bench-scale tests. It is the policy of the ISGS to assist and enhance the role of the private enterprise in the state's economy. In certain scientific areas where it has capabilities not readily found in the private sector, the ISGS will provide assistance in the public interest. Interested parties may contact the authors of this study.

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Appendix A

Mineralogic Analysis

We have used XRF chemical analyses and XRD mineralogical analyses to determine the mineralogical content of these sands and the underlying lacustrine (lake-deposited) sands. The XRD data on mineral content are generally less accurate and less precise than bulk chemical analyses, so the all-important calculation of quartz and feldspar contents are based on the XRF chemical data. Table 1 presents the mineral content and feldspar content ratios calculated from XRF data on the three composite dune sand samples from each of the test borings, both in bulk and after they were screened to <1 mm and >63 μm. A sample (3669A) from Ehrlinger and Masters (1974) was also submitted for XRF analysis. Because this sample contains both calcite and dolomite, the calcium in these minerals causes an overestimation of the Ca-plagioclase in this sample. Our calculations were made by (1) using the XRD percentages for illite and mica, chlorite, hornblende, and pyrite/marcasite to calculate the percentages of chemical oxides for these minerals; (2) subtracting these percentages from the bulk oxide composition (see table A3); (3) calculating from the remaining percentages of K_2O, Na_2O, and CaO the K-feldspar, Na-plagioclase, and Ca-plagioclase contents, respectively; and (4) calculating the percentage of quartz by subtracting the SiO_2 content of each of the three feldspars from the total SiO_2 remaining after calculation 2. We also checked the feldspar estimates by calculating the percentage of Al_2O_3 that the three feldspars would contain and comparing it to the amount remaining after the corrections in calculation 1. That calculation indicated that the estimates of feldspar content are probably accurate to 1% or less, except for the Ca-plagioclase calculated for sample 3669A. On the basis of the average feldspar ratios calculated for the six 3706 samples in table 1, the Ca-plagioclase content of sample 3669A is about 6%. A final comment about accuracy is that most of the small differences between bulk and screened samples are probably caused by variation in the feldspar content of the <63-μm tailings.

Mineralogical percentages calculated from XRD for dune and lacustrine sands (samples 3707A–U) are shown in table A1. The XRD results also are given for the three bulk composite dune samples that were analyzed by XRF (3706A–C). The results are given for 5-foot intervals of the three borings and the lacustrine samples from all three borings. The means and standard deviations of each of the four sets of XRD data are also given. With the XRD data for samples 3706A–C, we have included the Na-plagioclase ratio calculated from the XRF data. The method was modified to use the percentages of quartz and feldspar calculated from XRF data to refine our XRD mineral quantification ratios. Because these values combine errors from both chemical and XRD determinations, these data likely contain greater errors (generally 5% to 10% of the amount). However, the uniformity of the percentages from interval to interval and boring to boring, and their low standard deviations, suggests that the determinations are very precise; that is, they give the same result each time and for replicate samples. Measuring the error in these estimates, however, requires XRF chemical analyses for each XRD sample, which is beyond the scope of this project. Neither XRF nor XRD analyses allow illite to be distinguished from mica or pyrite from marcasite. The illite versus mica distinction is a construct, because both minerals have a wide particle-size range, and fine-grained micas behave like coarse-grained illite. Further, because marcasite is so unstable in oxygenated groundwater, most of the pyrite/marcasite in these sands is almost certainly pyrite. Also, other methods should be employed in follow-up studies to determine whether pyrite is actually present and, if so, the accurate pyrite content. Finally, the properties of illite and mica and pyrite and marcasite are so similar that the composite percentage is adequate for our estimates of both processing and marketing feasibility.

The chemical contents of acetic acid extracts (supernates) from individual 5-foot intervals, composites, and the Ehrlinger and Masters (1974) samples are shown in table A2. These determinations are made by inductively coupled plasma analyses, and only 9 of the 31 elements occur at concentrations great enough to be detectable. The results show that the dune sands contain small amounts of all the elements, and so little calcium and magnesium are present in the dune sand samples (3706 and 3707) that an acid or carbonate flotation step may be eliminated from the process. The estimated contents of the carbonate minerals are given in the last three columns of table A2; these estimates were calculated by converting the calcium and magnesium contents of each sample to calcite, dolomite, and total carbonate contents.

Table A1 Average mineral composition (as percentages) determined by XRD analysis (recalculated based upon XRD factors modified from XRF chemical analyses) and ratios of K-spar and Na-plag.

Sample (bulk pack)	Illite & mica	Chlorite	Horn-blende	Quartz	K-spar	Plag	Calcite	Dolomite	Pyrite/ marcasite	Total feldspar	K-spar ratio[1,2]	K-spar ratio[1,2]	Na-plag ratio[1,3]
3707A	1.8	0.4	0.7	80	6.2	10	0.0	0.0	0.4	17	0.37		
3707B	1.7	0.7	0.5	77	5.9	14	0.0	0.0	0.8	20	0.30		
3707C	2.7	0.5	0.6	74	8.8	11	0.0	0.0	1.6	20	0.43		
3707D	2.3	0.4	0.3	82	5.3	8.9	0.0	0.0	0.3	14	0.37		
Mean	2.1	0.5	0.5	78	6.5	11			0.8	18	0.37		
Std dev	0.42	0.13	0.14	3.0	1.3	1.8			0.50	2.4	0.05		
3706A	1.3	1.6	0.6	75	5.8	15	ND[4]	ND	ND	21	0.28	0.37	0.58
3707F	0.9	0.4	0.5	83	7.8	7.1	0.0	0.0	0.0	15	0.52		
3707G	1.3	0.2	0.3	79	8.2	10	0.0	0.0	0.7	18	0.45		
3707H	1.7	0.3	0.2	78	9.7	10	0.0	0.0	0.0	20	0.49		
3707I	1.9	0.2	0.1	80	7.9	9.4	0.0	0.0	0.5	17	0.46		
3707J	2.6	0.4	0.6	74	10	12	0.0	0.0	0.0	22	0.45		
Mean	1.7	0.3	0.3	79	8.8	9.8			0.2	19	0.47		
Std dev	0.57	0.08	0.16	3.0	1.0	1.7			0.30	2.5	0.03		
3706B	1.5	0.8	0.5	82	3.8	11	ND	ND	ND	15	0.26	0.47	0.61
3707M	1.5	0.5	0.5	77	8.3	11	0.0	0.0	0.8	19	0.43		
3707N	1.7	0.6	0.7	77	9.0	9.7	0.0	0.0	0.8	19	0.48		
3707O	1.8	0.5	0.5	77	7.8	12	0.0	0.0	0.0	20	0.39		
3707P	1.6	0.3	0.2	74	10	13	0.0	0.0	0.3	23	0.43		
3707Q	1.7	0.6	0.4	80	7.5	9.4	0.0	0.0	0.5	17	0.44		
3707R	1.9	0.4	0.4	74	10	12	0.0	0.0	0.6	22	0.46		
3707S	2.0	0.6	0.6	74	9.3	13	0.0	0.0	0.7	23	0.41		
Mean	1.8	0.5	0.5	76	8.9	12			0.5	20	0.44		
Std dev	0.14	0.11	0.15	2.1	1.0	1.4			0.27	2.1	0.03		
3706C	1.5	0.9	0.6	74	4.5	18	ND	ND	ND	23	0.20	0.44	0.57
3707E[5]	2.4	0.8	1.0	68	8.8	16	1.2	2.0	0.0	25	0.35		
3707K[5]	1.3	0.4	0.4	76	7.2	11	1.8	1.8	0.3	18	0.39		
3707L[5]	1.4	0.4	0.3	71	9.6	11	2.3	3.3	0.3	21	0.46		
3707T[5]	1.9	0.4	0.2	74	10	13	0.3	0.0	0.0	23	0.43		
3707U[5]	1.2	0.4	0.6	62	11	16	3.4	5.8	0.0	27	0.40		
Mean	1.7	0.5	0.5	70	9.3	14			0.12	3	0.41		
Std dev	0.43	0.16	0.31	4.9	1.2	2.1			0.15	2.9	0.04		

[1] By XRD.
[2] Calculated ratio of %K-spar to %K-spar + %plagioclase feldspars.
[3] Calculated ratio of %Na-plag to %Na-plag + %Ca-plag.
[4] Not determined.
[5] Samples taken from the lacustrine sediments from the bottom of each of the three boreholes.

Table A3 gives the XRF data for these samples; it also includes a calculated loss on ignition (LOI), which is determined by subtracting the sum of the chemical oxides from 100%. A better LOI can be calculated by extracting the samples with acetic acid and employing a modified LOI procedure, which requires (1) heating to 110°C overnight and weighing, (2) heating the samples at 350°C for 4 hours and weighing, and (3) heating the samples for 2 hours at 1,000°C and weighing. The LOI for illite and mica, chlorite, hornblende, and pyrite/marcasite can then be calculated and, for validation and improved estimates of mineral content, compared with the result from heating. The liquid (supernates) from the acetic acid extractions can also be submitted for inductively coupled plasma analyses, and those results can be used to calculate calcite and dolomite contents.

Tables A4 and A5 show the averages and standard deviations of mineral contents of samples from the three boreholes and the lacustrine sediments in the boreholes. As shown in table A4, the dunes are composed of an average of about 74% silica and 21% feldspar. Small amounts of illite and mica, cholrite, hornblende, and pyrite/marcasite, totaling about 5%, also are present. Calcite and dolomite were detected by XRD in only the underlying lacustrine sediments. If the lacustrine sediments are grouped separately, they contain about 70% silica and 23% feldspar (table A5).

Table A6 shows the chemical oxide contents of sand in the boreholes, and table A7 lists the mineral contents as well as the chemical oxide contents of the sand from Ehrlinger and Masters (1974). Tables A5 to A8 indicate that the mineralogical as well as chemical oxide compositions of the sand as determined during the present study, agree closely with results of Ehrlinger and Masters (1974). The minor differences in the results of the two studies are due mainly to the separate identification by

Table A2 Acetic acid-extractable content (milligrams per gram of sample) as determined by inductively coupled plasma (ICP) chemical analyses and percentages of calcite and dolomite and their sums, calculated from ICP results.

Sample	Al	B	Ca	Fe	Mg	Mn	Na	S	Si	Calcite (%)	Dolomite (%)	Calcite + dolomite (%)
3706A	0.16	0.04	0.32	0.29	0.08	0.03	0.12	0.62	0.09	0.05	0.06	0.11
3706B	0.21	0.04	0.33	0.35	0.08	0.02	0.12	0.71	0.14	0.05	0.06	0.11
3706C	0.25	0.03	0.15	0.20	0.02	0.02	0.12	0.61	0.10	0.03	0.02	0.04
Mean	0.21	0.04	0.27	0.28	0.06	0.02	0.12	0.65	0.11	0.04	0.05	0.09
Std dev	0.04	0.001	0.09	0.06	0.03	0.003	0.002	0.04	0.02	0.01	0.02	0.03
3707A	0.41	0.07	0.55	0.20	0.06	0.01	0.13	0.18	0.18	0.11	0.05	0.16
3707B	0.37	0.08	0.96	0.41	0.09	0.02	0.17	0.12	0.32	0.20	0.07	0.27
3707C	0.28	0.09	0.85	0.56	0.57	0.03	0.17	0.14	0.51	0.00	0.43	0.41
3707D	0.20	0.15	0.41	0.17	0.14	0.02	0.17	0.21	0.12	0.05	0.10	0.15
Mean	0.31	0.10	0.69	0.33	0.21	0.02	0.16	0.16	0.28	0.09	0.16	0.25
Std dev	0.08	0.03	0.22	0.16	0.21	0.005	0.01	0.03	0.15	0.08	0.16	0.10
3707F	0.34	0.08	0.37	0.16	0.03	0.01	0.12	0.11	0.15	0.08	0.02	0.10
3707G	0.47	0.08	0.36	0.21	0.03	0.02	0.11	0.11	0.19	0.08	0.02	0.10
3707H	0.26	0.11	0.33	0.13	0.05	0.02	0.14	0.11	0.15	0.06	0.03	0.10
3707I	0.28	0.18	0.38	0.18	0.20	0.02	0.24	0.29	0.25	0.01	0.15	0.16
3707J	0.22	0.20	0.24	0.06	0.03	0.003	0.12	0.03	0.08	0.05	0.02	0.07
Mean	0.31	0.13	0.34	0.15	0.07	0.01	0.15	0.13	0.17	0.06	0.05	0.11
Std dev	0.09	0.05	0.05	0.05	0.07	0.01	0.05	0.08	0.06	0.02	0.05	0.03
3707M	0.48	0.08	0.34	0.28	0.02	0.005	0.11	0.20	0.15	0.07	0.02	0.09
3707N	0.48	0.09	0.29	0.29	0.03	0.005	0.12	0.18	0.20	0.06	0.02	0.08
3707O	0.49	0.08	0.43	0.18	0.03	0.01	0.13	0.13	0.19	0.10	0.02	0.12
3707P	0.64	0.07	0.29	0.14	0.04	0.01	0.12	0.14	0.23	0.05	0.03	0.09
3707Q	0.44	0.08	0.32	0.15	0.02	0.01	0.11	0.09	0.17	0.07	0.02	0.09
3707R	0.36	0.08	0.27	0.26	0.02	0.02	0.10	0.000	0.16	0.06	0.02	0.07
3707S	0.38	0.08	0.42	0.17	0.03	0.01	0.15	0.15	0.15	0.09	0.02	0.11
Mean	0.47	0.08	0.34	0.21	0.03	0.01	0.12	0.13	0.18	0.07	0.02	0.09
Std dev	0.09	0.005	0.06	0.06	0.01	0.004	0.02	0.06	0.03	0.02	0.01	0.02
3707E[1]	0.42	0.15	4.8	0.30	1.2	0.03	0.23	0.18	0.24	0.73	0.88	1.6
3707K[1]	0.29	0.14	6.3	0.19	1.2	0.02	0.20	0.31	0.13	1.1	0.92	2.0
3707L[1]	0.24	0.14	7.1	0.20	2.0	0.02	0.15	0.23	0.12	0.95	1.5	2.4
3707T[1]	0.34	0.14	0.46	0.17	0.03	0.02	0.20	0.24	0.14	0.10	0.02	0.12
3707U[1]	0.74	0.12	9.6	0.24	3.1	0.03	0.21	0.000	0.41	1.1	2.4	3.5
Ave	0.39	0.14	5.3	0.21	1.3	0.02	0.19	0.16	0.20	0.76	1.0	1.8
Std dev	0.17	0.01	2.9	0.05	1.0	0.01	0.02	0.12	0.10	0.34	0.77	1.1
3669A[2]	0.29	0.14	3.3	0.15	0.47	0.03	0.18	0.000	0.14	0.62	0.36	0.98

[1] Samples taken from the lacustrine sediments from the bottom of each of the three boreholes.
[2] Ehrlinger and Masters (1974) sample.

Table A3 Chemical content (as percentages) by XRF chemical analyses.

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	P_2O_5	MnO	LOI[1]	Sr (ppm)	Ba (ppm)	Zr (ppm)
3706A[2]	87.78	5.36	1.87	0.71	0.40	1.63	0.87	0.34	0.06	0.03	0.95	121	279	244
3706B[2]	89.83	4.97	0.92	0.42	0.24	1.77	0.75	0.17	0.02	0.02	0.89	109	317	80
3706C[2]	88.67	5.36	1.18	0.53	0.31	1.83	0.84	0.22	0.07	0.02	0.97	111	327	123
3706A[3]	88.64	5.01	1.04	0.54	0.15	1.43	0.81	0.12	0.01	0.03	2.2	93	65	124
3706B[3]	89.11	5.31	1.00	0.44	0.26	1.81	0.77	0.18	0.03	0.02	1.1	105	311	66
3706C[3]	87.90	5.67	1.40	0.59	0.34	1.89	0.87	0.27	0.04	0.03	1.0	119	338	193
3669A[3]	85.14	5.34	1.58	1.90[4]	0.72[4]	1.76	0.92	0.29	0.06	0.03	2.3	128	305	256

[1] Calculated as 100% minus sum of oxides.
[2] Samples screened <1 mm >65 μm.
[3] Bulk samples.
[4] Percentages are elevated because of the presence of calcite and dolomite.

Ehrlinger and Masters of mixed-mineral (silica and feldspar) grains, feldspathic rock fragments, and chert.

Table A8 gives the particle-size distributions for composite samples of the dune sands in the three cores. Dune sands in general have narrow ranges of particle size, which seem to fit this normal trend. Although the average particle-size ranges reported in table A8 are coarser than those found in the 1974 study, the range is similar in both studies. The finer average particle size found in the earlier study indicates that the samples of Ehrlinger and Masters (1974) were from the finer, distal (i.e., farther downwind and thinner) parts of dunes, suggesting that part or all of the difference in feldspar content, if any, is due to differences in sampling sites for the two studies.

Table A4 Average (mean ± standard deviation) mineral content for dune sands in three borings, calculated from XRF and XRD analyses (see table A1).

Mineral	Content (%)	Analysis
Quartz	73.5 ± 1.5	XRF
K-feldspar	8.8 ± 1.3	XRF
Plagioclase	11.8 ± 0.9	XRF
Total feldspar	20.6 ± 1.6	XRF
Illite and mica	1.4 ± 0.1	XRD
Chlorite	1.1 ± 0.4	XRD
Hornblende	0.6 ± 0.1	XRD
Pyrite/marcasite	0.1 ± 0.2	XRD

Table A5 Average (mean ± standard deviation) mineral content for lacustrine sediments in three borings, calculated from XRF and XRD analyses (see table A1).

Mineral	Content (%)	Analysis
Quartz	70 ± 4.9	XRF
K-feldspar	9.3 ± 1.2	XRF
Plagioclase	13.6 ± 2.2	XRF
Total feldspar	22.9 ± 2.9	XRF
Calcite	1.8 ± 1.0	XRF
Dolomite	2.6 ± 1.9	XRF
Illite and mica	1.7 ± 0.4	XRD
Chlorite	0.5 ± 0.2	XRD
Hornblende	0.5 ± 0.3	XRD
Pyrite/marcasite	0.1 ± 0.2	XRD

Table A6 Average (mean ± standard deviation) chemical oxide content for dune sands in three borings, determined by XRF analyses (see table A3).

Chemical oxide	Content (%)
SiO_2	88.6 ± 0.5
Al_2O_3	5.33 ± 0.3
Fe_2O_3	1.15 ± 0.2
CaO	0.53 ± 0.06
MgO	0.25 ± 0.08
K_2O	1.71 ± 0.20
Na_2O	0.82 ± 0.04
TiO_2	0.19 ± 0.06
P_2O_5	0.03 ± 0.01
MnO	0.03 ± 0.01
LOI[1]	1.43 ± 0.56

[1] Calculated as 100% minus the sum of the other oxides.

Table A7 Average chemical oxide and mineralogical composition for dune sands from 13 samples from Ehrlinger and Masters (1974).

Chemical	(%)	Mineral	(%)
K_2O	1.45	Quartz	69.9
Na_2O	0.89	Feldspar	17.65
CaO	0.68	Quartz/feldspar mixed	6.05
Al_2O_3	5.03	Feldspathic rock fragments	1.53
SiO_2	85.07	Chert	0.90
Fe_2O_3	1.23	Heavy minerals	1.32
TiO_2	0.18	Weight loss	2.65
Weight loss	4.47	Total	
Total	100.00		

Table A8 Particle size obtained by wet screening of composite samples of dune sands from boreholes 1, 3, and 5 (weight percentages).

	Screen size					
Composite	>1 mm	1–0.5 mm	500–250 μm	250–125 μm	125–63 μm	<63 μm
Borehole 1	0.00	34	32	27	3.1	3.2
Borehole 3	0.02	32	17	39	8.7	3.6
Borehole 5	0.00	6.9	31	53	7.6	2.2

Appendix B Plant Investments and Hourly Costs for Mining Dune Sands

Table B1 Plant investments for mining and processing dune sands near Kankakee, Illinois (in 1997 U.S. dollars).

EQUIPMENT COMMON TO ALL FOUR FLOW DIAGRAMS		
Mining		
1 Rear dump truck, 20 tons, 15-yd³ capacity, 180 hp (SU 34)[1]		$276,000
1 Wheel loader, 3.5-yd³ bucket, 9 ft 4 in dump half-ton, 170 hp (SU 22)		$221,000
	Subtotal 1	**$497,000**
Processing plant		
1 Feed storage bin, hopper bottom, 9 ft × 24 ft, 1,277 ft³, 50–60 tons (MI 108)		$12,800
1 Feeder belt (estimated)		$1,000
1 Inclined screen, 6 ft × 12 ft, single deck, 7.5 hp (ML 58)		$16,265
2 Tanks, one with stirrers, for acid treatment and mixing (company quote to L.A. Khan for 15 tons/hr + $120,000; estimated cost by the 0.6 rule)		$200,000
1 Slurry pump, centrifugal, 1,000 gal/min to handle 32 tons/hr solids in a 20% solids slurry, 50 ft head, 20 hp (MI 86)		$14,284
1 Hydrocyclone, 15 inches steel/rubber, 250–1,000 gal/min, 20% solids (ML 18)		$4,590
	Subtotal 2	**$248,939**
ADDITIONAL EQUIPMENT		
Flow diagram I: Amber glass sand		
1 Wet magnetic drum separator, 36 in × 5 ft drum, 6–7 tons/hr per foot of drum length capacity (ML 46; see also CIM[2])		$44,480
1 Dryer, rotary, gas fired, 6 in × 50 ft, 2,120–11,310 lbs of water/hr (ML 20)		$175,000
1 Dry product storage bin, 2,500-ton capacity, 5 days of production (MI 108), Using 0.6 rule applied to the 29 ft × 72 ft tank		$200,000
	Subtotal 3	**$419,480**
	Total for flow diagram I	**$1,165,419**
Flow diagram II: Foundry sand and amber glass sand		
1 Wet magnetic drum separator, 36 in × 5 ft drum, 6–7 tons/hr per foot of drum length capacity (ML 46; see also CIM),		$44,480
1 Dryer as in flow diagram I.		$175,000
1 Air classifier (separator), 10 ft × 17 ft, 40 tons/hr with motor		$93,000
1 Dry product storage bin for foundry sand, 1,300-ton capacity (estimated by the 0.6 rule from flow diagram I)		$135,100
1 Dry product storage bin for amber glass sand, 1,200-ton capacity (estimated by the 0.6 rule from flow diagram I)		$128,800
	Subtotal 4	**$576,380**
	Total for flow diagram II	**$1,322,319**

Flow diagram III: Feldspar and amber glass sand

20 Spirals @ 2 tons/hr capacity, $4,000 each (company quote to L.A. Khan)	$80,000
1 Wet magnetic drum separator, 36 in × 5 ft drum, 6–7 tons/hr per foot of drum length capacity (ML 46; see also CIM)	$44,480
1 Tank, 32 tons/hr capacity (estimated from data common to flow diagrams I, II, and III)	$100,000
1 Flotation circuit: 20 cells @ 22.5-ft^3 capacity (25 tons/day), $7,400 per cell (ML 32)	$148,000
5 Motors, 900 rpm, 7.5 hp each, @ $1,657 (MI 46)	$8,285
1 Dewatering cyclone for feldspar, 5.3 tons/hr, 20% solids, 6-in diameter, steel/rubber, 55–130 gal/min (ML 18)	$2,255
1 Dewatering cyclone for amber sand, 26 tons/hr, 20% solids, 15-in diameter, steel/rubber, 250–1,000 gal/min (ML 18)	$4,590
1 Tank for feldspar circuit, 4,000 gal (MI 106)	$4,100
1 Tank for amber glass sand circuit, 10,000 gal (MI 106)	$11,000
2 Feeder belts @ $1,000	$2,000
1 Dryer, rotary, gas fired for feldspar, 4 in × 30 ft, 560–3,020 lbs of water/hr, 20 hp (ML 20)	$110,000
1 Dryer, rotary, gas fired for amber glass sand, 6 in × 50 ft, as in flow diagram I (ML 20)	$175,000
1 Dry product storage bin for feldspar, 425-ton capacity, 5 days of production (estimated by the 0.6 rule from flow diagram I)	$69,000
1 Dry product storage bin for amber glass sand, 2,100-ton capacity, 5 days of production (estimated by the 0.6 rule)	$180,000
Subtotal 5	**$938,710**
Total for flow diagram III	**$1,684,649**

Flow diagram IV: Feldspar

1 Tank, 32 tons/hr capacity (estimated from data common to all flow diagrams above)	$100,000
1 Flotation circuit: 20 cells @ 22.5-ft^3 capacity (25 tons/day), $7,400 per cell (ML 32)	$148,000
5 Motors, 900 rpm, 7.5 hp each, @ $1,657 (MI 46)	$8,285
20 Spirals @ 2 tons/hr capacity, $4,000 each (company quote to L.A. Khan)	$80,000
1 Wet magnetic drum separator, 36 in × 5 ft drum, 6–7 tons/hr per foot of drum length capacity (ML 46; see also CIM)	$28,800
1 Dewatering cyclone for feldspar, 5.3 tons/hr, 20% solids, 6-in diameter, steel/rubber, 55–130 gal/min (ML 18)	$2,255
1 Feeder belt	$1,000
1 Dryer, rotary, gas fired for feldspar, 4 in × 30 ft, 560–3,020 lbs of water/hr, 20 hp (ML 20)	$110,000
1 Dry product storage bin for feldspar, 550-ton capacity, 5 days of production (estimated by the 0.6 rule from flow diagram I)	$80,000
Subtotal 6	**$558,340**
Total for flow diagram IV (subtotals 1 + 2 + 6)	**$1,304,279**

[1] Numbers in parentheses refer to page numbers in *Mine and Mill Equipment Costs: An Estimator's Guide* (Western Mine Engineering, Inc. 2000).

[2] Canadian Institute of Mining and Metallurgy (1982).

Table B2 Hourly costs for mining and processing dune sands near Kankakee, Illinois (in 1997 U.S. dollars).

EQUIPMENT COMMON TO ALL FOUR FLOW DIAGRAMS

	Parts	Maint. labor	Lube	Tires	Electricity	Gas	Total
Mining							
Rear dump truck	$2.78	$2.96	$2.02	$1.78	$2.23		$11.77
Wheel loader	$3.78	$3.12	$3.42	$1.45	$2.13		$13.90
						Subtotal 1	**$25.67**
Processing plant							
Feed storage bin	$0.26	$0.18					$0.44
Feeder belt	$0.03	$0.02					$0.05
Inclined screen	$0.52	$0.58	$0.14				$1.24
Tanks (estimated at 1% of investment per year)							$0.65
Slurry pump	$0.72	$1.39					$2.11
Hydrocyclone	$0.03	$0.03					$0.06
						Subtotal 2	**$4.55**

ADDITIONAL EQUIPMENT

	Parts	Maint. labor	Lube	Tires	Electricity	Gas	Total
Flow diagram I: Amber glass sand							
Magnetic separator	$0.53	$0.43	$0.25		$0.48		$1.69
Dryer	$0.63	$0.51	$1.00		$1.90	$41.83	$45.87
Product bin	$4.04	$2.85					$6.89
						Subtotal 3	**$54.45**
						Total for flow diagram I subtotals 1 + 2 + 3)	**$84.67**

	Parts	Maint. labor	Lube	Tires	Electricity	Gas	Total
Flow diagram II: Foundry sand and amber glass sand							
Magnetic separator	$0.53	$0.43	$0.25		$0.48		$1.69
Dryer (as in I)							$45.87
1 Air classifier (separator)	$1.11	$0.90	$0.53		$0.79		$3.33
Product bin (foundry sand) 52% of capacity of bin in I, prorated							$3.58
Product bin (amber glass sand) 48% of capacity of bin in I, prorated							$3.31
						Subtotal 4	**$57.78**
						Total for flow diagram II (subtotals 1 + 2 + 4)	**$88.00**

	Parts	Maint. labor	Lube	Tires	Electricity	Gas	Total
Flow diagram III: Feldspar and amber glass sand							
Spirals (estimated 7% of investment based on ML 67)							$1.75
Magnetic separator	$0.53	$0.43	$0.25		$0.48		$1.69
Tank (estimated 1% of investment per year, see data common to all flow diagrams)							$0.35
20 Flotation cells (per cell)	$0.09	$0.07	$0.04		$0.12		$6.40[1]
5 Electric motors(per motor)	$0.04	$0.06	$0.01		$0.24		$1.75[2]
Cyclone for feldspar	$0.02	$0.01					$0.03
Cyclone for amber glass	$0.03	$0.03					$0.06
Tank for feldspar	$0.08	$0.06					$0.14
Tank for amber glass sand	$0.22	$0.16					$0.38
Feeder belt	$0.03	$0.02					$0.05
Feeder belt	$0.03	$0.02					$0.05
Dryer for feldspar	$0.39	$0.32	$0.63		$0.63	$11.09	$13.06
Dryer for amber glass sand	$0.63	$0.51	$1.00		$1.90	$41.83	$45.87
Product bin (feldspar) 35% of capacity of bin in I, prorated							$2.38
Product bin (amber glass sand) 90% of capacity of bin in I, prorated							$6.20
Subtotal 5							**$80.16**
Total for flow diagram III (subtotals 1 + 2 + 5)							**$110.38**

	Parts	Maint. labor	Lube	Tires	Electricity	Gas	Total
Flow diagram IV: Feldspar							
Tank (estimated 1% of investment per year, see data common to all flow diagrams)							$0.35
20 Flotation cells (per cell)	$0.09	$0.07		$0.04	$0.12		$6.40[1]
5 Electric motors (per motor)	$0.04	$0.06		$0.01	$0.24		$1.75[2]
Spirals (estimated 7% of investment based on ML 67)							$1.75
Magnetic separator	$0.34	$0.28		$0.16	$0.16		$0.94
Cyclone for feldspar	$0.02	$0.01					$0.03
Feeder belt	$0.03	$0.02					$0.05
Dryer for feldspar	$0.39	$0.32		$0.63	$0.63	$11.09	$13.06
Product bin (feldspar), 35% of capacity of bin in I, prorated							$2.76
Subtotal 6							**$27.09**
Total for flow diagram IV (subtotals 1 + 2 + 6)							**$57.31**

[1] Total is for 20 cells.
[2] Total is for 5 electric motors.

Appendix C Net Present Value Analyses

Table C1 Break-even price estimates using net present value method for the procedure described in flow diagram I.

Selling price product mix ($/ton)	10.02
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,165,419
Transport, installation, pumps, pipes, instrumentation ($)	501,130

Product breakdown	(%)	($/ton)	(tons/yr)
Sand	91	11.01	101,920
Loss	9	0.00	10,080

	Year 0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	1,666,549	1,666,549	1,333,239	1,066,591	853,273	682,619	546,095	436,876	349,501
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		85							
Operation (hrs/day per person)		8							
Operation (days/yr)		200							
Annual throughput (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		270,944	279,072	287,444	296,068	304,950	314,098	323,521	333,227
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		10							
Wages and benefits ($/yr)		314,080							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		386,560	398,157	410,102	422,405	435,077	448,129	461,573	475,420
Working capital (3 months) ($)		280,535	288,951	288,951	288,951	288,951	288,951	288,951	288,951
Interest on working capital at 9% ($)		34,790	35,834	36,909	38,016	39,157	40,332	41,542	42,788
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		333,310	266,648	213,318	170,655	136,524	109,219	87,375	69,900
Cumulative depreciation ($)		333,310	599,958	813,276	983,931	1,120,454	1,229,673	1,317,048	1,386,949
Revenues ($/yr)		1,122,139	1,144,582	1,167,474	1,190,823	1,214,640	1,238,932	1,263,711	1,288,985
Total expenses for the year ($)		814,694	715,535	737,001	759,111	781,885	805,341	829,501	854,386
Net operating income ($)		307,445	429,047	430,472	431,712	432,755	433,591	434,210	434,599
Net income after depreciation ($)		(25,865)	162,399	217,154	261,057	296,231	324,372	346,834	364,699
Taxable income ($)		0	162,399	217,154	261,057	296,231	324,372	346,834	364,699
Taxes paid ($)		0	64,960	86,862	104,423	118,492	129,749	138,734	145,879
Net income after taxes ($)		0	97,439	130,292	156,634	177,739	194,623	208,101	218,819
Cash flow after taxes, incl. deprec. ($)	(1,666,549)	307,445	364,087	343,611	327,289	314,262	303,842	295,476	288,719
Net present value (at 18% discount rate)	1,431								
Required price schedule ($/ton)		10.02	10.22	10.42	10.63	10.84	11.06	11.28	11.51

Table C2 Break-even price estimates using the net present value method for the procedure described in flow diagram II.

Selling price product mix ($/ton)	10.56
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,322,319
Transport, installation, pumps, pipes, instrumentation ($)	568,597

Product breakdown	(%)	($/ton)	(tons/yr)
Foundry sand	44	11.00	49,280
Amber glass sand	47	12.17	52,640
Losses	9	0.00	10,080

	Year 0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	1,890,916	1,890,916	1,512,733	1,210,186	968,149	774,519	619,615	495,692	396,554
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		88							
Operating (hrs/day per person)		8							
Operation (days/yr)		200							
Annual throughput (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		281,600	290,048	298,749	307,712	316,943	326,452	336,245	346,332
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		10							
Wages and benefits ($/yr)		314,080							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		386,560	398,157	410,102	422,405	435,077	448,129	461,573	475,420
Working capital (3 months) ($)		295,677	304,548	304,548	304,548	304,548	304,548	304,548	304,548
Interest on working capital at 9% ($)		34,790	35,834	36,909	38,016	39,157	40,332	41,542	42,788
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		378,183	302,547	242,037	193,630	154,904	123,923	99,138	79,311
Cumulative depreciation ($)		378,183	680,730	922,767	1,116,397	1,271,301	1,395,224	1,494,362	1,573,673
Revenues ($/yr)		1,182,709	1,206,363	1,230,490	1,255,100	1,280,202	1,305,806	1,331,922	1,358,561
Total expenses for the year ($)		825,350	726,511	748,306	770,755	793,878	817,694	842,225	867,492
Net operating income ($)		357,358	479,852	482,184	484,345	486,324	488,112	489,697	491,069
Net income after depreciation ($)		(20,825)	177,305	240,147	290,715	331,420	364,189	390,558	411,758
Taxable income ($)		0	177,305	240,147	290,715	331,420	364,189	390,558	411,758
Taxes paid ($)		0	70,922	96,059	116,286	132,568	145,675	156,223	164,703
Net income after taxes ($)		0	106,383	144,088	174,429	198,852	218,513	234,335	247,055
Cash flow after taxes, incl. deprec. ($)	(1,890,916)	357,358	408,930	386,125	368,059	353,756	342,436	333,474	326,365
Net present value (at 18% discount rate)	1,413								
Required price schedule ($/ton)		10.56	10.77	10.99	11.21	11.43	11.66	11.89	12.13

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Year											
9	10	11	12	13	14	15	16	17	18	19	20
279,601	223,680	178,944	143,155	0	0	0	0	0	0	0	0
343,224	353,520	364,126	375,050	386,301	397,890	409,827	422,122	434,786	447,829	461,264	475,102
489,683	504,373	519,504	535,089	551,142	567,676	584,707	602,248	620,315	638,925	658,093	677,835
288,951	288,951	288,951	288,951	288,951	288,951	288,951	288,951	288,951	288,951	288,951	288,951
44,071	45,394	46,755	48,158	49,603	51,091	52,624	54,202	55,828	57,503	59,228	61,005
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
55,920	44,736	35,789	143,155	0	0	0	0	0	0	0	0
1,442,869	1,487,605	1,523,394	1,666,549	1,666,549	1,666,549	1,666,549	1,666,549	1,666,549	1,666,549	1,666,549	1,666,549
1,314,765	1,341,060	1,367,881	1,395,239	1,423,144	1,451,607	1,480,639	1,510,252	1,540,457	1,571,266	1,602,691	1,634,745
880,018	906,419	933,611	961,620	990,468	1,020,182	1,050,788	1,082,311	1,114,781	1,148,224	1,182,671	1,218,151
434,747	434,642	434,270	433,620	432,676	431,425	429,851	427,940	425,676	423,042	420,020	416,594
378,827	389,906	398,481	290,464	432,676	431,425	429,851	427,940	425,676	423,042	420,020	416,594
378,827	389,906	398,481	290,464	432,676	431,425	429,851	427,940	425,676	423,042	420,020	416,594
151,531	155,962	159,393	116,186	173,070	172,570	171,940	171,176	170,270	169,217	168,008	166,638
227,296	233,943	239,089	174,278	259,605	258,855	257,911	256,764	255,406	253,825	252,012	249,956
283,216	278,679	274,878	317,434	259,605	258,855	257,911	256,764	255,406	253,825	252,012	249,956
11.74	11.97	12.21	12.46	12.71	12.96	13.22	13.48	13.75	14.03	14.31	14.60

Year											
9	10	11	12	13	14	15	16	17	18	19	20
317,243	253,794	203,036	162,428	0	0	0	0	0	0	0	0
356,722	367,424	378,447	389,800	401,494	413,539	425,945	438,724	451,885	465,442	479,405	493,787
489,683	504,373	519,504	535,089	551,142	567,676	584,707	602,248	620,315	638,925	658,093	677,835
304,548	304,548	304,548	304,548	304,548	304,548	304,548	304,548	304,548	304,548	304,548	304,548
44,071	45,394	46,755	48,158	49,603	51,091	52,624	54,202	55,828	57,503	59,228	61,005
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
63,449	50,759	40,607	162,428	0	0	0	0	0	0	0	0
1,637,122	1,687,881	1,728,488	1,890,916	1,890,916	1,890,916	1,890,916	1,890,916	1,890,916	1,890,916	1,890,916	1,890,916
1,385,732	1,413,446	1,441,715	1,470,550	1,499,961	1,529,960	1,560,559	1,591,770	1,623,606	1,656,078	1,689,199	1,722,983
893,517	920,322	947,932	976,370	1,005,661	1,035,831	1,066,906	1,098,913	1,131,880	1,165,837	1,200,812	1,236,836
492,215	493,124	493,783	494,180	494,300	494,129	493,653	492,857	491,725	490,241	488,388	486,147
428,766	442,365	453,176	331,751	494,300	494,129	493,653	492,857	491,725	490,241	488,388	486,147
428,766	442,365	453,176	331,751	494,300	494,129	493,653	492,857	491,725	490,241	488,388	486,147
171,507	176,946	181,271	132,701	197,720	197,652	197,461	197,143	196,690	196,096	195,355	194,459
257,260	265,419	271,906	199,051	296,580	296,477	296,192	295,714	295,035	294,145	293,033	291,688
320,708	316,178	312,513	361,479	296,580	296,477	296,192	295,714	295,035	294,145	293,033	291,688
12.37	12.62	12.87	13.13	13.39	13.66	13.93	14.21	14.50	14.79	15.08	15.38

Table C3 Break-even price estimates using net present value method for the procedures described in flow diagram III (scenario A)

Selling price product mix ($/ton)	12.89
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,684,649
Transport, installation,pumps, pipes, instrumentation ($)	724,399

Product breakdown	(%)	($/ton)	(tons/yr)
Feldspar	17	41.69	19,040
Amber glass sand	72.5	8.00	81,200
Losses	10.5	0.00	11,760

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	2,409,048	2,409,048	1,927,238	1,541,791	1,233,433	986,746	789,397	631,517	505,214
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		110							
Operating (hrs/day per person)		8							
Operation (days/yr)		200							
Annual production (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		353,216	363,812	374,727	385,969	397,548	409,474	421,758	434,411
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		12							
Wages and benefits ($/yr)		376,896							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		449,376	462,857	476,743	491,045	505,777	520,950	536,578	552,676
Working capital (3 months) ($)		360,844	371,670	371,670	371,670	371,670	371,670	371,670	371,670
Interest on working capital at 9% ($)		40,444	41,657	42,907	44,194	45,520	46,885	48,292	49,741
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		481,810	385,448	308,358	246,687	197,349	157,879	126,303	101,043
Cumulative depreciation ($)		481,810	867,257	1,175,615	1,422,302	1,619,651	1,777,531	1,903,834	2,004,877
Revenues ($/yr)		1,443,378	1,472,245	1,501,690	1,531,724	1,562,358	1,593,605	1,625,478	1,657,987
Total expenses for the year ($)		965,436	870,799	896,923	923,831	951,545	980,092	1,009,495	1,039,779
Net operating income ($)		477,942	601,446	604,767	607,893	610,813	613,514	615,983	618,208
Net income after depreciation ($)		(3,868)	215,999	296,409	361,207	413,464	455,634	489,680	517,165
Taxable income ($)		0	215,999	296,409	361,207	413,464	455,634	489,680	517,165
Taxes paid ($)		0	86,399	118,564	144,483	165,385	182,254	195,872	206,866
Net income after taxes ($)		0	129,599	177,845	216,724	248,078	273,381	293,808	310,299
Cash flow after taxes, incl. deprec. ($)	(2,409,048)	477,942	515,047	486,204	463,411	445,427	431,260	420,111	411,342
Net present value (at 18% discount rate)	318								
Required price schedule ($/ton)		12.89	13.15	13.41	13.68	13.95	14.23	14.51	14.80

Table C4 Break-even price estimates using the net present value method for the procedure described in flow diagram III (scenario B)

Selling price product mix ($/ton)	12.89
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,684,649
Transport, installation, pumps, pipes, instrumentation ($)	724,399

Product breakdown	(%)	($/ton)	(tons/yr)
Feldspar	21	36.40	23,520
Amber glass sand	68.5	7.66	76,720
Losses	10.5	0.00	11,760

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	2,409,048	2,409,048	1,927,238	1,541,791	1,233,433	986,746	789,397	631,517	505,214
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		110							
Operation (hr/day per person)		8							
Operation (days/yr)		200							
Annual production (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		353,216	363,812	374,727	385,969	397,548	409,474	421,758	434,411
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		12							
Wages and benefits ($/yr)		376,896							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		449,376	462,857	476,743	491,045	505,777	520,950	536,578	552,676
Working capital (3 months) ($)		360,951	371,779	371,779	371,779	371,779	371,779	371,779	371,779
Interest on working capital at 9% ($)		40,444	41,657	42,907	44,194	45,520	46,885	48,292	49,741
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		481,810	385,448	308,358	246,687	197,349	157,879	126,303	101,043
Cumulative depreciation ($)		481,810	867,257	1,175,615	1,422,302	1,619,651	1,777,531	1,903,834	2,004,877
Revenues ($/yr)		1,443,803	1,472,679	1,502,133	1,532,176	1,562,819	1,594,075	1,625,957	1,658,476
Total expenses for the year ($)		965,436	870,799	896,923	923,831	951,545	980,092	1,009,495	1,039,779
Net operating income ($)		478,367	601,880	605,210	608,345	611,274	613,984	616,462	618,697
Net income after depreciation ($)		(3,442)	216,433	296,852	361,658	413,924	456,104	490,159	517,654
Taxable income ($)		0	216,433	296,852	361,658	413,924	456,104	490,159	517,654
Taxes paid ($)		0	86,573	118,741	144,663	165,570	182,442	196,064	207,062
Net income after taxes ($)		0	129,860	178,111	216,995	248,355	273,663	294,095	310,592
Cash flow after taxes, incl. deprec. ($)	(2,409,048)	478,367	515,307	486,469	463,682	445,704	431,542	420,399	411,635
Net present value (at 18% discount rate)	1,720								
Required price schedule ($/ton)		12.89	13.15	13.41	13.68	13.95	14.23	14.5	14.81

Year											
9	10	11	12	13	14	15	16	17	18	19	20
404,171	323,337	258,670	206,936	0	0	0	0	0	0	0	0
447,443	460,867	474,693	488,934	503,602	518,710	534,271	550,299	566,808	583,812	601,327	619,366
569,256	586,334	603,924	622,041	640,703	659,924	679,722	700,113	721,117	742,750	765,033	787,984
371,670	371,670	371,670	371,670	371,670	371,670	371,670	371,670	371,670	371,670	371,670	371,670
51,233	52,770	54,353	55,984	57,663	59,393	61,175	63,010	64,900	66,848	68,853	70,919
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
80,834	64,667	51,734	206,936	0	0	0	0	0	0	0	0
2,085,711	2,150,379	2,202,112	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048
1,691,147	1,724,970	1,759,469	1,794,659	1,830,552	1,667,163	1,904,506	1,942,596	1,981,448	2,021,077	2,061,499	2,102,729
1,070,973	1,103,102	1,136,195	1,170,281	1,205,389	1,241,551	1,278,798	1,317,161	1,356,676	1,397,377	1,439,298	1,482,477
620,174	621,868	623,274	624,378	625,162	625,612	625,709	625,435	624,772	623,700	622,201	620,252
539,340	557,200	571,540	417,442	625,162	625,612	625,709	625,435	624,772	623,700	622,201	620,252
539,340	557,200	571,540	417,442	625,162	625,612	625,709	625,435	624,772	623,700	622,201	620,252
215,736	222,880	228,616	166,977	250,065	250,245	250,283	250,174	249,909	249,480	248,880	248,101
323,604	334,320	342,924	250,465	375,097	375,367	375,425	375,261	374,863	374,220	373,320	372,151
404,438	398,988	394,658	457,401	375,097	375,367	375,425	375,261	374,863	374,220	373,320	372,151
15.10	15.40	15.71	16.02	16.34	16.67	17.00	17.34	17.69	18.05	18.41	18.77

Year											
9	10	11	12	13	14	15	16	17	18	19	20
404,171	323,337	258,670	206,936	0	0	0	0	0	0	0	0
447,443	460,867	474,693	488,934	503,602	518,710	534,271	550,299	566,808	583,812	601,327	619,366
569,256	586,334	603,924	622,041	640,703	659,924	679,722	700,113	721,117	742,750	765,033	787,984
371,779	371,779	371,779	371,779	371,779	371,779	371,779	371,779	371,779	371,779	371,779	371,779
51,233	52,770	54,353	55,984	57,663	59,393	61,175	63,010	64,900	66,848	68,853	70,919
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
80,834	64,667	51,734	206,936	0	0	0	0	0	0	0	0
2,085,711	2,150,379	2,202,112	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048
1,691,646	1,725,478	1,759,988	1,795,188	1,831,092	1,867,713	1,905,068	1,943,169	1,982,032	2,021,673	2,062,107	2,103,349
1,070,973	1,103,102	1,136,195	1,170,281	1,205,389	1,241,551	1,278,798	1,317,161	1,356,676	1,397,377	1,439,298	1,482,477
620,673	622,376	623,793	624,907	625,702	626,162	626,270	626,008	625,356	624,296	622,809	620,872
539,838	557,709	572,059	417,971	625,702	626,162	626,270	626,008	625,356	624,296	622,809	620,872
539,838	557,709	572,059	417,971	625,702	626,162	626,270	626,008	625,356	624,296	622,809	620,872
215,935	223,084	228,824	167,188	250,281	250,465	250,508	250,403	250,142	249,719	249,123	248,349
323,903	334,625	343,235	250,783	375,421	375,697	375,762	375,605	375,214	374,578	373,685	372,523
404,737	399,293	394,969	457,718	375,421	375,697	375,762	375,605	375,214	374,578	373,685	372,523
15.10	15.41	15.71	16.03	16.35	16.68	17.01	17.35	17.70	18.05	18.41	18.78

Table C5 Break-even price estimates using the net present value method for the procedure described in flow diagram III (scenario C).

Selling price product mix ($/ton)	12.89				
Land purchase ($)	100,000	Product breakdown	(%)	($/ton)	(tons/yr)
Building cost ($)	20,000				
Equipment ($)	1,684,649	Feldspar	15	46.18	16,800
Transport, installation, pumps,		Amber glass sand	74.5	8.00	83,440
pipes, instrumentation ($)	724,399	Losses	10.5	0.00	11,760

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	2,409,048	2,409,048	1,927,238	1,541,791	1,233,433	986,746	789,397	631,517	505,214
Hourly production (tons)		35							
Hourly production (tons)		35							
Operating (hr/day per person)		8							
Operating (days/yr)		200							
Annual production (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		353,216	363,812	374,727	385,969	397,548	409,474	421,758	434,411
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		12							
Wages and benefits ($/yr)		376,896							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		449,376	462,857	476,743	491,045	505,777	520,950	536,578	552,676
Working capital (3 months) ($)		360,836	371,661	371,661	371,661	371,661	371,661	371,661	371,661
Interest on working capital at 9% ($)		40,444	41,657	42,907	44,194	45,520	46,885	48,292	49,741
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		481,810	385,448	308,358	246,687	197,349	157,879	126,303	101,043
Cumulative depreciation ($)		481,810	867,257	1,175,615	1,422,302	1,619,651	1,777,531	1,903,834	2,004,877
Revenues ($/yr)		1,443,344	1,472,211	1,501,655	1,531,688	1,562,322	1,593,568	1,625,440	1,657,949
Total expenses for the year ($)		965,436	870,799	896,923	923,831	951,545	980,092	1,009,495	1,039,779
Net operating income ($)		477,908	601,412	604,732	607,858	610,776	613,477	615,945	618,169
Net income after depreciation ($)		(3,901)	215,964	296,374	361,171	413,427	455,597	489,642	517,126
Taxable income ($)		0	215,964	296,374	361,171	413,427	455,597	489,642	517,126
Taxes paid ($)		0	86,386	118,550	144,468	165,371	182,239	195,857	206,851
Net income after taxes ($)		0	129,579	177,824	216,703	248,056	273,358	293,785	310,276
Cash flow after taxes, incl. deprec. ($)	(2,409,048)	477,908	515,026	486,183	463,389	445,406	431,238	420,088	411,319
Net present value (at 18% discount rate)	208								
Required price schedule ($/ton)		12.89	13.14	13.41	13.68	13.95	14.23	14.51	14.80

Table C6 Break-even price estimates using the net present value method for the procedure described in flow diagram IV (scenario A).

Selling price product mix ($/ton)	10.23				
Land purchase ($)	100,000	Product breakdown	(%)	($/ton)	(tons/yr)
Building cost ($)	20,000				
Equipment ($)	1,304,279	Feldspar	17	60.16	19,040
Transport, installation, pumps,		Amber glass sand	72.5	0.00	81,200
pipes, instrumentation ($)	560,840	Losses	10.5	0.00	11,760

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)1,865,119	1,865,119	1,492,095	1,193,676	954,941	763,953	611,162	488,930	391,144	
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		57							
Operating (hr/day per person)		8							
Operating (days/yr)		200							
Annual production (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		183,392	188,894	194,561	200,397	206,409	212,602	218,980	225,549
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		12							
Wages and benefits ($/yr)		376,896							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		449,376	462,857	476,743	491,045	505,777	520,950	536,578	552,676
Working capital (3 months) ($)		286,362	294,952	294,952	294,952	294,952	294,952	294,952	294,952
Interest on working capital at 9% ($)		40,444	41,657	42,907	44,194	45,520	46,885	48,292	49,741
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		373,024	298,419	238,735	190,988	152,791	122,232	97,786	78,229
Cumulative depreciation ($)		373,024	671,443	910,178	1,101,166	1,253,957	1,376,189	1,473,975	1,552,204
Revenues ($/yr)		1,145,446	1,168,355	1,191,722	1,215,557	1,239,868	1,264,665	1,289,959	1,315,758
Total expenses for the year ($)		795,612	695,880	716,757	738,259	760,407	783,219	806,716	830,917
Net operating income ($)		349,835	472,475	474,966	477,298	479,461	481,446	483,243	484,841
Net income after depreciation ($)		(23,189)	174,056	236,231	286,309	326,670	359,214	385,457	406,612
Taxable income ($)		0	174,056	236,231	286,309	326,670	359,214	385,457	406,612
Taxes paid ($)		0	69,622	94,492	114,524	130,668	143,685	154,183	162,645
Net income after taxes ($)		0	104,434	141,738	171,786	196,002	215,528	231,274	243,967
Cash flow after taxes, incl. deprec. ($)	(1,865,119)	349,835	402,853	380,474	362,774	348,793	337,761	329,060	322,196
Net present value (at 18% discount rate)	121								
Required price schedule ($/ton)		10.23	10.43	10.64	10.85	11.07	11.29	11.52	11.75

Year											
9	10	11	12	13	14	15	16	17	18	19	20
404,171	323,337	258,670	206,936	0	0	0	0	0	0	0	0
447,443	460,867	474,693	488,934	503,602	518,710	534,271	550,299	566,808	583,812	601,327	619,366
569,256	586,334	603,924	622,041	640,703	659,924	679,722	700,113	721,117	742,750	765,033	787,984
371,661	371,661	371,661	371,661	371,661	371,661	371,661	371,661	371,661	371,661	371,661	371,661
51,233	52,770	54,353	55,984	57,663	59,393	61,175	63,010	64,900	66,848	68,853	70,919
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
80,834	64,667	51,734	206,936	0	0	0	0	0	0	0	0
2,085,711	2,150,379	2,202,112	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048
1,691,108	1,724,930	1,759,428	1,794,617	1,830,509	1,867,119	1,904,462	1,942,551	1,981,402	2,021,030	2,061,451	2,102,680
1,070,973	1,103,102	1,136,195	1,170,281	1,205,389	1,241,551	1,278,798	1,317,161	1,356,676	1,397,377	1,439,298	1,482,477
620,135	621,828	623,233	624,336	625,120	625,568	625,664	625,389	624,726	623,653	622,153	620,203
539,300	557,160	571,499	417,400	625,120	625,568	625,664	625,389	624,726	623,653	622,153	620,203
539,300	557,160	571,499	417,400	625,120	625,568	625,664	625,389	624,726	623,653	622,153	620,203
215,720	222,864	228,600	166,960	250,048	250,227	250,266	250,156	249,890	249,461	248,861	248,081
323,580	334,296	342,900	250,440	375,072	375,341	375,399	375,234	374,835	374,192	373,292	372,122
404,415	398,964	394,633	457,376	375,072	375,341	375,399	375,234	374,835	374,192	373,292	372,122
15.10	15.40	15.71	16.02	16.34	16.67	17.00	17.34	17.69	18.04	18.41	18.77

Year											
9	10	11	12	13	14	15	16	17	18	19	20
312,915	250,332	200,266	160,212	0	0	0	0	0	0	0	0
232,315	239,285	246,464	253,857	261,473	269,317	277,397	285,719	294,290	303,119	312,213	321,579
569,256	586,334	603,924	622,041	640,703	659,924	679,722	700,113	721,117	742,750	765,033	787,984
294,952	294,952	294,952	294,952	294,952	294,952	294,952	294,952	294,952	294,952	294,952	294,952
51,233	52,770	54,353	55,984	57,663	59,393	61,175	63,010	64,900	66,848	68,853	70,919
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
1,614,787	1,664,853	1,704,906	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119
1,342,073	1,368,914	1,396,293	1,424,219	1,452,703	1,481,757	1,511,392	1,541,620	1,572,452	1,603,901	1,635,980	1,668,699
855,845	881,520	907,966	935,205	963,261	992,159	1,021,924	1,052,581	1,084,159	1,116,683	1,150,184	1,184,689
486,228	487,394	488,327	489,014	489,442	489,598	489,469	489,039	488,294	487,218	485,796	484,010
423,645	437,328	448,274	328,801	489,442	489,598	489,469	489,039	488,294	487,218	485,796	484,010
423,645	437,328	448,274	328,801	489,442	489,598	489,469	489,039	488,294	487,218	485,796	484,010
169,458	174,931	179,310	131,521	195,777	195,839	195,787	195,616	195,318	194,887	194,318	193,604
254,187	262,397	268,964	197,281	293,665	293,759	293,681	293,423	292,976	292,331	291,477	290,406
316,770	312,463	309,017	357,493	293,665	293,759	293,681	293,423	292,976	292,331	291,477	290,406
62,583	50,066	40,053	160,212	(0)	0	0	0	0	0	0	0
11.98	12.22	12.47	12.72	12.97	13.23	13.49	13.76	14.04	14.32	14.61	14.90

Table C7 Break-even price estimates using the net present value method for the procedure described in flow diagram IV (scenario B).

Selling price product mix ($/ton)	10.23
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,304,279
Transport, installation, pumps, pipes, instrumentation ($)	560,840

Product breakdown	(%)	($/ton)	(tons/yr)
Feldspar	15	68.20	16,800
Amber Glass Sand	74.5	0.00	83,440
Losses	10.5	0.00	11,760

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	1,865,119	1,865,119	1,492,095	1,193,676	954,941	763,953	611,162	488,930	391,144
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		57							
Operating (hr/day per person)		8							
Operating (days/yr)		200							
Annual production (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		183,392	188,894	194,561	200,397	206,409	212,602	218,980	225,549
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		12							
Wages and benefits ($/yr)		376,896							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		449,376	462,857	476,743	491,045	505,777	520,950	536,578	552,676
Working capital (3 months) ($)		286,440	295,033	295,033	295,033	295,033	295,033	295,033	295,033
Interest on working capital at 9% ($)		40,444	41,657	42,907	44,194	45,520	46,885	48,292	49,741
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		373,024	298,419	238,735	190,988	152,791	122,232	97,786	78,229
Cumulative depreciation ($)		373,024	671,443	910,178	1,101,166	1,253,957	1,376,189	1,473,975	1,552,204
Revenues ($/yr)		1,145,760	1,168,675	1,192,049	1,215,890	1,240,207	1,265,012	1,290,312	1,316,118
Total expenses for the year ($)		795,612	695,880	716,757	738,259	760,407	783,219	806,716	830,917
Net operating income ($)		350,148	472,795	475,292	477,630	479,800	481,792	483,596	485,201
Net income after depreciation ($)		(22,876)	174,376	236,557	286,642	327,010	359,560	385,810	406,972
Taxable income ($)		0	174,376	236,557	286,642	327,010	359,560	385,810	406,972
Taxes paid ($)		0	69,750	94,623	114,657	130,804	143,824	154,324	162,789
Net income after taxes ($)		0	104,626	141,934	171,985	196,206	215,736	231,486	244,183
Cash flow after taxes, incl. deprec. ($)	(1,865,119)	350,148	403,045	380,669	362,974	348,996	337,968	329,272	322,412
Net present value (at 18% discount rate)	1,154								
Required price schedule ($/ton)		10.23	10.43	10.64	10.86	11.07	11.29	11.52	11.75

Table C8 Break-even price estimates using the net present value method for the procedure described in flow diagram IV (scenario C).

Selling price product mix ($/ton)	10.23
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,304,279
Transport, installation, pumps, pipes, instrumentation ($)	560,840

Product breakdown	(%)	($/ton)	(tons/yr)
Feldspar	15	53.30	27,509
Amber glass sand	74.5	3.00	83,440
Losses	10.5	0.00	11,760

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	1,865,119	1,865,119	1,492,095	1,193,676	954,941	763,953	611,162	488,930	391,144
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		57							
Operating (hr/day per person)		8							
Operating (days/yr)		200							
Annual production (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		183,392	188,894	194,561	200,397	206,409	212,602	218,980	225,549
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		12							
Wages and benefits ($/yr))		376,896							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		449,376	462,857	476,743	491,045	505,777	520,950	536,578	552,676
Working capital (3 months) ($)		286,440	295,033	295,033	295,033	295,033	295,033	295,033	295,033
Interest on working capital at 9% ($)		40,444	41,657	42,907	44,194	45,520	46,885	48,292	49,741
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		373,024	298,419	238,735	190,988	152,791	122,232	97,786	78,229
Cumulative depreciation ($)		373,024	671,443	910,178	1,101,166	1,253,957	1,376,189	1,473,975	1,552,204
Revenues ($/yr)		1,145,760	1,168,675	1,192,049	1,215,890	1,240,207	1,265,012	1,290,312	1,316,118
Total expenses for the year ($)		795,612	695,880	716,757	738,259	760,407	783,219	806,716	830,917
Net operating income ($)		350,148	472,795	475,292	477,630	479,800	481,792	483,596	485,201
Net income after depreciation ($)		(22,876)	174,376	236,557	286,642	327,010	359,560	385,810	406,972
Taxable income ($)		0	174,376	236,557	286,642	327,010	359,560	385,810	406,972
Taxes paid ($)		0	69,750	94,623	114,657	130,804	143,824	154,324	162,789
Net income after taxes ($)		0	104,626	141,934	171,985	196,206	215,736	231,486	244,183
Cash flow after taxes, incl. deprec. ($)	(1,865,119)	350,148	403,045	380,669	362,974	348,996	337,968	329,272	322,412
Net present value (at 18% discount rate)	1,154								
Required price schedule ($/ton)		10.23	10.43	10.64	10.86	11.07	11.29	11.52	11.75

Year											
9	10	11	12	13	14	15	16	17	18	19	20
312,915	250,332	200,266	160,212	0	0	0	0	0	0	0	0
232,315	239,285	246,464	253,857	261,473	269,317	277,397	285,719	294,290	303,119	312,213	321,579
569,256	586,334	603,924	622,041	640,703	659,924	679,722	700,113	721,117	742,750	765,033	787,984
295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033
51,233	52,770	54,353	55,984	57,663	59,393	61,175	63,010	64,900	66,848	68,853	70,919
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
62,583	50,066	40,053	160,212	(0)	0	0	0	0	0	0	0
1,614,787	1,664,853	1,704,906	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119
1,342,440	1,369,289	1,396,675	1,424,609	1,453,101	1,482,163	1,511,806	1,542,042	1,572,883	1,604,341	1,636,427	1,669,156
486,596	487,769	488,709	489,404	489,840	490,004	489,882	489,461	488,724	487,657	486,243	484,467
424,013	437,703	448,656	329,191	489,840	490,004	489,882	489,461	488,724	487,657	486,243	484,467
424,013	437,703	448,656	329,191	489,840	490,004	489,882	489,461	488,724	487,657	486,243	484,467
169,605	175,081	179,462	131,677	195,936	196,002	195,953	195,784	195,490	195,063	194,497	193,787
254,408	262,622	269,194	197,515	293,904	294,002	293,929	293,677	293,235	292,594	291,746	290,680
316,991	312,688	309,247	357,727	293,904	294,002	293,929	293,677	293,235	292,594	291,746	290,680
855,845	881,520	907,966	935,205	963,261	992,159	1,021,924	1,052,581	1,084,159	1,116,683	1,150,184	1,184,689
11.99	12.23	12.47	12.72	12.97	13.23	13.50	13.77	14.04	14.32	14.61	14.90

Year											
9	10	11	12	13	14	15	16	17	18	19	20
312,915	250,332	200,266	160,212	0	0	0	0	0	0	0	0
232,315	239,285	246,464	253,857	261,473	269,317	277,397	285,719	294,290	303,119	312,213	321,579
569,256	586,334	603,924	622,041	640,703	659,924	679,722	700,113	721,117	742,750	765,033	787,984
295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033	295,033
51,233	52,770	54,353	55,984	57,663	59,393	61,175	63,010	64,900	66,848	68,853	70,919
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
62,583	50,066	40,053	160,212	(0)	0	0	0	0	0	0	
1,614,787	1,664,853	1,704,906	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119
1,342,440	1,369,289	1,396,675	1,424,609	1,453,101	1,482,163	1,511,806	1,542,042	1,572,883	1,604,341	1,636,427	1,669,156
855,845	881,520	907,966	935,205	963,261	992,159	1,021,924	1,052,581	1,084,159	1,116,683	1,150,184	1,184,689
486,596	487,769	488,709	489,404	489,840	490,004	489,882	489,461	488,724	487,657	486,243	484,467
424,013	437,703	448,656	329,191	489,840	490,004	489,882	489,461	488,724	487,657	486,243	484,467
424,013	437,703	448,656	329,191	489,840	490,004	489,882	489,461	488,724	487,657	486,243	484,467
169,605	175,081	179,462	131,677	195,936	196,002	195,953	195,784	195,490	195,063	194,497	193,787
254,408	262,622	269,194	197,515	293,904	294,002	293,929	293,677	293,235	292,594	291,746	290,680
316,991	312,688	309,247	357,727	293,904	294,002	293,929	293,677	293,235	292,594	291,746	290,680
11.99	12.23	12.47	12.72	12.97	13.23	13.50	13.77	14.04	14.32	14.61	14.90

Table C9 Break-even price estimates using net present value for the procedure described in flow diagram IV (scenario D).

Selling price product mix ($/ton)	10.23
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,304,279
Transport, installation, pumps, pipes, instrumentation ($)	560,840

Product breakdown	(%)	($/ton)	(tons/yr)
Feldspar	17	47.37	19,040
Amber glass sand	72.5	3.00	81,200
Losses	10.5	0.00	11,760

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	1,865,119	1,865,119	1,492,095	1,193,676	954,941	763,953	611,162	488,930	391,144
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		57							
Operating (hr/day per person)		8							
Operating (days/yr)		200							
Annual production (tons), 2 shifts/day		112,000							
Total operating cost ($/yr), 2 shifts/day		183,392	188,894	194,561	200,397	206,409	212,602	218,980	225,549
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		12							
Wages and benefits ($/yr)		376,896							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		449,376	462,857	476,743	491,045	505,777	520,950	536,578	552,676
Working capital (3 months) ($)		286,381	294,973	294,973	294,973	294,973	294,973	294,973	294,973
Interest on working capital at 9% ($)		40,444	41,657	42,907	44,194	45,520	46,885	48,292	49,741
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		373,024	298,419	238,735	190,988	152,791	122,232	97,786	78,229
Cumulative depreciation ($)		373,024	671,443	910,178	1,101,166	1,253,957	1,376,189	1,473,975	1,552,204
Revenues ($/yr)		1,145,525	1,168,435	1,191,804	1,215,640	1,239,953	1,264,752	1,290,047	1,315,848
Total expenses for the year ($)		795,612	695,880	716,757	738,259	760,407	783,219	806,716	830,917
Net operating income ($)		349,913	472,555	475,047	477,381	479,546	481,533	483,331	484,931
Net income after depreciation ($)		(23,111)	174,136	236,312	286,393	326,755	359,300	385,545	406,702
Taxable income ($)		0	174,136	236,312	286,393	326,755	359,300	385,545	406,702
Taxes paid ($)		0	69,654	94,525	114,557	130,702	143,720	154,218	162,681
Net income after taxes ($)		0	104,482	141,787	171,836	196,053	215,580	231,327	244,021
Cash flow after taxes, incl. deprec. ($)	(1,865,119)	349,913	402,901	380,523	362,824	348,844	337,813	329,113	322,250
Net present value (at 18% discount rate)	379								
Required price schedule ($/ton)		10.23	10.43	10.64	10.85	11.07	11.29	11.52	11.75

Table C10 Break-even price estimates using the net present value method for the procedure described in flow diagram III (high-capacity utilization scenario).

Selling price product mix ($/ton)	10.23
Land purchase ($)	100,000
Building cost ($)	20,000
Equipment ($)	1,684,649
Transport, installation, pumps, pipes, instrumentation ($)	724,399

Product breakdown	(%)	($/ton)	(tons/yr)
Feldspar	15	35.40	31,500
Amber glass sand	74.5	6.60	156,450
Losses	10.5	0.00	22,050

	Year								
	0	1	2	3	4	5	6	7	8
Total depreciable investment ($)	2,409,048	2,409,048	1,927,238	1,541,791	1,233,433	986,746	789,397	631,517	505,214
Hourly production (tons)		35							
Hourly operation/maintenance cost ($)		110							
Operating (hr/day per person)		8							
Operating (days/yr)		250							
Annual production (tons), 3 shifts/day		210,000							
Total operating cost ($/yr), 3 shifts/day		662,280	682,148	702,613	723,691	745,402	767,764	790,797	814,521
Hourly labor wage ($)		13							
Benefits (% of wages)		51							
Persons on wages (no.)		18							
Wages and benefits ($/yr)		706,680							
Foreman's salary ($/yr)		48,000							
Foreman's salary and benefits ($/yr)		72,480							
Total wages, salaries, benefits ($/yr)		779,160	802,535	826,611	851,409	876,951	903,260	930,358	958,269
Working capital (3 months) ($)		536,918	553,025	553,025	553,025	553,025	553,025	553,025	553,025
Interest on working capital at 9% ($)		70,124	72,228	74,395	76,627	78,926	81,293	83,732	86,244
Real estate taxes ($)		2,400	2,472	2,546	2,623	2,701	2,782	2,866	2,952
Depreciation (10-yr double declining balance) ($)		481,810	385,448	308,358	246,687	197,349	157,879	126,303	101,043
Cumulative depreciation ($)		481,810	867,257	1,175,615	1,422,302	1,619,651	1,777,531	1,903,834	2,004,877
Revenues ($/yr)		2,147,670	2,190,623	2,234,436	2,279,125	2,324,707	2,371,201	2,418,625	2,466,998
Total expenses for the year ($)		1,633,964	1,559,383	1,606,165	1,654,350	1,703,980	1,755,100	1,807,753	1,861,985
Net operating income ($)		513,706	631,240	628,271	624,775	620,727	616,102	610,873	605,012
Net income after depreciation ($)		31,896	245,792	319,913	378,088	423,378	458,222	484,569	503,970
Taxable income ($)		31,896	245,792	319,913	378,088	423,378	458,222	484,569	503,970
Taxes paid ($)		12,758	98,317	127,965	151,235	169,351	183,289	193,828	201,588
Net income after taxes ($)		19,138	147,475	191,948	226,853	254,027	274,933	290,741	302,382
Cash flow after taxes, incl. deprec. ($)	(2,409,048)	500,947	532,923	500,306	473,539	451,376	432,813	417,045	403,425
Net present value (at 18% discount rate)	1,453								
Required price schedule ($/ton)		10.23	10.43	10.64	10.85	11.07	11.29	11.52	11.75

Year											
9	10	11	12	13	14	15	16	17	18	19	20
312,915	250,332	200,266	160,212	0	0	0	0	0	0	0	0
232,315	239,285	246,464	253,857	261,473	269,317	277,397	285,719	294,290	303,119	312,213	321,579
569,256	586,334	603,924	622,041	640,703	659,924	679,722	700,113	721,117	742,750	765,033	787,984
294,973	294,973	294,973	294,973	294,973	294,973	294,973	294,973	294,973	294,973	294,973	294,973
51,233	52,770	54,353	55,984	57,663	59,393	61,175	63,010	64,900	66,848	68,853	70,919
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
62,583	50,066	40,053	160,212	(0)	0	0	0	0	0	0	0
1,614,787	1,664,853	1,704,906	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119	1,865,119
1,342,165	1,369,008	1,396,388	1,424,316	1,452,802	1,481,858	1,511,496	1,541,726	1,572,560	1,604,011	1,636,091	1,668,813
855,845	881,520	907,966	935,205	963,261	992,159	1,021,924	1,052,581	1,084,159	1,116,683	1,150,184	1,184,689
486,320	487,488	488,423	489,111	489,541	489,700	489,572	489,144	488,401	487,328	485,908	484,124
423,737	437,422	448,369	328,899	489,541	489,700	489,572	489,144	488,401	487,328	485,908	484,124
423,737	437,422	448,369	328,899	489,541	489,700	489,572	489,144	488,401	487,328	485,908	484,124
169,495	174,969	179,348	131,560	195,817	195,880	195,829	195,658	195,361	194,931	194,363	193,650
254,242	262,453	269,022	197,339	293,725	293,820	293,743	293,487	293,041	292,397	291,545	290,474
316,825	312,519	309,075	357,552	293,725	293,820	293,743	293,487	293,041	292,397	291,545	290,474
11.98	12.22	12.47	12.72	12.97	13.23	13.50	13.77	14.04	14.32	14.61	14.90

Year											
9	10	11	12	13	14	15	16	17	18	19	20
404,171	323,337	258,670	206,936	0	0	0	0	0	0	0	0
838,956	864,125	890,049	916,750	944,253	972,581	1,001,758	1,031,811	1,062,765	1,094,648	1,127,487	1,161,312
987,017	1,016,627	1,047,126	1,078,540	1,110,896	1,144,223	1,178,549	1,213,906	1,250,323	1,287,833	1,326,468	1,366,262
553,025	553,025	553,025	553,025	553,025	553,025	553,025	553,025	553,025	553,025	553,025	553,025
88,831	91,496	94,241	97,069	99,981	102,980	106,069	109,252	112,529	115,905	119,382	122,964
3,040	3,131	3,225	3,322	3,422	3,524	3,630	3,739	3,851	3,967	4,086	4,208
80,834	64,667	51,734	206,936	0	0	0	0	0	0	0	0
2,085,711	2,150,379	2,202,112	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048
2,085,711	2,150,379	2,202,112	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048	2,409,048
1,917,845	1,975,380	2,034,642	2,095,681	2,158,551	2,223,308	2,290,007	2,358,707	2,429,468	2,502,352	2,577,423	2,654,746
598,493	591,284	583,356	574,677	565,214	554,932	543,798	531,774	518,822	504,904	489,979	474,004
517,659	526,617	531,622	367,741	565,214	554,932	543,798	531,774	518,822	504,904	489,979	474,004
517,659	526,617	531,622	367,741	565,214	554,932	543,798	531,774	518,822	504,904	489,979	474,004
207,063	210,647	212,649	147,096	226,085	221,973	217,519	212,710	207,529	201,962	195,991	189,602
310,595	315,970	318,973	220,645	339,128	332,959	326,279	319,064	311,293	302,942	293,987	284,402
391,429	380,638	370,707	427,580	339,128	332,959	326,279	319,064	311,293	302,942	293,987	284,402
11.98	12.22	12.47	12.72	12.97	13.23	13.49	13.76	14.04	14.32	14.61	14.90

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820-6964