An Analysis of Sand Mining Alternatives Along the Kansas River Basin

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ALTERNATIVES ALONG THE KANSAS
RIVER BASIN

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Chapter 1
Introduction

In its natural state, a river is a dynamic system. The process becomes more complicated when man and his activities intrude. Sand mining, adjacent land use, and the existence of reservoirs on the main tributaries complicate nature's effort. Fortunately or unfortunately, these activities are a vital part of the progress of man. Though vital, these activities are rarely implemented without tremendous debate and controversy.

The issue of this paper is sand mining on the Kansas River (Environmentalists often refer to the Kansas River by its Indian name of Kaw River). Many people believe the river should be left in its natural state for all to enjoy, while others believe the sand is an inexpensive resource that should be mined to build houses and roads. In recent years, the debate between the two groups has become heated and emotional.

Dredging on the Kansas River has occurred for nearly 100 years. In the last few decades, the problems associated with man's activities on the river have become readily noticeable. Indicators such as the exposure of buried pipes and buried bridge pilings, eroded farm lands, and changes in fish species are only a few of the signs that indicate environmental stress.

The citizens of the communities along the Kansas River are entitled to safe drinking water. Any activity that takes place on the river, including sand dredging, has the potential to harm the drinking water and merits investigation. The opponents of sand dredging believe that dredging would agitate the pollutants on the bottom and re-suspend them. In turn, this would make those chemicals available for the water intake structures and they would appear in the drinking water. The Kansas Department of Health and Environment studied the effects that current river dredging practices have on water quality. They determined that, "There would be little or no effect except where the dredge return flows re-enter the river." (U.S. Army Corps of Engineers, 1990) This finding ended the discussions on the possibility of sand dredging degrading the water quality.

Fish in the Kansas River require a safe, healthy habitat. The opponents of sand dredging point to this as an issue that should preclude sand dredging on the Kansas River. However, most studies do not support this claim. The Cross and DeNoyelles (1982), *Report on the Impacts of Commercial Dredging on the Fishery of the Lower Kansas River*, was an extensive study. It concluded that species diversity actually increased in dredged areas, which is an indicator of a healthy environment. Dr. John R. Kelley (1978) reached the same conclusion in his study, *Fisheries Report for the Kansas River, Environmental Effects of Dredging on Fish Populations,* several years earlier. He stated, "Dredging operations could potentially have a desirable effect to many species of fishes by increasing the availability of nutrients and bottom organisms that are utilized by fishes."

It was then suggested that the increased turbidity would effect the spawning of many fish species. Burns and McDonnell (1982) addressed this issue in *Cumulative Impacts of Commercial Dredging on the Kansas River*. This report concluded that the Kansas River was naturally a very turbid river, with turbidity increasing with increased flow. The periods of increased flow overlapped the period of maximum spawning activity and the small amount of turbidity caused by the dredges was insignificant. This ended the discussions on the possible harmful effects of sand dredging on fish.

The effect of dredges on river morphology was another important issue that needed to be addressed. Many believed that the dredges had significant impact on changes in the river. It was impossible to discount this idea based on the numerous studies that had implied this to be true. The U.S. Army Corps of Engineers, Kansas City District (COE KCD) studied the possibility of limiting dredging to lessen the impacts caused by dredging. They concluded - if dredging was conducted in a limited way and constantly monitored, the impacts associated with dredging could be mitigated. This led to the current restrictions and subsequent practices on the Kansas River. It will take a few years to collect and analyze enough data to fully understand the impact of the new operating procedures on the Kansas River. The morphology of the river, as well as the current operating procedures, is examined more closely in chapters 2 and 3.

There has been a new push to remove the dredges from the Kansas River. The current thought is that the river's sole use should be recreational. The opponents of sand dredging claim that the dredges on the river ruin the aesthetics associated with recreational activities. They claim that the two activities cannot co-exist. In April of 1996, American Rivers, a non-profit organization, placed the Kansas River on its list of the ten most endangered rivers (Mellinger, Gwen, "Kaw Joins Endangered River Listing," *Lawrence Journal-World*, April 18, 1995). Pollution and sand dredging were cited as the reasons for its inclusion on the list. The opponents of dredging now had the environmental cause on their side. This led it to become an attractive political issue. After all, who wants to be considered anti-environment? Lawrence City Commissioner Allen Levine stated that the dredges posed a safety hazard to canoeists and others who use the river for recreation. He also stated that the dredging could stir up chemicals from farm runoff and threaten the city's drinking water (Fagan, Mark, "Commissioner Opposes Sand Plans," *Lawrence Journal-World*, June 5, 1995). State Senator Sandy Praeger introduced a bill that would place a two-year moratorium on all new sand-dredging permits while a study of the economic potential associated with recreation was conducted (Toplikar, Dave, "Tactics Stall Dredging Bill," *Lawrence Journal-World*, March 20, 1996). She stated that others had called the bill a "significant environmental piece of legislation..." (Toplikar, Dave, "Session's End a Review Time for Legislators," *Lawrence Journal-World*, April 29, 1996). The moratorium was defeated, but a study on the recreational possibilities was initiated. The findings of that study are due in January of 1998.

For a recreational corridor to be established on the entire river or a section of the river, the dredges located in the corridor would have to be relocated. The only practical location is in the floodplain. The U.S. Fish and Wild life Service first studied the alternative of sandpit mining in 1967, but due to recent events, it should be examined again. This paper will address this alternative in somewhat more detail than it has been examined in the past.

In this paper I evaluate the history and development of the current operating procedures, as implemented by the COE KCD, in chapters 2 and 3 respectively. The sandpit alternative will be examined in detail. In chapter 4, I describe the river-based and land-based alternatives. In chapter 5, I will cover data collection of sections along the Kansas River. Chapter 6 includes economic feasibility in terms of profit margin for the sections along the Kansas River. Finally, in chapters 7, 8, and 9, I examine the additional screening criteria of cost of transportation, social acceptance, and profitability respectively. Chapter 10 provides a summary and recommendation.

Chapter 2
History

The COE KCD is the agency responsible for regulating commercial dredging activities on the Kansas River. The initial mission of the U.S. Army Corps of Engineers (COE) was to protect navigation. The decisions that the COE made in fulfillment of this responsibility were quite simple. They had to do whatever was necessary to keep the rivers open for commerce. The COE saw this role expand to its current responsibilities as a result of the environmental movement of the 1960's and 1970's. Their current role is more encompassing. The COE must now consider the full public interest for protection, as well as, utilization of water resources. This has resulted in a radically different and challenging view of water resources. The dramatic shift in attitude of people toward environmental values is quite complex and often very difficult, if not impossible, to quantify. The environmental issues must be quantified in order to incorporate them into the decision making process.

Two laws give the COE KCD its authority to exercise control over the extraction of sand and gravel from the Kansas River. The first law is contained in Section 10 of the Rivers and Harbors Act of 1899. This law prohibits the obstruction or alteration of the navigable waters of the United States without permission from the COE. In this act, the term navigation is referenced to past, present and future uses. The original intent of this law was to protect navigation and navigable capacity

(Dzurik, 1996). The second law is Section 301 of Section 404 of the Clean Water Act (Public Law 92-500). This law prohibits the discharge of dredged or fill material into waters of the United Sates without a permit from the COE (COE KCD, 1997). The discharge is defined as being the return flow from the on-shore portion of the dredging operation (see figure 1). Other laws that may apply to dredging on the Kansas River are the National Environmental Policy Act, the Coastal Zone Management Act, the Fish and Wildlife Coordination Act, the Endangered Species Act, the National Historic Preservation Act, the Deepwater Port Act, the Federal Power Act, the Marine Mammal Protection Act, the Wild and Scenic Rivers Act, and the National Fishing Enhancement Act of 1984 (COE KCD, 1997). The process of permitting sand extraction operations can be quite complicated, lengthy, and expensive.

Figure 1. View of return pipe from the sand processing plant located at the Penny Concrete dredge site below Bowersock Dam

Indication that the dredging of sand and gravel from the river might be detrimental first surfaced in 1967 in a report by the U.S. Geological Survey (USGS) entitled *Kansas River, Bonner Springs to Mouth-Degradation of Channel* (1967). This report addressed how the river had changed and predicted how much it would change in the future. Critical to these two topics was the cause of the change. Federal reservoirs and changes in river characteristics, including slope, sediment load and flow characteristics, were examined as possible causes. The USGS determined that these factors were not the causes of the degradation. When the removal of sand was examined as a possible cause, the conclusion was different. The USGS determined that the rate of degradation was directly related to sand removal, frequency and magnitude of floods, bankfull floods, and low flows (COE KCD,1990).

While this report should have provided the needed impetus to regulate the sand and gravel industry with regard to dredging, it did not. The sand and gravel industry remained unregulated, and in the 1970's and 1980's more evidence supporting the findings in the USGS 1967 report became apparent. This evidence was in the form of exposed gas pipelines downstream of river mile 22, and degradation around the Atchison, Topeka and Santa Fe Railway Bridge at Bonner Springs (COE KCD, 1990). In 1974, the U.S. Senate Committee on Public Works directed the COE to study the feasibility of stabilization projects along the Kansas

River. The COE KCD began the study in 1977, but it did not include commercial sand and gravel dredging in its scope of work.

In the spring of 1977, most of the existing dredging permits expired and the sand and gravel producers applied for new permits. As part of the renewal process, the COE KCD gave public notice and accepted comments. Among those providing comments were the U.S. Fish and Wildlife Service and the City of Lawrence. The Fish and Wildlife Service expressed concerns about the environmental effects associated with dredging and requested that the sand and gravel producers be encouraged to move from the river and dredge in the floodplain. The City of Lawrence was concerned about the undermining of Bowersock Dam and a sewer pipe buried in the riverbed downstream from Bowersock Dam. The COE KCD, due to the controversy surrounding the issue and lack of information on how best to regulate the dredges, did not renew the permits. Dredging continued unrestricted and without Department of the Army approval (COE KCD, 1990).

In the fall of 1977, the COE KCD completed its first study of the effects of dredging on the Kansas River. The report, *Impact of Commercial Sand Dredging in the Lower Kansas River*, was never issued in final version. It concluded that the unrestricted removal of sand and gravel had resulted in severe adverse impacts on the lower Kansas River. It was the first document the COE KCD could use as a basis to regulate the removal of sand and gravel. Two recommendations resulted from the study. The first was to limit each producer between De Soto and Bowersock Dam to the removal of 150,000 tons of sand and gravel per year. The second recommendation was to implement a five-year program to reduce the amount of material removed between the Turner Bridge and the town of De Soto down to the natural replenishment rate. No restrictions were placed on the reaches upstream of Bowersock Dam and below Turner Bridge (COE KCD 1990).

In 1978, the COE KCD finally issued permits that covered the period from 1 April 1977 to 1 April 1978. This covered the time frame that the sand and gravel producers had operated without permits. Of the two recommendations made in the Burns and McDonnell (1982), *Impact of Commercial Sand Dredging in the Lower Kansas River* report, only one was accepted. The permit for the location just downstream from Bowersock Dam was restricted to 150,000 tons per year. The remaining permits were still unrestricted. The possibility of undermining of the dam was the primary factor in placing this limit.

The COE KCD continued to study the issue. In summary, the 1967 USGS report and the 1977 COE KCD draft report concluded that commercial dredging activities were the primary cause of riverbed degradation in the Lower Kansas River. A later report published by Simons, Li, and Associates in 1984 stated, "Sand and gravel dredging appears to be the primary cause of the bank erosion and channel widening in the lower 30 miles of the Kansas River", (Simons, Li, and Associates, 1984). A 1986 Burns and McDonnell report contracted by the COE KCD concluded, "Channel degradation has occurred in the lower reaches of the Kansas River in recent years which is believed attributable to commercial sand and gravel dredging operations", (Burns and McDonnell, 1986). No one could argue against the fact that sand and gravel mining in the Kansas River was detrimental to the stability of the river, but was there another way to support the ever-increasing demand for sand and gravel? This is when sandpit operations became an alternative. The COE KCD contracted Booker Associates to study the economic feasibility of floodplain mining. The findings of their analysis were published in 1986 in the report titled *Kansas River Dredging Operations, Baseline Study and Comparison of Alternatives*. Booker Associates concluded that floodplain mining was economically feasible. All this led the COE KCD to recommend in 1987 what the U.S. Fish and Wildlife had recommended in 1977: that commercial dredging be banned from the river and moved into the floodplain.

After the aggregate producers were informed of the conclusion that the COE KCD had reached, they provided more information. They informed the COE KCD that the land available for floodplain mining was extremely expensive, was farm land and therefore difficult to obtain, and was almost impossible to have rezoned to allow mining operations.

The COE KCD, armed with this new information, changed its position and decided that it would allow dredging to continue on the Kansas River. It concluded that regulated dredging would limit the adverse effects dredging had on the river.

In 1991, after intense study and recommendations from several authorities on the subject, the COE KCD published a regulatory plan for commercial dredging on the Kansas River. The COE KCD specified many restrictions including, but not limited to, amount of riverbed degradation, rate of extraction, permit area lengths, distance between dredges, and dredging near manmade structures and natural formations. For a complete list of these restrictions, refer to the COE KCD *Regulatory Plan for Commercial Dredging Activities on the Kansas River* (1991).

Chapter 3

Current Operating Procedures

The *Regulatory Plan for Commercial Dredging Activities on the Kansas River* governs the extraction of sand and gravel from the Kansas River. To enforce the rate-of-extraction restriction, the plan divided the river into reaches and set limits on each reach. The limits were based primarily on what was occurring on the ten-mile reach near Topeka. This reach was determined to be a typical reach and had a long history of dredging. It also had the largest historical database on extraction rates and their associated riverbed degradation levels. The COE KCD based its restrictions on this real-life model and used it to set limits on the different reaches. It was estimated that the removal of approximately 500,000 tons of sand and gravel per year in this ten-mile stretch had led to one foot of degradation of the riverbed after ten years. This was expanded to 750,000 tons per year for a fifteen-mile reach. This became the basis of the regulatory plan.

Historical dredging data for reaches other than Topeka are sparse. To determine how these new restrictions affected the dredges currently operating on the river, Mr. Robert Smith of the COE KCD Regulatory Branch was contacted. The interview with him provided a good history on all the reaches. His expertise is based on several years of work in this area and his numerous interviews with dredgers. He is also the author of the COE KCD (1991) *Regulatory Plan for Commercial Dredging*

Activities on the Kansas River. He provided a history of each reach. See Table 1 for the definition of each reach.

Prior to the 1991 regulations, reach one did not have extraction limits. There is very little recorded data, but it is estimated that between four and six dredges removed between 2-3 million tons per year. The history of reach 2 is recent and only dates back five to seven years with no appreciable dredging occurring before this time. The same family has dredged within reach 3 for 50-60 years. There are no records available, but the removal rate was probably around 250,000 tons per year for reach 3. This reach is the most studied and most restricted reach on the river due to its proximity to the Bowersock Dam. The stretch of river from Bowersock Dam to Topeka has not seen any activity with the exception of one dredge. It was established for the purpose of providing materials for the construction of a nearby bridge. It was removed upon completion of the bridge.

The dredging history of the Topeka area can be traced back 40-50 years. Three separate dredges removed approximately 200,000-400,000 tons of sand and gravel per year each in this reach. The three dredges were static. The reach from Topeka to Manhattan saw little to no activity. One dredge was located at Manhattan, but it was removed from the river approximately 5 years ago. Another dredge at Wamego had a long history. This operation was moved to the floodplain as it was determined to be more economical. It currently removes about 300,000 tons per year.

There is also one dredge located in the Blue River near the confluence with the Kansas River.

Table 1 summarizes the removal-rate restrictions contained in the *Regulatory Plan for Commercial Dredging Activities on the Kansas River* and compares them to the historical removal rates.

Reach	Start	End	River Miles	New Limit/Year	Historical Removal
1	Confluence of Missouri and Kansas Rivers	Atchison, Topeka & Santa Fe Railway Company Bridge at Bonner Springs	0-21.2	1 million tons	2-3 million tons
2	Atchison, Topeka & Santa Fe Railway Company Bridge at Bonner Springs	River Mile 48.0	21.2-48.0	750,000 tons/15 miles	Minimal
3	River Mile 48.0	Bowersock Dam at Lawrence	48.0-51.8	150,000 tons	250,000 tons
4	Bowersock Dam at Lawrence	Confluence of the Kansas, Smoky Hill & Republican Rivers near Junction City	51.8-170.4	750,000 tons/15 miles	Minimal

Table 1. Sand removal rate restrictions by reach

Table 1 clearly illustrates that the reaches of intense dredging (1 and 3) were impacted the most. These were also the areas that were showing the most degradation. The remaining reaches were not under intense dredging pressures and fell under the general rule of 750,000 tons per year per fifteen-mile stretch. Table 2 shows all current permits.

In reach 1, the limit of 1,000,000 tons per year is divided among the three companies. Permits 96-02337, 96-02336, and 96-02335 issued to Holliday Sand and Gravel Company are allotted a total of 450,000 tons per year. Permit 97-00113, issued to Builder's Sand, Inc. is allotted 300,000 tons per year. Permits 96-02295 and 96-02296, issued to Kaw Valley Sand and Gravel, Inc. are allotted a total of 250,000 tons per year.

Dredge Owner	River Mile Location	Reach	Permit Number
Kaw Valley Sand	9.4-10.4	1	96-02295
Kaw Valley Sand	12.8-13.9	1	96-02296
Holliday Sand	15.4-16.9	1	96-02337
Holliday Sand	17.5-18.4	1	96-02336
Builder's Sand	19.1-20.6	1	97-00113
Holliday Sand	21.0-21.15	1	96-02335
Kaw Sand	26.1-27.6	2	97-00106
Holliday Sand	29.2-30.2	2	97-00053
Builder's Sand	31.1-31.9	2	97-00114
Kaw Sand	35.4-36.4	2	97-00107
Kaw Sand	42.6-44.1	2	97-00109
Penney's Concrete	45.2-46.7	2	97-00110
Kaw Sand	47.1-48.0	2	97-00108
Penney's Concrete	49.6-51.35	3	97-00111
Kansas Sand	84.5-85.8	4	96-02135
Victory Sand	86.3-86.5	4	97-02295
Meier's Ready Mix	90.1-91.6	4	96-02151

Table 2. Current Corps of Engineers permits for dredging on the Kansas River.

In reach 2, the rule of 750,000 tons per year per 15-mile stretch applies. Permits 97-00106 and 97-00107 are allotted a total of 250,000 tons per year. To date, permit 97-00107 has never been used. Permit 97-00109 has a 200,000 tons per year allotment and permit 97-00108 has a 300,000 tons per year allotment. These two permits are further restricted as their total cannot exceed 450,000 tons per year. Permits 97-00053 and 97-00114 are each allotted 250,000 tons per year. Permit 97-00110 is allotted 300,000 tons per year. Permit 97-00111 is allotted 150,000 tons per year.

The *Regulatory Plan for Commercial Dredging Activities on the Kansas River* specifies that a program be established to monitor the dredging-related effects on the Kansas River. The program established by the COE KCD is paid for by the sand and gravel producers and executed by an independent consulting firm. Results from the program can be used to modify or terminate existing permits. The main criterion that may be used as grounds for termination of dredging in a given reach is when degradation exceeds 2 feet in a 5-mile stretch. The 5-mile stretch can begin at any location.

The plan established monumented survey ranges by dividing the river into three sections. The first section is from river mile (RM) 0 to RM 51.8 (Bowersock Dam location). In this reach, monumented survey ranges were established at 1.5-mile intervals from Turner Bridge (RM 9.3) to within 1000 feet of Bowersock Dam. In addition, five ranges were located at intervals of 1000 to 1500 feet through or adjacent to each permitted reach. The second section is from RM 80 to RM 90. It also established ranges at 1.5- mile intervals that begin five miles below the most permitted reach and end five miles above the most permitted reach. The same requirement for survey ranges through or adjacent to each permitted reach applied. In addition to these two requirements, a survey range was located within 500 feet of the downstream side of the Topeka water-supply weir. The last section covers any isolated dredging operations and is handled on a case-by-case basis.

The program was established by the Regulatory Plan in 1991. The aggregate producers were given until the end of 1991 to establish baseline conditions from which future measurements would be made. The ideal situation would have been to collect all the data in the 1991 calendar year. This did not happen. Data collection extended into 1992, and this became the base year. Once the base year was established, the aggregate producers, through an independent consulting firm, were to provide updates every two years. The 1993 flood, as well as the large water event of 1995, hampered this effort. The end result is shown in the Regulatory Monitoring Program Mean Bed Profile graph (Graph A-1). This graph was compiled by the COE KCD with data provided by Land Planning Engineering of Lawrence, Kansas.

There are two caveats that must be made when interpreting the graph. First, the data set only contains a base year and one comparison year. Trends cannot be established with two data points. The second is that degradation or aggradation effects of the major flood in 1993 or the smaller flood in 1995 are not known. Cause-and-effect relationships, whether drawn from water events or from dredging, cannot be made with this data set. The COE KCD would be acting prematurely if it modified its current plan in either direction based on this current information. The graph may indicate the effectiveness of the regulatory plan.

With the above caveats, the following observations are made. The permit limits became effective in 1992, the new base year. A solid red line on the graph indicates this. With the horizontal scale exaggerated with respect to the vertical scale, the dredge locations appear as downward spikes on the graph. The graph indicates that all dredging locations are within the degradation limit of two feet per five miles. In fact, all locations have aggraded since 1992 with the exception of permit 97-00106, located between RM 26.6 to 27.6. The owner of this permit is currently on notice that this location appears to be very close to the degradation limit of two feet per five miles. If the 1997 data set indicates he is over the degradation limit, his permit for the area will be terminated.

An anomaly occurs at approximately RM 39. No dredge exists at this location, and the cause of the three feet of degradation is unknown. This area will be investigated further in the 1997 data set. No action has been taken.

Chapter 4

Description of Alternatives

This analysis compares a river-based sand and gravel mining operation to a land-based or sandpit operation. Alternatives that made significant changes to the current way of mining sand were not considered. The alternative of mining on the Missouri River was eliminated due to a difference of river equipment. The Missouri River alternative requires a completely different type of dredge. The dredge is much larger and does not anchor via cables attached to the shore. Land mining out of the floodplain was also discounted as an alternative due to the difference of mining equipment.

The following description of the ladder-type dredge and sand plant located just below Bowersock dam is typical of all river-based operations. The sand plant at this location is used almost exclusively for Penney's Concrete and supports the Lawrence area. The dredge, which is mobile, is also used at other dredge permit locations. When the allotment at one location is exhausted, the dredge is simply moved to another permitted location.

The operation consists of two components: a land-based component and a water-based component. The water-based component is the beginning of the sand mining process, and consists of a dredge and a pipeline that connects to the land-based component (Figure 2). The dredge is a floating platform with two pumps, a crew cabin, a ladder auger, and anchor lines. The largest pump, used as a vacuum, has a 12- inch-diameter intake and a 10-inch-diameter discharge. It operates at approximately 20% solids.

Figure 2. Downstream view of dredge located at the Penny's Concrete dredge site. Notice pipe on right rear of dredge.

Figure 3. View of a ladder auger on front of dredge. (Penny's Concrete, Lawrence, KS.)

The smaller pump on the dredge is used as a jet to assist the vacuum.

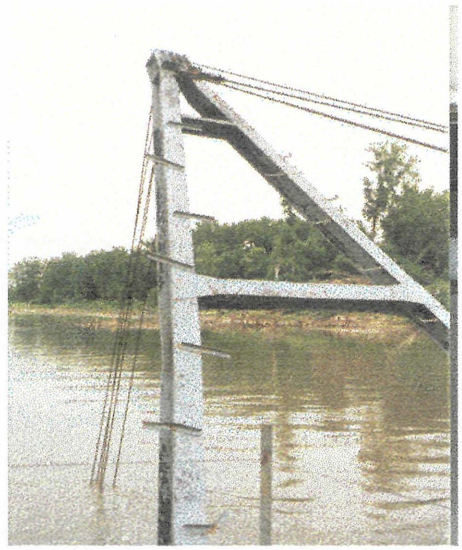

Figure 4. A-frame used to raise and lower the ladder auger. (Penny's Concrete, Lawrence, KS.)

The crew cabin is a small shelter with one chair, control levers, and a panel of instruments. The operator uses these instruments, past knowledge, and feel to operate the dredge. The ladder auger is a metal linked conveyer belt with teeth (Figures 3 and 4). It is lowered into the sediment with a winch and is used to break apart the sand and gravel. It also removes large debris, such as tree limbs or rocks, to prevent the pipeline from clogging. In the base configuration, the ladder can reach sediments up to 25 feet deep. With an extension, it can reach depths up to 65 feet.

Two cables, made of approximately ½-inch steel wire, are located on each side of the dredge. One end of the anchor line is attached to the dredge and the other is attached to an anchor on shore. The cables run from the dredge to the shore and effectively block the entire river. The majority of their length lies below the water surface and cannot be detected. The cables pose a potential threat to canoes and boats. The dredge operator must constantly look for canoes and boats upstream on the river. If a canoe or boat approaches the dredge, the dredge operator, following standard operating procedures, will let one side of the cables go slack as the boat and/or canoe passes by the dredge. The procedure seems to be lacking in protocol, but there have been no serious accidents.

The land-based component consists of a sand sorter, conveyors, and a return flow pipe. The sand sorter is a large hopper that sorts the sand by size (Figure 5). The different sizes are then carried via conveyor to their respective size graded sand piles (Figure 6). The water used to bring the sediment into the hoppers fall out the bottom and returns to the river through a large pipe.

Figure 5. Sand hopper used to sort bulk sand. (Penny's Concrete, Lawrence, KS.)

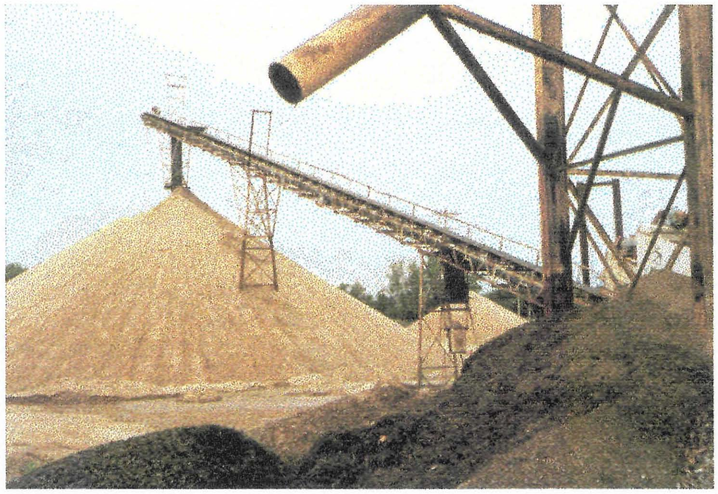

Figure 6. Conveyor belt from sand hopper to sand stockpile. (Penny's Concrete, Lawrence, KS.)

A sandpit or floodplain operation operates in the same manner. The land is cleared of silt and clay overlaying the sand deposit (overburden). Land excavating techniques are continued until the dredge can float. The dredge is then placed in the sandpit where it dredges the sand in the same manner as the river-based operation. The same equipment is used for both operations (Figures 7 and 8).

Figure 7. Floodplain dredge. (Midwest Concrete Materials, Inc., Manhattan, KS)

Figure 8. Sand hopper for a floodplain dredging operation. (Midwest Concrete Materials, Inc., Manhattan, KS)

Chapter 5
Data Collection

The first step in the economic analysis of a sand operation is to locate an acceptable source of sand and gravel. The source must possess large amounts of usable material with little overburden. Overburden is defined as the portion of unusable material that lies above the saleable material. The thickness of the layer of saleable material is referred to as a pay zone. Sources of sand and gravel are glacial drift, terrace deposits, and alluvium. These regions can clearly be seen on soils maps or geology maps of the area. The majority of the glacial deposits are located north of the Kansas River with some thin deposits to the south. These deposits are well graded but contain large amounts of clay. Their use is limited and extraction of the sand and gravel from the clay matrix is difficult. Further consideration of glacial deposits as a source of acceptable material is eliminated in this study. Terrace deposits, primarily of the Wisconsinian and Illinoisian stages of the Pleistocene, are generally less than 10 feet thick in the river region (Daicoff, October, 1978). The terrace deposits also consist of large amounts of silt and clay. Due to their limited availability, terrace deposits have also been removed from further consideration in this study. The important alluvium deposits are located within the Kansas River and its floodplain, and in some of its tributaries. The location and composition of these deposits warrant further investigation as a source of material.

To determine the location and quantity of these deposits, soil boring logs from the Kansas River floodplain in Geary, Riley, Pottawatomie, Wabaunsee, Shawnee, Jefferson, Douglas, Leavenworth, Johnson and Wyandotte Counties were examined. In order to minimize the expense associated with exploratory soil borings, existing boring logs were used. An excellent source for boring logs is the Kansas Geological Survey (KGS). The KGS maintains a file of all water-well logs drilled in the state. The logs may not be exact in description or depth of material, but this was not the purpose of the drilling effort. That purpose was to locate water, but the descriptive logs do give a general idea of soil composition. These logs provide a good graphical representation of the river area and highlight areas of shallow overburden and a thick pay zone. Several areas were identified as potential floodplain dredge sites.

The logs that were used needed to meet certain criteria. They had to be from bore holes that were drilled until bedrock was encountered. The location of shale or limestone was not always annotated on the log, but was readily apparent when compared with nearby logs. In sections where a portion of the section was in a terrace deposit and a portion was in the alluvium, only alluvium logs were used. These logs determined the characteristics of the entire section. In the entire study area, a section (generally one square mile) is the smallest size area that is represented. This was determined to be an adequate area based on the goal of finding deposits and the number of logs of borings that were available. The exact amount of overburden and pay zone would have to be determined by further exploration efforts by the company desiring to establish sandpit operations.

The use of well logs to represent the amount of overburden and sand and gravel in a section has a few caveats. First, the classification description used by the driller is very subjective, as a sieve analysis is not conducted in the field. The classification of the soil types is done by inspection and experience. Tables 3 and 4 relate common qualitative descriptions with quantitative sizes.

Size Range (phi)	Major Class	Minor Class	Grade Name
-12 to –11	Gravel	Boulder	Very Large
-11 to –10	Gravel	Boulder	Large
-10 to –9	Gravel	Boulder	Medium
-9 to –8	Gravel	Boulder	Small
-8 to –7	Gravel	Cobbles	Large
-7 to –6	Gravel	Cobbles	Small
-6 to –5	Gravel	Pebbles	Very Coarse
-5 to –4	Gravel	Pebbles	Coarse
-4 to –3	Gravel	Pebbles	Medium
-3 to –2	Gravel	Pebbles	Fine
-2 to –1	Gravel	Pebbles	Very Fine
-1 to 0	Sand	Sand	Very Coarse
0 to 1	Sand	Sand	Coarse
1 to 2	Sand	Sand	Medium
2 to 3	Sand	Sand	Fine
3 to 4	Sand	Sand	Very Fine
4 to 5	Mud	Silt	Coarse
5 to 6	Mud	Silt	Medium
6 to 7	Mud	Silt	Fine
7 to 8	Mud	Silt	Very Fine
8 to 9	Mud	Clay	Coarse
9 to 10	Mud	Clay	Medium
10 to 11	Mud	Clay	Fine
11 to 12	Mud	Clay	Very Fine

Table 3. Common qualitative descriptions and quantitative sizes of sand

Thousands of logs were screened and 645 logs were selected to represent the study area. These 645 logs were averaged to represent 354 individual sections of land. At the conclusion of the screening process, 56 sections did not have logs. Engineering judgement was used to select and average surrounding sections to represent those sections lacking data. The sections that were determined with this averaging technique are indicated by the term "estimation" in the "Data Source" column of Table A-1.

Phi	mm	inches	U.S. Standard Sieve Sizes
-12	4096	161.3	-
-11	2048	80.6	-
-10	1024	40.3	-
-9	512	10.1	-
-8	256	5	-
-7	128	2.52	63 mm
-6	64	1.26	31.5mm
-5	32	0.63	16mm
-4	16	0.32	8mm
-3	8	0.16	No. 5
-2	4	0.08	No. 10
-1	2	0.04	No. 18
0	1	-	No. 35
1	.5	-	No. 60
2	.25	-	No. 120
3	.125	-	No. 230
4	.062	-	-
5	.031	-	-
6	.016	-	-
7	.008	-	-
8	.004	-	-
9	.002	-	-
10	.001	-	-
11	.0005	-	-
12	.00025	-	-

Table 4. Grain-size scale used by American geologists. This table is modified from Roy L. Ingram (1982, AGI data sheet 17.1).

Chapter 6
Economics

The economic analysis is based on the technique contained in *Kansas River Dredging Operations: Baseline Study and Comparison of Alternatives*, published by Booker Associates (1986). This study was quite general and does not consider exploration fees, legal fees, differences in depth of sand deposit and overburden from location to location, and varying production rates. This analysis includes these additional costs and variations in soil depths, and considers a wide variety of production rates. The costs are represented in 1996 dollars and all comparisons are made based on 1996 dollars. The additional cost figures, as well as the cost figures used in the Booker Associates study (1986), were confirmed by interviews with sand producers Mr. Bill Penny of Penny's Concrete (Lawrence, KS), Mr. John Eichman of Midwest Concrete and Materials (Manhattan, KS), and consulting geologist Mr. Verne Dow of Dow Geological Services, Inc. (Topeka, KS). Cost figures from more than one source are averaged unless otherwise noted.

The cost figures for the river-based operations are calculated for each section along the Kansas River. These costs vary with depth of overburden, depth of sand or pay zone, and production level. The end result is a ratio of overburden, expressed in cubic yards of overburden, to tons of saleable sand. This ratio can be used as a screening criterion to eliminate sections that are not expected to yield an acceptable profit margin. The calculation of the overburden ratio is shown below.

$$OVBD\ ratio\ in\ yd^3\ /\ ton = \left[(feet\ of\ OVBD) \times (\frac{1yd}{3ft}) \right] \div$$

$$\left[(feet\ of\ pay\ zone) \times (\frac{1yd}{3ft}) \times (\frac{109lbs}{ft^3}) \times (\frac{3ft}{1yd})^3 \times (\frac{1ton}{2000lb}) \right]$$

This ratio represents cubic yards of overburden per ton of sand.

Table 5 indicates the average price of sand during 1986. The percentage of sand used for each general final product was determined from data from the Kansas chapter of the U.S. Bureau of Mines Minerals Yearbook. Several years of data were averaged to establish long term trends in sand use. Individual use prices are from the Booker Associates study.

To bring these prices forward to reflect 1996 prices, the effect of inflation had to be considered. The Implicit Price Deflator (IPD) was used for this purpose.

Use	*Percent Use	1986 Prices	Individual Contribution
Concrete	50	$2.50	$1.25
Asphalt	21	$2.40	$0.50
Road Base	11	$7.00	$0.77
Fill & Misc.	18	$1.50	$0.27
		Average Price/Ton =	$2.79

Table 5. 1986 Sand prices and uses-Kansas District 1 (Northeast Kansas).

* Estimate based on USBM and USGS data for the last ten years (Ohl and Grisafe, 1988, 1992; White and Grisafe, 1990; Zelton and Grisafe, 1994; U.S. Geological Survey, 1996)

The analysis covers real estate, labor, operations and maintenance, and facilities. It was determined that individual inflation indexes for real estate, labor, operations and maintenance, and facilities would not be used. Instead, the IPD index was used. This index is based on the Gross Domestic Product and accurately reflects changes in all components of the analysis. Table 6 indicates inflation (IPD) indexes from 1986-1996. The inflation rate for the period 1986-1996 is 36.85%. This is the inflation rate used in the analysis.

((period 1/period 2) – 1) x 100 or $\left(\left(\frac{110.3}{80.6}\right)-1\right)\times 100 = 36.85\%$

Year	Index
1986	80.6
1987	83.1
1988	86.1
1989	89.7
1990	93.6
1991	97.3
1992	100
1993	102.6
1994	105
1995	107.5
1996	110.3

Table 6. Gross domestic product inflation indexes (1986-1996)
Source: Department of Commerce, Bureau of Economic Analysis.

Table 7 shows how the 1996 average sand price was calculated. The individual use contribution prices were calculated by multiplying the 1986 price for each use by the factor 1.3685 and that rate by percent of use.

Use	1996 Prices	Individual Contribution
Concrete	$3.42	$1.71
Asphalt	$3.28	$0.69
Road Base	$9.58	$1.05
Fill & Misc.	$2.05	$0.37
	Average Price/Ton =	$3.82

***Table** 7.* 1996 Sand prices and uses.

Table 8 is an economic analysis of a river-based operation with different production values expressed in 1986 dollars. This table is created to develop a similar table for 1996 dollars. The column indicating a production level of 300,000 tons/year is the base column. This was the production level used in the Booker Associates study and all other calculations are based on it. Items 1-6 come directly from the Booker Associates study. These items remained the same for production rates less than 300,000 tons/year. No production rates greater than 300,000 tons/year are calculated since this is the maximum any one dredge can remove under present COE KCD restrictions.

The Booker Associates study concluded that 10 acres of land is required for a river dredge operation with a production of 300,000 tons/year. The land requirement for other production rates is simply a ratio of a given production rate to the base production rate of 300,000 tons/year multiplied by the base land requirement of 10 acres. The land requirement for a production rate of 250,000 tons/year is shown as an example.

$$\left(\frac{250000 tons/year}{300000 tons/year}\right)10 acres = 8\frac{1}{3} acre$$

Item 7 is the cost of land, \$3,000/acre, multiplied by the acreage.

Items 8 and 9 in the base column are from the Booker Associates study. The other production rates are calculated in the same manner as the land requirement.

Item 10 is the annual cost associated with items 7-9. This money would be borrowed by the producers and repaid during the life of the equipment. The Booker Associates study determined the life of the equipment to be 12 years. The Booker Associates study also indicates that the interest rate would be 1 to 2 percent over the prime rate. The rate of 11% is used in this analysis. There was no significant impact when this was varied up and down by 2%. The annual cost is determined as follows:

$$\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{A}{P}$$

where n = the number of time periods in years
i = the interest rate per period
A = a uniform annual amount over a period of time
P = a capital amount at the present time

For the base column, $\frac{0.11(1+0.11)^{12}}{(1+0.11)^{12} - 1} \times \$86,350 = \$13,300.26$

Items 11,12 and 14 are based on the Booker Associates study. The ratio method was used to determine the costs associated with different production rates.

Item 15, the total, is the sum of items 1-6 divided by the equipment life, plus items 10, 11, 12, and 14. The cost per ton is the total cost divided by the production rate. The selling price was determined in Table 5. Profit is the selling price minus the cost per ton. The gross profit margin (GPM) is the selling price minus the cost per ton divided by the selling price and expressed as a percentage. The Booker Associates study indicates that the majority of producers (those that produce between 200,000 and 350,000 tons/year) show profits between 5-15%. This agrees with the profits shown in Table 8.

Item	1986 Costs	Production (tons) 300,000	Production (tons) 250,000	Production (tons) 200,000	Production (tons) 150,000
1	Dredge	$500,000.00	$500,000.00	$500,000.00	$500,000.00
2	Plant	$275,000.00	$275,000.00	$275,000.00	$275,000.00
3	Conveyor	$200,000.00	$200,000.00	$200,000.00	$200,000.00
4	Loader	$150,000.00	$150,000.00	$150,000.00	$150,000.00
5	Scale	$30,000.00	$30,000.00	$30,000.00	$30,000.00
6	Misc.	$100,000.00	$100,000.00	$100,000.00	$100,000.00
7	Land	$30,000.00	$25,000.00	$20,000.00	$15,000.00
8	Office	$49,000.00	$40,833.33	$32,666.67	$24,500.00
9	Cont. Fund	$7,350.00	$6,125.00	$4,900.00	$3,675.00
10	Annual Cost	$13,300.26	$11,083.55	$8,866.84	$6,650.13
11	Maint.	$65,000.00	$54,166.67	$43,333.33	$32,500.00
12	Labor	$360,000.00	$300,000.00	$240,000.00	$180,000.00
13	Taxes	$4,533.38	$3,777.81	$3,022.25	$2,266.69
14	Misc.	$150,000.00	$125,000.00	$100,000.00	$75,000.00
15	Total	$692,883.59	$624,583.33	$520,583.33	$416,583.33
16	Cost/Ton	$2.31	$2.50	$2.60	$2.78
17	Selling Price	$2.79	$2.79	$2.79	$2.79
18	Profit	$0.48	$0.29	$0.19	$0.01
19	GPM	17.22%	10.45%	6.71%	0.46%

Table 8. Summary of 1986 river operation costs.

Item	1996 Costs	Production (tons) 450,000	Production (tons) 400,000	Production (tons) 350,000	Production (tons) 300,000	Production (tons) 250,000	Production (tons) 200,000	Production (tons) 150,000
1	Dredge	$1,368,500.00	$1,368,500.00	$684,250.00	$684,250.00	$684,250.00	$684,250.00	$684,250.00
2	Plant	$752,675.00	$752,675.00	$376,337.50	$376,337.50	$376,337.50	$376,337.50	$376,337.50
3	Conveyor	$273,700.00	$273,700.00	$273,700.00	$273,700.00	$273,700.00	$273,700.00	$273,700.00
4	Loader	$410,550.00	$410,550.00	$205,275.00	$205,275.00	$205,275.00	$205,275.00	$205,275.00
5	Scale	$41,055.00	$41,055.00	$41,055.00	$41,055.00	$41,055.00	$41,055.00	$41,055.00
6	Misc.	$136,850.00	$136,850.00	$136,850.00	$136,850.00	$136,850.00	$136,850.00	$136,850.00
7	Land	$61,582.50	$54,740.00	$47,897.50	$41,055.00	$34,212.50	$27,370.00	$20,527.50
8	Office	$100,584.75	$89,408.67	$78,232.58	$67,056.50	$55,880.42	$44,704.33	$33,528.25
9	Cont. Fund	$15,087.71	$13,411.30	$11,734.89	$10,058.48	$8,382.06	$6,705.65	$5,029.24
10	Annual Cost	$26,014.53	$23,124.02	$20,233.52	$17,343.02	$14,452.51	$11,562.01	$8,671.51
11	Maint.	$133,428.75	$118,603.33	$103,777.92	$88,952.50	$74,127.08	$59,301.67	$44,476.25
12	Labor	$738,990.00	$656,880.00	$574,770.00	$492,660.00	$410,550.00	$328,440.00	$246,330.00
13	Taxes	$9,305.89	$8,271.90	$7,237.91	$6,203.92	$5,169.94	$4,135.95	$3,101.96
14	Misc.	$307,912.50	$273,700.00	$239,487.50	$205,275.00	$171,062.50	$136,850.00	$102,637.50
15	Total	$1,454,956.61	$1,320,918.19	$1,081,391.23	$947,352.81	$813,314.39	$679,275.97	$545,237.55
16	Cost/Ton	$3.23	$3.30	$3.09	$3.16	$3.25	$3.40	$3.63
17	Selling Price	$3.82	$3.82	$3.82	$3.82	$3.82	$3.82	$3.82
18	Profit	$0.59	$0.52	$0.73	$0.66	$0.57	$0.42	$0.19
19	GPM	15.36%	13.55%	19.12%	17.33%	14.84%	11.09%	4.85%

Note: Production > 350,000 Requires 2 loaders, 2 dredges, 2 plants

Table 9. Summary of 1996 river operation costs.

Table 8 was used to construct the 1996 cost table (Table 9). Table 9 is used to compare profit margins of river-based operations against land-based operations. The calculations in table 9 are the same in table 8. The base figures are adjusted for inflation.

The next step in the analysis is to calculate costs associated with a river-based operation. This will then be used to calculate the GPM. The calculation of GPM for a river-based operation includes:

Step 1: Calculation of the expected yield for a given section in tons/acre.

$$yield\ in\ \frac{tons}{acre} = (depth\ of\ pay\ zone\ in\ feet) \times (\frac{43{,}560\ ft^2}{acre}) \times (\frac{109\ lb}{ft^3}) \times (\frac{1\ ton}{2000\ lbs}).$$

Step 2: Calculation of the annual land requirement for a given section and given production rate expressed in acre/year.

$$annual\ land\ requirement\ in\ \frac{acre}{year} = production\ rate\ in\ \frac{tons}{year} \div \frac{tons}{Acre}$$

Step 3: Calculation of the 12-year land requirement in acres.

$$12\ year\ land\ requrement\ in\ acres = annual\ land\ requiremet\ in \frac{acre}{year} \times 12\ years$$

Step 4: Calculation of the land required, in acres, for an office and a sand plant. This is based on the Booker Associates study requirement of 10 acres for a production rate of 300,000 tons/year.

$$office\ \&\ sand\ plant\ land\ in\ acres = production\ rate\ in\ \frac{tons}{year} \times \frac{10\ acres}{300{,}000\ \frac{tons}{year}}$$

Step 5: Calculation of the land required for a buffer. A 25-foot buffer is required around the entire perimeter of the operation according to the Booker Associates study, Mr. Dow, and Mr. Penny.

$$\textit{buffer land in acres} = ABS((((((\textit{office \& plant land} + 12 \textit{ year land requirement}) \times (43560 \frac{ft^2}{acre}))^{1/2}) - 50)^2) \times (\frac{acre}{43560\ ft^2}) - (\textit{office \& plant land} + 12 \textit{ year land requirement}))$$

Step 6: Calculation of the cost of the land. This varies from $3,000/acre for land in Douglas, Johnson, Leavenworth, and Wyandotte counties to $1,000/acre for all others, as reported by the Booker Associates Study, Mr. Dow, and Mr. Penny.

$$\textit{cost of land in \$} = \textit{unit cost of land in } \frac{\$}{acre} \times (12 \textit{ year land requirement in acres} + \textit{office \& plant land in acres} + \textit{buffer land in acres})$$

Step 7: Calculation of the plant construction costs. This includes the office building(s) and associated utility hook-ups, contingencies, and miscellaneous site improvements. Figures are based on costs reported in the Booker Associates study.

$$\textit{office, utilities, \& contingency costs in \$} = \frac{\textit{production rate } \frac{tons}{year}}{300{,}000 \frac{tons}{year}} \times (\textit{land based office \& contingencies expenditures for } 300{,}000 \frac{tons}{year} \textit{ in \$})$$

Step 8: Calculation of annual cost of land, office, utilities, and contingencies given total present costs, 11% interest rate, and 12-year equipment life.

$$\frac{i(1+i)^n}{(1+i)^n-1}=\frac{A}{P}$$

where n = the number of time periods in years.
i = the interest rate per period.
A = a uniform annual amount over a period of time.
P = a capital amount at the present time.

$$\textit{total annual costs in \$/year} = \frac{0.11(1+0.11)^{12}}{(1+0.11)^{12}-1}$$
$$\times(\textit{cost of land} + \textit{cost of office, utilities, \& contingencies})$$

Step 9: Calculation of annual equipment costs. These remain the same as the land-based alternative for production quantities below 300,000 tons/year.

Step 10: Calculation of the annual equipment costs.

$$\textit{annual equipment costs in \$/year} = \textit{total equipment costs in \$} \div 12 \textit{ years}$$

Step 11: Calculation of the annual cost of overburden removal. Based on \$1/cy as reported in the Booker Associates study and Mr. Dow.

$$\textit{annual cost of OVBD removal in \$/year} = \textit{depth of OVBD in ft}$$
$$\times(\frac{43560\ ft^2}{acre})\times(\textit{annual land requirement in }\frac{acre}{year})\times(\frac{yd^3}{9\,ft^3})\times(\frac{\$1}{yd^3})$$

Step 12: Calculation of the annual maintenance costs. Maintenance costs are 90% of the river-based component due to unpredictable nature of the Kansas River. Based on the 1986 annual maintenance costs of \$65,000 and an inflation factor of

1.3685, the annual maintenance cost for a production rate of 300,000 tons/year is $88,952.00 (Booker, 1986).

$$annual\ maintenance\ costs\ in\ \$/year = \frac{production\ rate\ \frac{tons}{year}}{300{,}000\ \frac{tons}{year}} \times \$88{,}952 \times 90\%$$

Step 13: Calculation of annual labor costs. This figure is based on a twelve-person employment force for a production rate of 300,000 tons/year. These employees include management, clerical, equipment operators, and laborers. Based on an average 1986 salary of $30,000 per employee per year, twelve employees, and an inflation rate of 1.3685, the annual labor costs for a production rate of 300,000 tons/year is $492,660.00 (Booker, 1986).

$$annual\ labor\ costs\ in\ \$/year = \frac{production\ rate\ \frac{tons}{year}}{300{,}000\ \frac{tons}{year}} \times \$492{,}660$$

Step 14: Calculation of the property taxes for a land-based operation. Based on technique used in the Booker Associates study-taxes based on average rate of $175 per $1000 of assessed value with real property assessed at 30% of market value.

$$annual\ taxes\ in\ \$/year =$$

$$(Cost\ of\ land + cost\ of\ office, utilities, \&\ contingencies) \times 30\% \times \frac{\$175}{\$1000}$$

Step 15: Calculation of miscellaneous costs, including property insurance, property taxes, and interest charges on equipment purchases. The Booker Associates study states that the largest difference between a land-based operation and a river-based operation is related to property taxes. Miscellaneous costs for a land-based operation are the same as the river-based operation plus the additional property taxes.

$$miscellaneous\ costs\ in\ \$/year =$$
$$property\ taxes\ for\ a\ land-based\ operation\ in\ \$/year$$
$$-\left(\frac{production\ rate\ in\ \frac{tons}{year}}{300{,}000\ \frac{tons}{year}}\right) \times \$6204$$
$$+\left(\frac{production\ rate\ in\ \frac{tons}{year}}{300{,}000\ \frac{tons}{year}}\right) \times \$205{,}275$$

$6,204 is the annual tax amount (in 1996 dollars) associated with a 300,000 tons/year river-based operation. $205,275 is the annual amount for miscellaneous costs associated with a 300,000-tons/year river-based operation. See Table 9.

Step 16: Calculation of plant movement and set-up. This cost is based on the 1986 plant movement and set-up cost of \$23,000 in the Booker Associates study for a production of 300,000 tons/year.

$$plant\ movement\ \&\ set-up\ in\ \$ = \left(\frac{production\ rate\ in\ \frac{tons}{year}}{300{,}000\ \frac{tons}{year}}\right) \times 1.3685 \times \$23{,}000$$

Step 17: Estimate of exploration costs. (This figure is held constant for all production levels.) Based on interviews conducted with Mr. Dow and Mr. Penny, exploration costs were estimated to be \$5,000.

Step 18: Estimation of legal and consulting fees required to obtain zoning and permits. Based on interviews conducted with Mr. Dow and Mr. Penny and the Booker Associates study, these costs were estimated to be \$32,500.

Step 19: Calculation of the total annual cost of plant movement and set-up, exploration, and consulting fees to obtain zoning and permits.

$$total\ annual\ costs\ for\ movement / set-up / exploration / zoning / permits\ in\ \$ / year =$$

$$\frac{.11(1+.11)^{12}}{(1+.11)^{12}-1}$$

$$\times (cost\ of\ plant\ movement / set-up + cost\ of\ exploration + cost\ of\ zoning / permits)$$

Step 20: Calculation of the cost of production.

$$\begin{aligned}&cost\ of\ production\ in\ \$/ton = \\ &(annual\ land\ cost\ in\ \$/year + annual\ equipmant\ cost\ in\ \$/year + \\ &annual\ maintenance\ cost\ in\ \$/year + annual\ labor\ cost\ in\ \$/year + \\ &annual\ misc.\ cost\ in\ \$/year + \\ &annual\ cost\ of\ movement/exploration/zoning/permits\ in\ \$/year) \\ &\div production\ rate\ in\ tons/year\end{aligned}$$

Step 21: Calculation of gross profit margin. It is expressed as a percentage.

$$gross\ profit\ margin\ as\ a\ \% = (sale\ price - cost\ of\ production) \div sale\ price$$

To determine the overburden (OVBD) ratio screening criterion, the GPM was calculated for all sections. The cost of land was set at \$3,000/acre as determined by the Booker Associates study, Mr. Penny, and Mr. Dow. The production rates and sale prices were varied. The results are depicted in Figures 9 and 10. The number of sections was further reduced to only those that yielded a GPM of 5% or greater. This is shown in Table 10.

Figure 9 indicates that an OVBD ratio of 0.13 is required for an acceptable GPM at a sand price of \$3.82/ton and a production rate of 300,000 tons/year. Figure 10 indicates that an OVBD ratio of 0.19 is required for an acceptable GPM at a sand price of \$4.00/ton and a production rate of 300,000 tons/year. The OVBD ratio of 0.16 is established as the screening criterion.

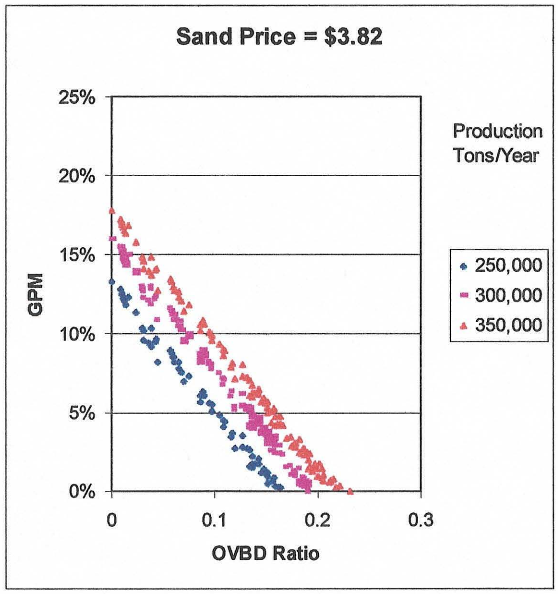

Figure 9. GPM vs. OVBD ($3.82/Ton).

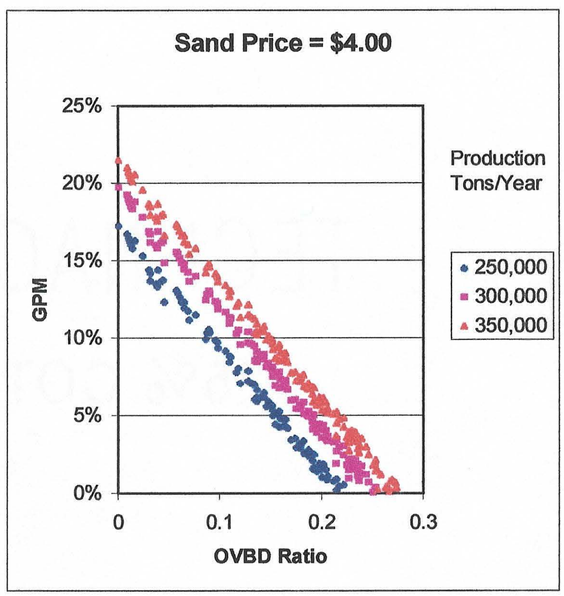

Figure 10. GPM vs. OVBD ($4.00/Ton).

Land Price	$3k/Acre	$3k/Acre	$3k/Acre	$3k/Acre	$3k/Acre	$3k/Acre	From Table 5			
Sale Price	3.82/Ton	3.82/Ton	$3.82/Ton	$4.00/Ton	$4.00/Ton	$4.00/Ton	Ave	Ave	Ave	OVBD
Production	250000	300000	350000	250000	300000	350000	OVBD	wl	PZ	Ratio
Geary	1	1	1	1	1	2	15.5188	6.45833	33.663	0.3133
Riley	2	2	3	3	4	5	23.8511	8.11236	30.558	0.5304
Pottawatomie	11	18	19	19	22	27	17.5673	7.97384	41.087	0.2906
Wabaunsee	2	6	9	9	14	16	17.9548	6.54798	37.874	0.3222
Shawnee	11	13	18	18	24	27	15.4502	8.06095	39.348	0.2668
Jefferson	3	3	4	4	4	6	22.04	8.70455	34.209	0.4378
Douglas	4	5	8	8	11	13	18.9004	9.22183	33.326	0.3854
Leavenworth	1	1	1	1	3	3	18.0857	8.00833	31.871	0.3856
Johnson	3	3	4	4	5	7	12.6571	22.1728	41.854	0.2055
Wyandotte	2	2	3	3	3	5	17.3778	19.225	44.304	0.2666
Not Profitable	314	300	284	284	263	243	18.5965	9.41041	36.741	0.344
Total Profitable	40	54	70	70	91	111				
Grand Total	354	354	354	354	354	354				

Table 10. Number of profitable sections (GPM Greater Than 5%).

All sections with an OVBD ratio greater than 0.16 are removed from consideration. The results are tabulated in Table 11.

Total sections in each county with an OVBD ratio < .16	
Geary	1
Riley	3
Pottawatomie	20
Wabaunsee	10
Shawnee	19
Jefferson	4
Douglas	8
Leavenworth	1
Johnson	5
Wyandotte	3
Profitable	74
Not Profitable	280
Grand	354

Table 11. Total sections in each county with an OVBD ratio < 0.16

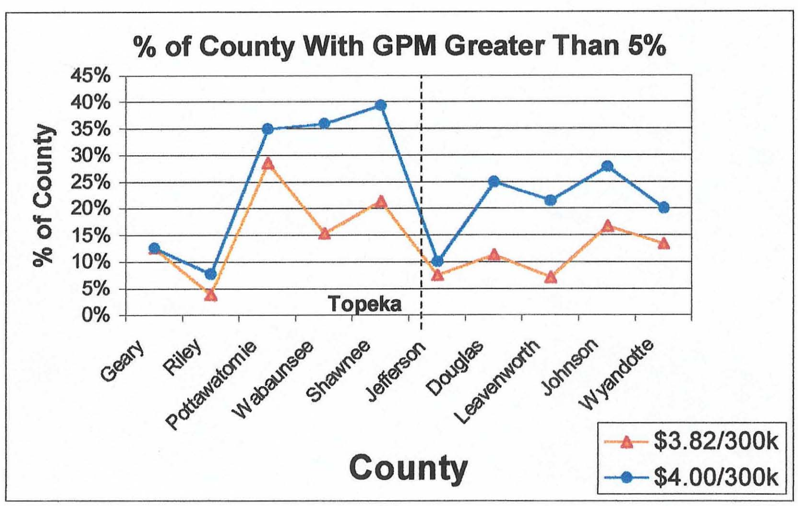

Figure 11. Percent of county with GPM > 5%.

Figure 11 is a plot of the percent of each county with a GPM greater than 5% at a sand price of $3.82/ton and $4.00/ton and a production rate of 300,000 tons/year. This figure indicates that some counties have a larger percentage of area with good OVBD ratios. The majority of these counties are located west of Topeka. It appears that sandpit operations can be successful in Pottawatomie, Wabaunsee, and Shawnee counties. Actually, the existing active sandpit operations are located in Riley (2), Johnson (2), Wabaunsee (1), and Shawnee (2) counties. The two locations in Riley County have OVBD ratios of 0.06 and 0.50. The two locations in Johnson County have OVBD ratios of 0.19 and 0.22. The locations in Shawnee County have an OVBD ratio of 0.55 and the location in Wabaunsee County has an OVBD ratio of 0.17. The only way to determine how the sandpit locations with higher OVBD ratios operate at a profit would be to inspect their business records, and have access to their exploration records to better determine the OVBD ratios in that specific location. Some additional plausible explanations for their successful businesses are the following:

1. Areas within a given section could have a much lower OVBD ratio than the boring records indicate. These areas would provide a more favorable GPM, assuming constants on other costs.

2. Some companies operate sandpit operations in conjunction with concrete operations. This technique eliminates the cost of transporting the

sand to the concrete plant and allows the concrete operation to remain competitive with rival businesses that must truck sand to their plant for concrete production.

3. The price of land varies. A certain producer may have been able to purchase a large quantity of land at a very reasonable cost. This could occur in Geary, Riley, Pottawatomie, and Wabaunsee counties.

4. Some counties are less resistant to sandpit operations. This greatly reduces cost such as legal fees, engineering fees, and exploration costs.

5. Some sand production companies have other businesses that have earth-moving equipment. This substantially lowers the cost of overburden removal.

Whatever the reason, the sandpit operation appears to be the favored option in some counties. The remainder of the analysis will focus on the counties east of Topeka. The data collection resulted in 91 sections in Douglas, Leavenworth, Wyandotte, and Johnson. The OVBD ratio criterion has screened out 74 of the 91 sections. Seventeen sections remain for further exploration and consideration. Table 12 provides a summary of these sections.

County	Township	Range	Section	OVBD Ratio	OVBD Ratio < .16
Douglas	11	18	28	0.08602	Yes
Douglas	11	18	29	0.08602	Yes
Douglas	12	19	9	0.01258	Yes
Douglas	12	20	18	0.139	Yes
Douglas	12	20	28	0.13592	Yes
Douglas	12	20	29	0.12742	Yes
Douglas	13	20	1	0.1563	Yes
Douglas	12	21	27	0.03829	Yes
Leavenworth	12	21	32	0.03089	Yes
Johnson	12	22	20	0.15172	Yes
Johnson	12	22	26	0.15102	Yes
Johnson	12	22	30	0.06796	Yes
Johnson	11	23	35	0.08666	Yes
Johnson	11	23	36	0.01062	Yes
Wyandotte	11	23	35	0.04384	Yes
Wyandotte	11	23	36	0.01062	Yes
Wyandotte	11	24	27	0.14562	Yes

Table 12. Individual sections with OVBD ratio < .16.

Chapter 7
Transportation

"No matter how difficult the evaluation, the transportation position of an aggregate resource must be the primary factor in making the cost judgement among alternate resources" (Dunn, Hudec, and Brown, 1970). Sand is a high-bulk, low unit-price product in which the transportation costs can quickly exceed the price of production. The average price to haul sand is $0.10 per loaded ton-mile. (Penny, Eichman, Dow). The established markets of the existing river-based operations must be maintained in order to avoid excessive transportation costs. To move into a new market and compete with an existing producer could lead to failure. The most desirable location for a sandpit operation would correspond closely to the existing river-based operation. In order to determine the feasibility of moving a sand mining operation from the river to the floodplain, these factors must be taken onto account. In this analysis, the land-based location for an existing river-based operation will be in the immediate vicinity of the current permit location. In a case where an individual producer is operating at more than one permit location, an average location of all permit sites will be used.

Acceptable roads are another important aspect of the transportation criterion. The owners and operators of the expensive 25-ton dump trucks used to haul sand are reluctant to use roads with poor trafficability. The risk of damage to the truck and the associated maintenance costs do not outweigh the small profit made from the haul. It is also cost prohibitive for the producers to build access roads. In general, one mile appears to be the limit on the length of road sand producers can build and still operate at an acceptable profit level. (Eichman, Penny) Of course, this is site-dependent. Additional costs are incurred in construction fees and engineering studies if bridges are needed along access roads. This is a fairly common engineering problem associated with establishing an operation in the floodway. The engineering fees are in response to Federal Emergency Management Administration (FEMA) requirements. FEMA requires an analysis of the change in hydraulics of the floodway due to construction. Any construction that decreases the capacity of the floodway channel must be compensated. If a structure is built in the floodway, it will decrease the cross-sectional area of the floodway channel. The owner of the structure must increase the cross-sectional area of the channel back to its original area. The cost to increase the channel must be paid for by the owner of the structure. This can be a costly proposition if large amounts of earthwork are involved.

The screening criterions of transportation for location of sandpits are as follows:

1. A good road network. This is defined as paved roads on at least two sides of the section.

2. The sandpit location within 3 miles of its existing location. The sandpit location can move no more than one mile west or two miles east of the existing river-based operation.

To apply these criteria, the location of the proposed sandpit operation must be known. Using the procedure described above and Table 2, Kaw Valley Sand and Gravel Inc. is relocated to river-mile 11.65. This is an average of permits 96-02295 and 96-02296. The combined production total of these permits is 250,000 tons per year. Holliday Sand and Gravel Co. is relocated to river-mile 18.3. This is an average of permits 96-02337, 96-02336, and 96-02335. The combined production total of these permits is 450,000 tons per year. Builders Sand, Inc. is relocated to river-mile 19.9. This is the average location of permit 97-00113 with a production total of 300,000 tons per year. Kaw Sand is relocated to river-mile 26.9. This is an average of permit 97-00106 with a production total of 250,000 tons per year. Permit 97-00107 was not included in the determination of this location due to the fact that sand has never been dredged from this permit. The second Kaw Sand location is at river-mile 45.3. This is an average of permit 97-00109 with a production total of 200,000 tons per year and 97-00108 with a production total of 300,000 tons per year. The second Holliday Sand and Gravel Co. location, river-mile 29.7, is an average of permit 97-00053 with a production total of 250,000 tons per year. The second Builders Sand, Inc. location, river-mile 31.5 is an average of permit 97-00114 with a production total of 250,000 tons per year. The Penny's Concrete, Inc. location at river-mile 48.27 is an average of permit 97-00110 with a production total of 300,000 and 91-00111 with a production total of 150,000 tons per year. The results are summarized in Table 13.

These locations were plotted on a map and the transportation criterion was applied. The sections that met this criterion and could serve as possible locations of sandpit operations are shown in Table 13. Of course, this is only one possible solution. The manner in which the individual companies consolidate their existing river permits and relocate to one or more locations on the floodplain is a function of existing market and future markets, rival company moves, owner preferences and many other factors.

Producer	Production Rate (Tons/Year)	Current Location (River Mile)	Proposed Sandpit Location				
			River Mile	County	Township	Range	Section
Kaw Valley	250,000	9.4-13.9	11.65	Wyandotte	11	24	27
Holliday	450,000	15.4-21.15	18.3	Wyandotte	11	23	35
				Wyandotte	11	23	36
Builders	300,000	19.1-20.6	19.9	Johnson	11	23	35
				Wyandotte	11	23	35
Kaw	250,000	26.1-27.6	26.9	Johnson	12	22	26
Kaw	450,000	42.6-48.0	45.3	Leavenworth	12	21	32
Holliday	250,000	29.2-30.2	29.7	None			
Buliders	250,000	31.1-31.9	31.5	Johnson	12	22	20
Penny's	450,000	45.2-51.35	48.27	Douglas	13	20	1

Table 13. Proposed sandpit locations

Chapter 8
Social Acceptance

Often, the good roads associated with the transportation criterion are located in areas where people live. In general, people do not want sandpits in their backyards. It does not take many citizen complaints at a re-zoning hearing to end the re-zoning process. Without the correct zoning, the sandpit cannot operate. It is paramount that sandpit operators understand the feelings of the citizens located around a potential site. Large sums of money can be spent in land acquisition, exploration, and engineer fees before the re-zoning takes place. The re-zoning hearing is not the time to discover large citizen opposition to a proposed location. Areas of historical opposition must be avoided. This is the basis of the next criterion.

Any area with a history of opposition should be eliminated from consideration. However, the history that supports this criterion is limited. Just because a location does not have a history of opposition, opposition might still exist. There may be cases where no attempts have been made to establish sandpit operations. Applying this criterion, the City of Lawrence, the town of Desoto, and the area east of Lawrence near Schaake Bend are eliminated from consideration.

The history of opposition on each of these locations is fairly recent. On January 25, 1990, Builders Sand requested a 40-acre site in Desoto for the land portion of their river-based sand operation. The request was denied on March 8th of that same year. The council denied the request because the local citizens did not want gravel trucks driving through the town (Kahler, Kirk, "Desoto Denies Sand Company Request", *Lawrence Journal-World*, March 9, 1990). On March 25, 1991, David Penny of Kaw Sand Company and Larry C. Schaake of Schaake & Schaake Farms Inc. applied for a conditional use permit for sand dredging and sales on 130 acres near Schaake bend. The commission approved the river-dredging permit, but deferred the request to operate a sandpit. "Carl McElwee, reading a letter signed by six people who live in the area, complained that granting the sand pit operation would lead to loss of prime farmland, have uncertain effects on the river banks, increase traffic, dust, noise and visual pollution, and possibly lead to contamination of the underground aquifer" (Hoyt, Tim, "Planners Approve Part of Sand Dredging Operation" *Lawrence Journal-World*, March 28, 1991). On June 23, 1994, the Lawrence Journal-World reported that Victory Sand and Gravel had withdrawn its application to establish operations four mile upstream of Lawrence. The company cited public opposition against the site. The site was located near an abandoned landfill, which was subsequently turned into a wildlife area (Lundquist, Peter, "Sand Dredgers Change Plans" *Lawrence Journal-World*, June 23, 1994). The result of eliminating these areas further limits the available relocations as shown in Table 14.

Producer	Production Rate (Tons/Year)	Current Location (River Mile)	Proposed Sandpit Location				
			River Mile	County	Township	Range	Section
Kaw Valley	250,000	9.4-13.9	11.65	Wyandotte	11	24	27
Holliday	450,000	15.4-21.15	18.3	Wyandotte	11	23	35
				Wyandotte	11	23	36
Builders	300,000	19.1-20.6	19.9	Johnson	11	23	35
				Wyandotte	11	23	35
Kaw	250,000	26.1-27.6	26.9	~~Johnson~~	~~12~~	~~22~~	~~26~~
Kaw	450,000	42.6-48.0	45.3	Leavenworth	12	21	32
Holliday	250,000	29.2-30.2	29.7	None			
Buliders	250,000	31.1-31.9	31.5	~~Johnson~~	~~12~~	~~22~~	~~20~~
Penny's	450,000	45.2-51.35	48.27	~~Douglas~~	~~13~~	~~20~~	~~1~~

Table 14. Proposed sandpit operations after application of the social acceptance criterion.

Chapter 9

Profitability

The final step in the relocation process is to calculate the GPM for each alternative listed in Table 14. Sections that are not within the acceptable profit margin of 5% or more are eliminated. When more than one section is available for relocation, the one with the higher GPM is selected. Applying these criteria, six of the original fourteen river locations can be consolidated and relocated in the flood plain. The results are summarized in Table 15.

Producer	Production Rate (Tons/Year)	Current Location (River Mile)	Final Sandpit Location					
			River Mile	County	Township	Range	Section	GPM
Holliday	450,000	15.4-21.15	18.3	Wyandotte	11	23	36	12.43%
Builder's	300,000	19.1-20.6	19.9	Wyandotte	11	23	35	9.71%
Kaw	450,000	42.6-48.0	45.3	Leavenworth	12	21	32	11.77%

Table 15. Recommended sandpit locations.

The relocation of these six dredges would reduce the sand extraction from 2,650,000 tons per year to 1,450,000 tons per year (R.M. 0.00-51.35).

Chapter 10
Conclusion

Sand is a critical element in the development of Kansas. It is used to make concrete, to make asphalt, as fill, and as road and base coverings. The problem is in the acquisition of sand. This analysis has shown that the river and the floodplain are both acceptable sources of sand. The issue is where the citizens of Kansas will allow the dredging of the sand. The sand producers are ambivalent. Of course, any increase in production or transportation costs will eventually be passed to the consumer. The possibility of relocating sand mining from the river to the floodplain does exist. This has always been the view of the sand producers. This view is summarized by Woody Moses, Executive Director of the Kansas Aggregate Producers Association, "Basically, the river is not as important to sand and gravel producers as everyone perceives...If they want to kick us off, that's fine...We'll go do something else." (Mellinger, Gwyn, "Warning Doesn't Worry Dredgers," *Lawrence Journal-World*, April 19,1995) Do the citizens of Kansas want them off of the river? If so, we must develop an institutional framework and allow them to produce sand from other sources.

In a push to remove the dredges from the river, the floodplain has been offered as a replacement source of sand. Is this the desired solution? Is it really being offered as a solution? The end result of the type of mining is a large hole on the floodplain. Because it is on the floodplain and probably within the floodway as defined by FEMA, it can not be developed. These holes are often illegally filled with garbage and become eyesores and potential threats to the ground water (Burns & McDonnell, 1982). Floodplain mining requires large tracts of land that may be prime agricultural land. Once this land is used for mining, it can never again be reclaimed for farming purposes. Therefore, the floodplain alternative is not always desirable.

Numerous companies have tried to re-locate on the floodplain, only to be turned down by a city or county commission. In a typical "not in my backyard," scenario, the people with existing roads and houses now want the industry curtailed. It was all right to construct their houses with Kansas River sand, but now that they are built, they want the sand producers somewhere else. This push to remove the dredges from the Kansas River has a strong political following and appears to be gaining momentum. The problem is the movement is being driven more by emotion than informed decision making. It is still believed by some that dredge operations negatively effect the river morphology, water quality, wildlife, and aesthetics.

There have been numerous studies conducted on all aspects of concern, with the exception of the aesthetics issue. However, no one would argue that dredges and associated plant operations are not eyesores. This factor is limited by the meandering of the river and the inability of a boat or canoe to maintain visual site of the dredges for any length of time. All the studies done on the river were funded by tax dollars.

This money will not be wasted if the studies are read before more decisions are made about the river. The dredges do not adversely impact the water quality or wildlife. They did and may still impact the river morphology. This is a known fact due to the numerous and costly studies done on the river.

To mitigate the effects of dredging on river morphology, the COE has implemented a restricted dredging program. This program severely limits the amount of material dredged from the river and monitors the progress. The program is in its infancy and with little or no data on the results of the current program, change is wanted.

What is the information base that calls for a moratorium on dredging and the establishment of a recreation corridor? Is there an information base, or does it just sound good to be "pro-environment"? The taxpayers have spent a lot of money to develop and implement the current mining procedures on the Kansas River. Let's see how this plan works before we spend more tax money on as new program. This is no way to manage a resource or tax dollars.

The development of a river corridor is probably a good idea. There are many stretches of river that would be appropriate for this. A portion of the stretch from Manhattan to Topeka is a likely candidate. This conclusion did not require years of study and thousands of tax dollars to fund. All one must do is plot the current permit locations on a map and look for site with no activity. If a location does not have a dredge, there must be a reason. Likely reasons are the COE KCD will not allow dredging in that location or the market won't support an operation at that location.

If the area is truly to be developed for recreation, then the real issues must be addressed. The first priority is water quality. It is difficult to believe that the Kansas River has tremendous recreational potential given its current water quality. This should be the focus of the legislature's efforts. Make the Kansas River swimmable, and then invest tax money to develop it as a recreation corridor. Removing dredges, building access ramps, encouraging tourism, and then improving the water quality does not appear to be the most logical progression of events. To establish a recreational corridor, the water quality must support contact recreation. The current water quality data do not. (Stevens, Selena, "Environmentalists: Kansas River Unsafe," *Lawrence Journal-World*, September 30, 1997).

The recommendations derived from this analysis are as follows:

1. Continue to operate under the current COE KCD regulations. Use the monitoring program for the intended purpose.
2. Establish a framework that allows dredging in the floodplain. This includes all counties along the Kansas River. This must be a viable alternative if the COE KCD decides to move one or more dredges off of the river.

3. Develop an unused portion of the river for recreational purposes. The first step in the development should be to improve the water quality.

Chapter 11

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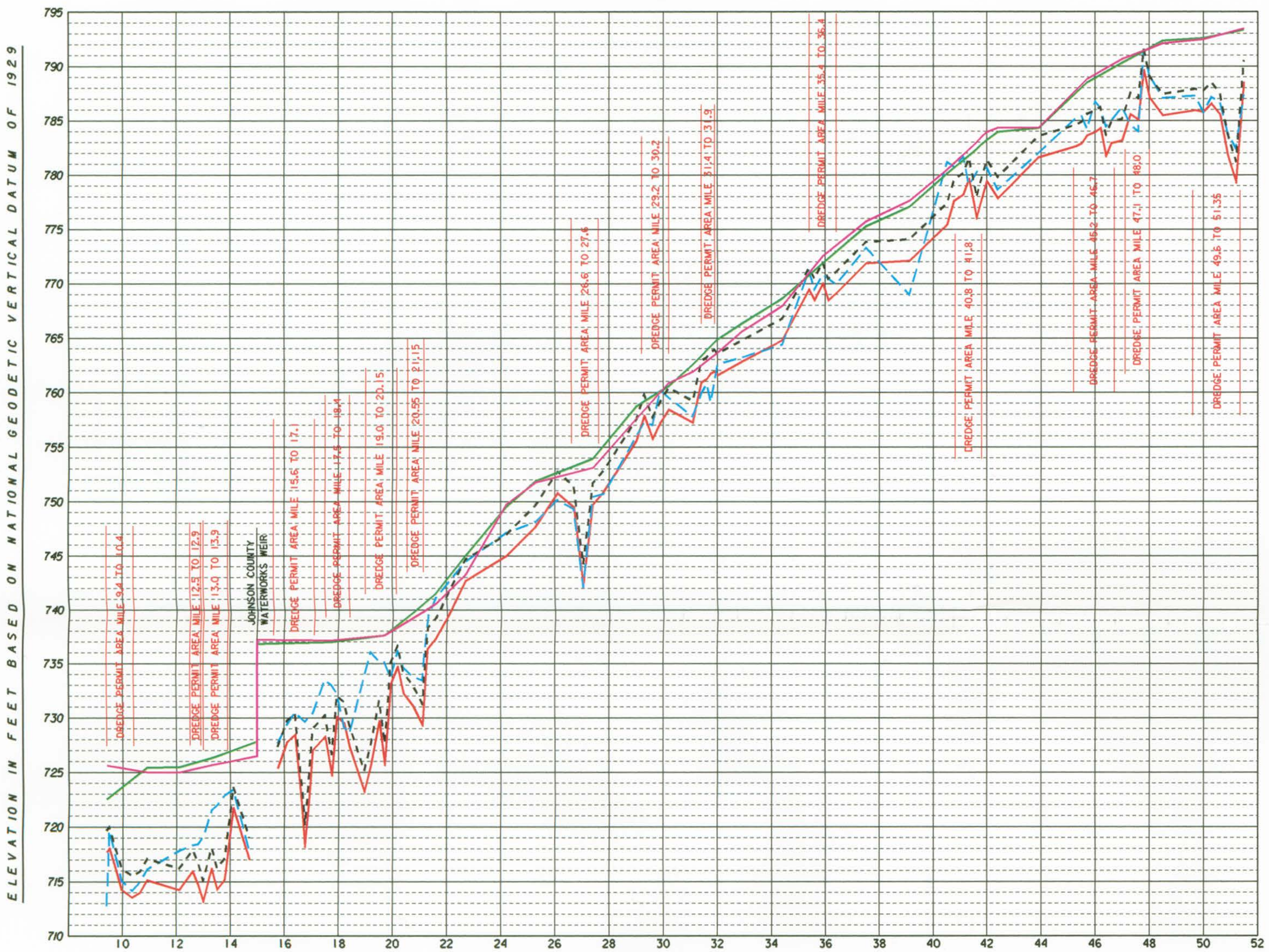
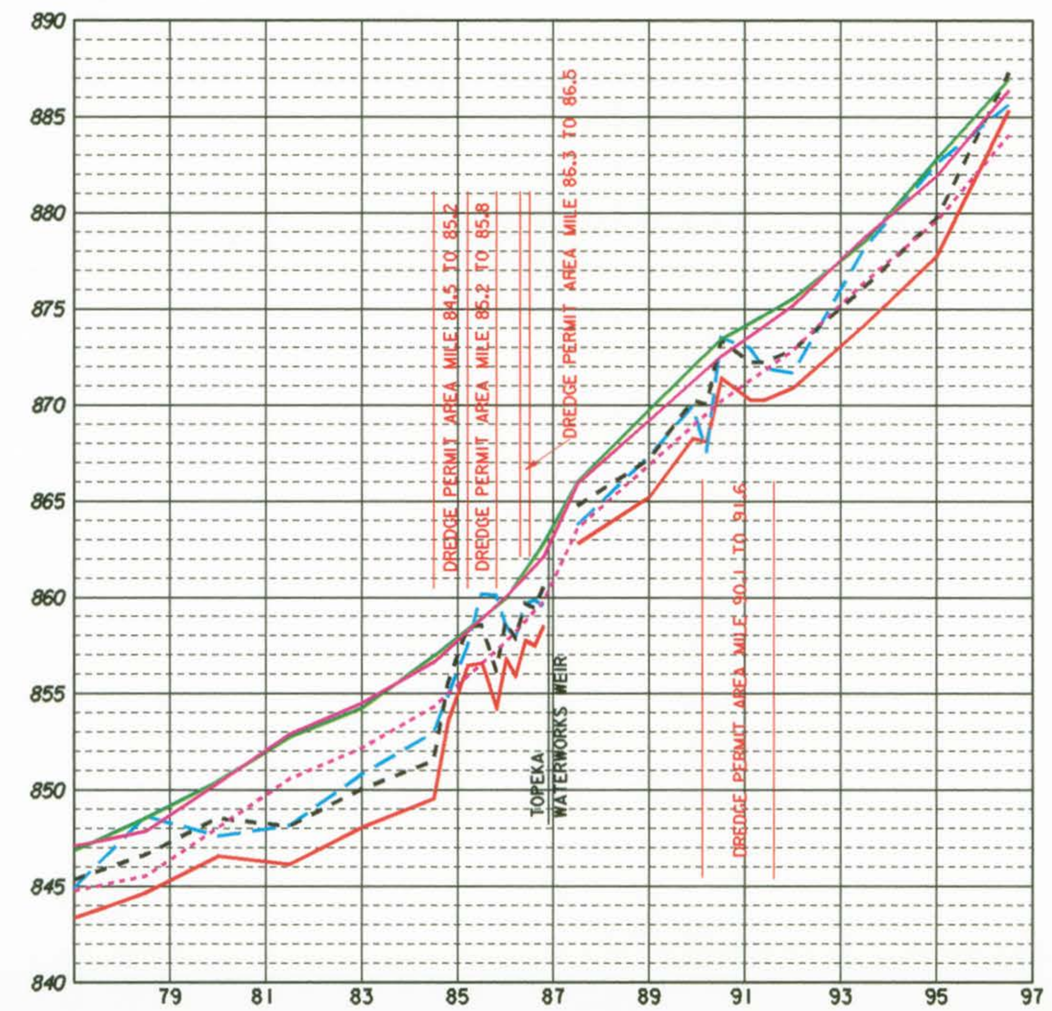
VALUE ENGINEERING PAYS

TURNER TO LAWRENCE KANSAS



RIVER MILES

TOPEKA AREA



RIVER MILES

TURNER BRIDGE	MILE 9.3
J.C.W.D. NO. 1 WEIR	MILE 15.0
I-435 BRIDGE	MILE 15.6
K-7 BRIDGE	MILE 20.2
DESOTO BRIDGE	MILE 31.0
EUDORA BRIDGE	MILE 42.5
BOWERSOCK DAM	MILE 51.8
SARDOU AVE BRIDGE	MILE 83.0
U.P. R.R. BRIDGE	MILE 83.7
KANSAS AVE BRIDGE	MILE 84.1
TOPEKA AVE BRIDGE	MILE 84.5
TOPEKA WATERWORKS WEIR	MILE 86.9
75 HWY	MILE 87.8

NOTE:
1992 DREDGE PERMIT AREAS ARE THOSE REACHES OF THE RIVER PERMITTED FOR DREDGING AT THE TIME OF THE BASELINE DATA COLLECTION.

LEGEND

- 1992 MEAN BED BASELINE EL.
- 1992 MEAN BED BASELINE EL. (MINUS 2 FEET)
- 1995 MEAN BED EL.
- 1992 HIGH PROFILE
- 1995 HIGH PROFILE
- 1995 LOW PROFILE

Revisions			
Symbol	Descriptions	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
KANSAS CITY, MISSOURI

US Army Corps of Engineers

KANSAS RIVER
COMMERCIAL DREDGING

REGULATORY MONITORING PROGRAM
MEAN BED PROFILE

Designed by:	T.A.E.
Drawn by:	J.W.P.
Checked by:	T.A.E.
Submitted by:	A.R.C.
Scale:	AS SHOWN
Date:	AUGUST 1996
Dwg. No.:	
Sheet number:	
Plot Scale:	2:1
Design File:	KRMBP1.DGN
File No.:	A-1-256

Y SKEW: .40

***Table A-1*.** Data summary.

Location					Measured Depth of				Average Depth of				
					Over-	Fine	Pay	water					OVBD
				Data	burden =	Sand=FS	Zone=PZ	level=wl	OVBD	FS	PZ	wl	Ratio
County	Township	Range	Section	Source	OVBD (ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(yd^3/ton)
Geary	11	5	27	Well Log	20	Not Given	34	10	20.0		34.0	10.0	0.400
Geary			28	Well Log	11	3	21	16	8.5	6.5	27.0	18.0	0.214
Geary				Well Log	6	10	33	20					
Geary	11	6	22	Well Log	2	16	34	17	11.0	6.3	38.0	15.0	0.197
Geary				Well Log	15	0	40	10					
Geary				Well Log	16	3	40	18					
Geary			24	Well Log	33	0	25	23	29.3	0.3	25.5	15.3	0.780
Geary				Well Log	19	1	30	17					
Geary				Well Log	35	0	22	11					
Geary				Well Log	30	0	25	10					
Geary			27	Well Log	21	5	19	20	17.4	10.7	23.8	17.8	0.497
Geary				Well Log	10	20	30	20					
Geary				Well Log	20	Not Given	23	7					
Geary				Well Log	18	7	23	20					
Geary				Well Log	18	Not Given	24	22					
Geary			30	Well Log	15	Not Given	47	23	15.0		47.0	23.0	0.217
Geary			32	Well Log	19	3	35	18	19.0	3.0	35.0	18.0	0.369
Geary			33	Well Log	1	21	41	Not Given	4.0	12.0	39.0		0.070
Geary				Well Log	7	3	37	Not Given					
Riley	11	6	12	Well Log	25	5	26	21	25.0	5.0	26.0	21.0	0.653
Riley			13	Estimation					26.3	3.6	27.3	19.3	0.655
Riley			14	Well Log	44	0	0	22	44.0	0.0	0.0	22.0	
Riley			15	Estimation					24.9	2.8	22.3	17.1	0.757
Riley			23	Well Log	26	Not Given	34	15	19.7	2.0	29.0	14.3	0.461
Riley				Well Log	17	1	33	13					
Riley				Well Log	18	Not Given	22	12					
Riley				Well Log	21	3	21	17					
Riley				Well Log	21	2	30	Not Given					
Riley				Well Log	15	Not Given	34	Not Given					
Riley	11	7	1	Well Log	22	Not Given	18	17	28.3	10.0	18.3	25.0	1.050
Riley				Well Log	18	Not Given	28	24					
Riley				Well Log	26	Not Given	30	26					
Riley				Well Log	30	Not Given	20	30					
Riley				Well Log	38		12	28					
Riley				Well Log	36	10	2	Not Given					
Riley			2	Well Log	35	Not Given	5	15	42.0		12.0	25.5	2.379
Riley				Well Log	35	Not Given	21	27					
Riley				Well Log	48	Not Given	12	30					
Riley				Well Log	50	Not Given	10	30					
Riley			4	Well Log	15	Not Given	26	15	18.8		32.0	15.6	0.399

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Riley				Well Log	12	Not Given	35	20					
Riley				Well Log	19	Not Given	34	13					
Riley				Well Log	18	Not Given	37	14					
Riley				Well Log	30	Not Given	28	16					
Riley			5	Well Log	13	6	47	23	13.5	6.0	49.0	18.5	0.187
Riley				Well Log	14	Not Given	51	14					
Riley			6	Well Log	19	Not Given	46	20	19.0		46.0	20.0	0.281
Riley			7	Fader, 1974	25	3	45	Not Given	25.0	3.0	45.0		0.378
Riley			8	Well Log	18	Not Given	36	15	18.0		36.0	15.0	0.340
Riley	10	7	20	Well Log	10	Not Given	7	149	10.0		7.0	149.0	0.971
Riley			22	Well Log	10	0	0	65	10.0	0.0	0.0	65.0	#DIV/0!
Riley			25	Estimation					13.5	16.0	40.6	25.0	0.226
Riley			26	Well Log	20	18	50	65	20.0	18.0	50.0	65.0	0.272
Riley			27	Well Log	15	3	40	14	11.8	6.5	35.4	16.0	0.227
Riley				Well Log	14	5	39	13					
Riley				Well Log	12	10	28	18					
Riley				Well Log	12	8	35	20					
Riley				Well Log	6	Not Given	35	15					
Riley			28	Well Log	45	Not Given	30	27	27.2	14.8	42.1	26.4	0.439
Riley				Well Log	40	Not Given	31	27					
Riley				Well Log	40	11	29	30					
Riley				Well Log	29	29	44	40					
Riley				Well Log	20	18	49	40					
Riley				Well Log	18	Not Given	46	18					
Riley				Well Log	42	Not Given	29	24					
Riley				Well Log	9	1	53	13					
Riley				Well Log	2	15	68	19					
Riley			29	Well Log	66	4	10	40	66.0	4.0	10.0	40.0	4.485
Riley			30	Well Log	32	Not Given	42	26	32.0		42.0	26.0	0.518
Riley			32	Well Log	30	Not Given	20	30	30.0		20.0	30.0	1.019
Riley			33	Well Log	22	Not Given	30	16	22.0		30.0	16.0	0.498
Riley			34	Well Log	18	Not Given	27	19	16.8	9.3	27.5	18.5	0.416
Riley				Well Log	17	Not Given	20	18					
Riley				Well Log	21	2	44	22					
Riley				Well Log	16	4	21	18					
Riley				Well Log	21	Not Given	24	18					
Riley				Well Log	8	22	29	16					
Riley			36	Well Log	7	Not Given	35	9	7.0		35.0	9.0	0.136
Riley	10	8	4	Well Log	30	Not Given	30	30	22.7	8.0	30.3	22.3	0.508
Riley				Well Log	27	1	23	22					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Riley				Well Log	11	15	38	15					
Riley			5	Well Log	22	13	23	22	22.0	13.0	23.0	22.0	0.650
Riley			6	Well Log	38	Not Given	27	Not Given	38.0		25.0	23.0	1.033
Riley				Well Log	38	Not Given	23	23					
Riley			8	Well Log	5	Not Given	60	20	5.4	5.0	61.2	20.0	0.060
Riley				Well Log	7	Not Given	60	20					
Riley				Well Log	5	Not Given	62	20					
Riley				Well Log	5	5	62	20					
Riley				Well Log	5	Not Given	62	20					
Riley			9	Well Log	15	Not Given	42	21	14.1		42.0	21.0	0.228
Riley				Well Log	19	Not Given	35	21					
Riley				Well Log	19	Not Given	35	21					
Riley				Well Log	5	Not Given	62	27					
Riley				Well Log	19	Not Given	38	21					
Riley				Well Log	19	Not Given	37	21					
Riley				Well Log	8	Not Given	59	13					
Riley				Well Log	10	Not Given	57	10					
Riley				Well Log	17	Not Given	50	11					
Riley				Well Log	10	Not Given	55	13					
Riley			10	Well Log	16	5	30	16	16.0	5.0	30.0	16.0	0.362
Riley			13	Well Log	36	Not Given	14	13	36.0		14.0	13.0	1.747
Riley			14	Estaimation					19.4	12.0	39.0	19.0	0.339
Riley			15	Well Log	15	3	22	16	15.0	3.0	22.0	16.0	0.463
Riley			16	Well Log	16	5	30	16	14.7	6.0	30.0	15.1	0.332
Riley				Well Log	14	3	32	15					
Riley				Well Log	15	Not Given	30	15					
Riley				Well Log	18	Not Given	27	15					
Riley				Well Log	15	Not Given	28	15					
Riley				Well Log	14	Not Given	28	15					
Riley				Well Log	12	10	33	15					
Riley				Well Log	13	Not Given	32	15					
Riley				Well Log	15	Not Given	30	15					
Riley			17	Well Log	10	Not Given	30	15	10.5	14.0	25.5	17.8	0.280
Riley				Well Log	6	12	18	22					
Riley				Well Log	16	16	25	19					
Riley				Well Log	10	Not Given	29	15					
Riley			19	Well Log	15	11	50	26	15.0	11.0	50.0	26.0	0.204
Riley			21	Well Log	12	6	31	16	12.0	6.0	31.0	16.0	0.263
Riley			22	Well Log	38	5	11	22	38.0	5.0	11.0	22.0	2.348
Riley			23	Well Log	43	Not Given	40	31	32.0	13.0	41.5	31.0	0.524

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Riley				Fader, 1974	21	13	43	Not Given					
Riley			24	Well Log	46	Not Given	29	25	46.0		29.0	25.0	1.078
Riley			25	Well Log	39	3	36	15	41.5	5.0	36.0	23.0	0.783
Riley				Well Log	44	7	36	31					
Riley			26	Well Log	44	4	36	18	44.0	4.0	36.0	18.0	0.831
Riley			30	Well Log	21	12	21	12	21.5	10.0	21.0	13.5	0.696
Riley				Well Log	22	8	21	15					
Riley			31	Well Log	5	22	61	12	5.0	20.0	55.0	16.7	0.062
Riley				Well Log	6	Not Given	58	18					
Riley				Well Log	4	18	46	20					
Riley	9	8	31	Well Log	20	Not Given	46	27	35.0	2.0	29.5	31.5	0.806
Riley				Well Log	50	2	13	36					
Riley	10	9	15	Estimation					14.1	10.5	42.4		0.226
Riley			16	Well Log	15	10	25	15	15.0	10.0	25.0	15.0	0.408
Riley			17	Well Log	6	12	26	18	10.5	12.0	23.0	19.0	0.310
Riley				Well Log	15	Not Given	20	20					
Riley			18	Estimation					16.6	13.0	30.8	19.0	0.367
Riley			19	Well Log	19	12	36	26	19.0	12.0	36.0	26.0	0.359
Riley			20	Well Log	15	Not Given	43	25	15.0		43.0	25.0	0.237
Riley			21	Well Log	18	4	35		18.0	4.0	35.0		0.349
Riley			22	Well Log	15	Not Given	47		15.0		47.0		0.217
Riley			29	Well Log	40	20	34	35	40.0	20.0	34.0	35.0	0.800
Riley			30	Well Log	74	0	0	35	74.0	0.0	0.0	35.0	
Pottawatomie	10	8	8	Well Log	18	Not Given	39	17	15.8		45.5	18.5	0.235
Pottawatomie				Well Log	18	Not Given	39	17					
Pottawatomie				Well Log	19	Not Given	48	20					
Pottawatomie				Well Log	8	Not Given	56	20					
Pottawatomie			9	Well Log	20	15	30	18	20.0	15.0	30.0	18.0	0.453
Pottawatomie			10	Well Log	26	Not Given	49	26	32.3	6.0	29.0	30.0	0.758
Pottawatomie				Well Log	41	Not Given	22	35					
Pottawatomie				Well Log	30	6	16	29					
Pottawatomie			11	Well Log	21	Not Given	29	20	21.0		29.0	20.0	0.492
Pottawatomie			12	Well Log	22	8	10	11	22.0	8.0	10.0	11.0	1.495
Pottawatomie			13	Well Log	36		14		36.0		14.0		1.747
Pottawatomie			14	Well Log	1	14	64	11	8.8	8.0	50.5	14.0	0.118
Pottawatomie				Well Log	23	Not Given	27	20					
Pottawatomie				Well Log	4	8	57	18					
Pottawatomie				Well Log	7	2	54	7					
Pottawatomie			15	Well Log	15	4	53	13	8.0	5.5	57.0	9.5	0.095
Pottawatomie				Well Log	1	7	61	6					

***Table A-1*.** Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Pottawatomie			22	Estimation					19.8	7.5	38.2	18.5	0.351
Pottawatomie			23	Estimation					28.1	7.9	33.8	20.3	0.565
Pottawatomie			24	Well Log	1	15	50	12	1.0	15.0	50.0	12.0	0.014
Pottawatomie	10	9	7	Well Log	15	Not Given	24	28	16.0		21.5	21.5	0.506
Pottawatomie				Well Log	17	Not Given	19	15					
Pottawatomie			8	Well Log	12	5	23	18	12.0	5.0	23.0	18.0	0.355
Pottawatomie			13	Well Log	25	Not Given	39	19	25.0		39.0	19.0	0.436
Pottawatomie			14	Well Log	8	27	52	75	7.5	17.5	57.0	75.0	0.089
Pottawatomie				Well Log	7	8	62	Not Given					
Pottawatomie			23	Well Log	15	Not Given	48	18	15.0		48.0	18.0	0.212
Pottawatomie	9	10	24	Well Log	29	2	49	29	29.0	2.0	49.0	29.0	0.402
Pottawatomie			25	Well Log	40	Not Given	47	27	40.0		47.0	27.0	0.578
Pottawatomie			26	Well Log	50	20	30	35	48.5	20.0	27.0	33.0	1.221
Pottawatomie				Well Log	47	Not Given	24	31					
Pottawatomie			27	Estimation					39.3	9.3	42.0	31.8	0.636
Pottawatomie			34	Well Log	37	7	50	36	37.0	7.0	50.0	36.0	0.503
Pottawatomie			35	Well Log	34	Not Given	46	24	32.5	1.0	49.0	26.5	0.451
Pottawatomie				Well Log	31	1	52	29					
Pottawatomie			36	Well Log	29	Not Given	25	20	25.0	2.0	28.7	23.3	0.593
Pottawatomie				Well Log	20	2	30	21					
Pottawatomie				Well Log	26	Not Given	31	29					
Pottawatomie	10	10	1	Estimation					11.1	9.3	37.2	19.7	0.203
Pottawatomie			2	Well Log	29	Not Given	53	29	19.7	8.0	38.0	25.3	0.352
Pottawatomie				Well Log	19	Not Given	28	19					
Pottawatomie				Well Log	11	8	33	28					
Pottawatomie			3	Well Log	26	Not Given	56	16	26.0		56.0	16.0	0.316
Pottawatomie			10	Well Log	28	2	51	32	28.0	2.0	51.0	32.0	0.373
Pottawatomie			11	Well Log	14	Not Given	33	17	14.0		33.0	17.0	0.288
Pottawatomie			12	Well Log	2	10	43	13	2.0	10.0	43.0	13.0	0.032
Pottawatomie			18	Well Log	9	5	58	17	9.0	5.0	58.0	17.0	0.105
Pottawatomie			19	Well Log	13	4	52	17	11.0	9.0	56.0	18.3	0.133
Pottawatomie				Well Log	18	Not Given	48	16					
Pottawatomie				Well Log	2	14	68	22					
Pottawatomie	9	11	27	Well Log	10	0	0	30	10.0	0.0	0.0	30.0	
Pottawatomie			28	Well Log	23	Not Given	40	27	23.0		40.0	27.0	0.391
Pottawatomie			29	Well Log	30	Not Given	26	26	30.0		26.0	26.0	0.784
Pottawatomie			30	Well Log	24	3	36	18	23.5	3.0	45.5	18.0	0.351
Pottawatomie				Beck, 1959	23	Not Given	55	Not Given					
Pottawatomie			31	Well Log	11	Not Given	34	24	11.0		36.5	24.0	0.205
Pottawatomie				Beck, 1959	11	Not Given	39	Not Given					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Pottawatomie			32	Well Log	25	Not Given	58	25	22.0		52.3	22.3	0.286
Pottawatomie				Well Log	23		42	18					
Pottawatomie				Well Log	18	Not Given	57	24					
Pottawatomie			33	Well Log	2	13	77	17	6.0	13.0	71.5	16.0	0.057
Pottawatomie				Well Log	10	Not Given	66	15					
Pottawatomie			34	Well Log	36	Not Given	25	17	20.7		44.7	15.7	0.314
Pottawatomie				Well Log	11	Not Given	59	15					
Pottawatomie				Well Log	15	Not Given	50	15					
Pottawatomie			35	Well Log	19	8	31	19	10.8	11.0	39.6	18.4	0.185
Pottawatomie				Well Log	15	Not Given	31	15					
Pottawatomie				Well Log	3	9	50	15					
Pottawatomie				Well Log	15	Not Given	35	20					
Pottawatomie				Well Log	2	16	51	23					
Pottawatomie			36	Well Log	15	Not Given	38	19	17.3		33.7	18.7	0.350
Pottawatomie				Well Log	12	Not Given	37	18					
Pottawatomie				Well Log	25	Not Given	26	19					
Pottawatomie	10	11	1	Well Log	18	Not Given	60	15	18.0		53.3	18.7	0.229
Pottawatomie				Well Log	14	Not Given	58	18					
Pottawatomie				Well Log	22	Not Given	42	23					
Pottawatomie			2	Well Log	11	Not Given	47	15	11.0		47.0	15.0	0.159
Pottawatomie			3	Well Log	7	5	67	18	9.3	5.5	57.0	16.5	0.110
Pottawatomie				Well Log	7	Not Given	53	21					
Pottawatomie				Well Log	9	6	62	19					
Pottawatomie				Well Log	14	Not Given	46	8					
Pottawatomie			4	Well Log	14	Not Given	50	18	14.0		50.0	18.0	0.190
Pottawatomie			5	Well Log	14	Not Given	45	19	14.0		45.0	19.0	0.211
Pottawatomie			6	Well Log	6	10	34	22	6.0	10.0	34.0	22.0	0.120
Pottawatomie			10	Estimation					7.0	7.0	43.7	12.3	0.109
Pottawatomie			11	Well Log	21	3	63	23	20.7	3.0	60.3	26.7	0.233
Pottawatomie				Well Log	18	Not Given	59	30					
Pottawatomie				Well Log	23	Not Given	59	27					
Pottawatomie			12	Well Log	6	5	70	15	6.0	5.0	70.0	15.0	0.058
Pottawatomie	10	12	4	Well Log	24	Not Given	20	24	24.0		20.0	24.0	0.815
Pottawatomie			5	Well Log	42	Not Given	6	30	42.0		6.0	30.0	4.757
Pottawatomie			6	Well Log	2	14	37	9	2.0	14.0	37.0	9.0	0.037
Pottawatomie			7	Well Log	4	17	60	17	6.7	11.5	46.3	17.5	0.098
Pottawatomie				Well Log	3	6	46	18					
Pottawatomie				Well Log	13	Not Given	33	Not Given					
Pottawatomie			8	Estimation					7.8	10.3	38.8	16.8	0.136
Pottawatomie			9	Well Log	15	Not Given	35	14	23.3	8.0	31.0	27.7	0.512

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Pottawatomie				Well Log	19	8	30	33					
Pottawatomie				Well Log	36	Not Given	28	36					
Pottawatomie			10	Well Log	13	3	27	16	13.0	3.0	27.0	16.0	0.327
Pottawatomie			14	Well Log	18	3	30	19	18.0	3.0	30.0	19.0	0.408
Pottawatomie			15	Well Log	25	Not Given	21	21	16.0	9.0	27.5	19.5	0.395
Pottawatomie				Well Log	7	9	34	18					
Pottawatomie			22	Well Log	1	8	67	25	1.0	8.0	67.0	25.0	0.010
Pottawatomie			23	Well Log	6	2	63	16	6.0	2.0	63.0	16.0	0.065
Pottawatomie			26	Well Log	10	7	52	14	10.0	7.0	52.0	14.0	0.131
Pottawatomie			27	Well Log	4	7	58	19	3.0	8.5	48.5	16.0	0.042
Pottawatomie				Well Log	2	10	39	13					
Pottawatomie			28	Well Log	4	21	61	22	11.0	21.0	45.0	17.0	0.166
Pottawatomie				Well Log	18	Not Given	29	12					
Wabaunsee	10	9	23	Well Log	13	Not Given	35	15	13.0		35.0	15.0	0.252
Wabaunsee			24	Estimation					13.4	10.5	48.8	27.1	0.187
Wabaunsee			25	Estimation					8.1	6.5	34.9	15.1	0.158
Wabaunsee	10	10	9	Well Log	15	Not Given	45	15	15.0		45.0	15.0	0.227
Wabaunsee			14	Well Log	14	2	26	12	14.0	2.0	26.0	12.0	0.366
Wabaunsee			15	Well Log	16	Not Given	54	14	16.0		54.0	14.0	0.201
Wabaunsee			16	Well Log	11	5	58	19	11.0	5.0	43.0	19.5	0.174
Wabaunsee				Well Log	11	Not Given	28	20					
Wabaunsee			17	Well Log	9	7	56	18	9.0	7.0	56.0	18.0	0.109
Wabaunsee			20	Well Log	15	Not Given	80	21	15.0		80.0	21.0	0.127
Wabaunsee			21	Well Log	11	3	33	17	11.0	3.0	33.0	17.0	0.227
Wabaunsee	10	11	3	Estimation					9.3	5.5	57.0	16.5	0.110
Wabaunsee			4	Estimation					14.0		50.0	18.0	0.190
Wabaunsee			6	Well Log	14	Not Given	38	21	14.0		38.0	21.0	0.250
Wabaunsee			8	Estimation					11.3	10.0	43.0	19.7	0.179
Wabaunsee			9	Estimation					10.7	7.0	48.7	16.5	0.150
Wabaunsee			10	Well Log	10	Not Given	26	10	7.0	7.0	43.7	12.3	0.109
Wabaunsee				Well Log	7	Not Given	29	11					
Wabaunsee				Well Log	4	7	76	16					
Wabaunsee			11	Estimation					20.7	3.0	60.3	26.7	0.233
Wabaunsee			13	Well Log	8	14	71	19	20.0	14.0	61.5	23.0	0.221
Wabaunsee				Well Log	32	Not Given	52	27					
Wabaunsee			14	Well Log	35	Not Given	15	29	34.0		12.5	29.0	1.848
Wabaunsee				Beck, 1959	33	Not Given	10	Not Given					
Wabaunsee			15	Well Log	16	0	0	80	16.0	0.0	0.0	80.0	
Wabaunsee	10	12	7	Estimation					6.7	11.5	46.3	17.5	0.098
Wabaunsee			8	Well Log	2	11	43	17	7.8	10.3	38.8	16.8	0.136

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Wabaunsee				Well Log	1	16	46	17					
Wabaunsee				Well Log	15	4	34	17					
Wabaunsee				Well Log	13	Not Given	32	16					
Wabaunsee			9	Estimation					11.6	6.3	27.3	15.9	0.290
Wabaunsee			16	Well Log	14	7	64	24	13.5	7.0	46.5	21.5	0.197
Wabaunsee				Well Log	13	Not Given	29	19					
Wabaunsee			17	Well Log	18	Not Given	28	18	18.0		28.0	18.0	0.437
Wabaunsee			18	Well Log	31	3	14	30	31.0	3.0	14.0	30.0	1.505
Wabaunsee			19	Well Log	34	Not Given	37	19	34.0		37.0	19.0	0.624
Wabaunsee			20	Well Log	32	Not Given	52	24	32.0		52.0	24.0	0.418
Wabaunsee			21	Well Log	21	Not Given	46	27	21.0		46.0	27.0	0.310
Wabaunsee			22	Well Log	19	Not Given	55	18	19.0		55.0	18.0	0.235
Wabaunsee			28	Well Log	26	Not Given	31	25	26.0		31.0	25.0	0.570
Wabaunsee			29	Beck, 1959	47	Not Given	9	Not Given	47.0		9.0		3.549
Wabaunsee			33	Well Log	41	Not Given	21	28	41.0		21.0	28.0	1.327
Wabaunsee			34	Estimation					18.2	12.2	39.5	20.0	0.313
Wabaunsee			35	Estimation					10.4	9.2	46.7	16.7	0.151
Wabaunsee	11	13	5	Estimation					2.0	2.0	45.0		0.030
Wabaunsee			6	Estimation					18.0	2.0	24.5	7.0	0.499
Wabaunsee			7	Well Log	34	Not Given	4	7	34.0		4.0	7.0	5.776
Wabaunsee			8	Well Log	47	Not Given	8	22	35.5		6.0	21.0	4.021
Wabaunsee				Well Log	24	Not Given	4	20					
Wabaunsee			9	Well Log	14	3	29	15	9.0		27.0	14.0	0.227
Wabaunsee				Well Log	4	Not Given	25	13					
Shawnee	10	12	36	Well Log	1	7	42	16	8.8	6.3	34.0	14.8	0.175
Shawnee				Well Log	3	7	38	14					
Shawnee				Well Log	21	Not Given	22	18					
Shawnee				Well Log	10	5	34	11					
Shawnee	11	12	1	Estimation					18.0	2.0	24.5	7.0	0.499
Shawnee	10	13	19	Well Log	25	Not Given	66	19	25.7		53.0	21.5	0.329
Shawnee				Well Log	26	Not Given	54	24					
Shawnee				Beck, 1959	26	Not Given	39	Not Given					
Shawnee			20	Estimation					13.9	7.0	36.7	13.8	0.257
Shawnee			29	Well Log	2	11	30	9	2.0	11.0	30.0	9.0	0.045
Shawnee			30	Well Log	14	3	27	11	14.0	3.0	27.0	11.0	0.352
Shawnee			31	Well Log	16	4	24	18	6.8	8.5	34.3	16.0	0.134
Shawnee				Well Log	1	13	45	14					
Shawnee				Beck, 1959	8	4	29	Not Given					
Shawnee				Beck, 1959	2	13	39	Not Given					
Shawnee			32	Well Log	11	Not Given	30	16	7.5		33.0	14.5	0.154

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Shawnee				Well Log	4	Not Given	36	13					
Shawnee	11	13	1	Well Log	39	3	6	16	39.0	3.0	6.0	16.0	4.417
Shawnee			2	Well Log	8	19	56	20	8.0	19.0	56.0	20.0	0.097
Shawnee			3	Well Log	1	18	58	21	13.0	11.7	37.5	19.5	0.236
Shawnee				Well Log	19	4	26	17					
Shawnee				Well Log	19	Not Given	33	23					
Shawnee				Well Log	13	13	33	17					
Shawnee			4	Well Log	15	Not Given	22	9	15.0		22.0	9.0	0.463
Shawnee			5	Well Log	2	2	45		2.0	2.0	45.0		0.030
Shawnee			9	Well Log	16	Not Given	31	13	16.0		31.0	13.0	0.351
Shawnee			10	Well Log	19	Not Given	31	22	19.0		31.0	22.0	0.417
Shawnee			11	Well Log	13	Not Given	25	9	12.0	7.0	30.7	13.7	0.266
Shawnee				Well Log	19	Not Given	31	16					
Shawnee				Well Log	4	7	36	16					
Shawnee			12	Well Log	2	3	84	19	2.0	3.0	84.0	19.0	0.016
Shawnee			13	Well Log	3	15	77	21	13.0	15.0	54.3	18.7	0.163
Shawnee				Well Log	20	Not Given	55	18					
Shawnee				Well Log	16	Not Given	31	17					
Shawnee			14	Well Log	16	Not Given	4	17	16.0		4.0	17.0	2.718
Shawnee	11	14	6	Well Log	40	Not Given	5	30	40.0		5.0	30.0	5.437
Shawnee			7	Well Log	8	7	23	16	7.0	7.5	41.0	16.0	0.116
Shawnee				Beck, 1959	6	8	59	Not Given					
Shawnee			8	Beck, 1959	13	Not Given	62	Not Given	13.0		62.0		0.142
Shawnee			9	Well Log	21	2	29	17	21.0	2.0	29.0	17.0	0.492
Shawnee			10	Well Log	24	Not Given	24	18	24.0		24.0	18.0	0.680
Shawnee			13	Well Log	29	7	26	27	28.3	4.0	25.8	21.3	0.746
Shawnee				Well Log	24	3	31	19					
Shawnee				Well Log	31	2	20	21					
Shawnee				Well Log	29	Not Given	26	18					
Shawnee			14	Well Log	30	Not Given	22	30	27.3		24.0	27.7	0.774
Shawnee				Well Log	27	Not Given	25	21					
Shawnee				Well Log	25	Not Given	25	32					
Shawnee			15	Well Log	23	4	64	24	22.5	6.5	64.0	25.5	0.239
Shawnee				Well Log	22	9	64	27					
Shawnee			16	Well Log	17	11	53	17	11.5	11.0	53.0	14.5	0.147
Shawnee				Well Log	6	Not Given	53	12					
Shawnee			17	Well Log	12	Not Given	57	20	7.0	11.0	63.0	19.0	0.076
Shawnee				Well Log	2	11	69	18					
Shawnee			18	Well Log	19	Not Given	52	21	14.0		60.3	21.5	0.158
Shawnee				Well Log	17	Not Given	61	22					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water Level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Shawnee				Beck, 1959	6	Not Given	68	Not Given					
Shawnee			20	Well Log	12	9	28	17	11.0	9.0	18.5	17.0	0.404
Shawnee				Beck, 1959	10	Not Given	9	Not Given					
Shawnee			21	Estimation					10.8	10.3	51.3	20.6	0.143
Shawnee			22	Well Log	2	14	58	27	2.0	14.0	58.0	27.0	0.023
Shawnee			23	Well Log	28	Not Given	32	17	15.3	10.0	45.7	14.0	0.228
Shawnee				Well Log	16	Not Given	63	11					
Shawnee				Well Log	2	10	42	14					
Shawnee			24	Well Log	23	Not Given	25	16	23.0		25.0	16.0	0.625
Shawnee			25	Well Log	4	9	70	18	4.0	9.0	70.0	18.0	0.039
Shawnee			26	Well Log	1	7	67	22	1.0	7.0	67.0	22.0	0.010
Shawnee			27	Well Log	1		76	17	1.0		76.0	17.0	0.009
Shawnee	11	15	11	Davis, et al, 1952	30	Not Given	3	Not Given	29.0		8.0		2.463
Shawnee				Davis, et al, 1952	28	Not Given	13	Not Given					
Shawnee			12	Davis, et al, 1952	19	6	16	Not Given	19.0	6.0	16.0		0.807
Shawnee			13	Well Log	28	Not Given	54	35	31.9	5.3	50.8	36.0	0.426
Shawnee				Well Log	38	Not Given	43	Not Given					
Shawnee				Well Log	38	Not Given	43	Not Given					
Shawnee				Well Log	33	Not Given	50	38					
Shawnee				Well Log	38	Not Given	43	35					
Shawnee				Well Log	38	Not Given	44	Not Given					
Shawnee				Well Log	38	Not Given	44	Not Given					
Shawnee				Well Log	33	Not Given	50	Not Given					
Shawnee				Well Log	33	Not Given	50	Not Given					
Shawnee				Davis, et al, 1952	20	4	71.5	Not Given					
Shawnee				Davis, et al, 1952	13	9	66	Not Given					
Shawnee				Davis, et al, 1952	30	3	60	Not Given					
Shawnee				Davis, et al, 1952	38	Not Given	34	Not Given					
Shawnee				Davis, et al, 1952	28	Not Given	59	Not Given					
Shawnee			14	Well Log	33	Not Given	52	31	24.5	7.0	57.0	31.0	0.292
Shawnee				Davis, et al, 1952	10	Not Given	63	Not Given					
Shawnee				Davis, et al, 1952	24	Not Given	57	Not Given					
Shawnee				Davis, et al, 1952	31	7	56	Not Given					
Shawnee			15	Well Log	31	Not Given	37	27	26.7		28.7	29.0	0.632
Shawnee				Well Log	24	Not Given	24	28					
Shawnee				Well Log	25	Not Given	25	32					
Shawnee			16	Well Log	33	Not Given	24	27	33.0		24.0	27.0	0.934
Shawnee			17	Well Log	30	Not Given	26	26	27.0		29.0	24.5	0.633
Shawnee				Well Log	24	Not Given	32	23					
Shawnee			18	Well Log	26	Not Given	24	22	27.5	4.0	24.0	20.0	0.779

Table A-1. Data summary (continued).

Location				Data Source	Measured Depth of				Average Depth of				
County	Township	Range	Section		Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Shawnee				Well Log	29	4	24	18					
Shawnee			19	Well Log	12	6	38	22	12.0	6.0	38.0	22.0	0.215
Shawnee			20	Well Log	11	Not Given	40	22	11.0		40.0	22.0	0.187
Shawnee			21	Well Log	9	3	36	17	9.0	3.0	36.0	17.0	0.170
Shawnee			22	Well Log	7	Not Given	66	21	8.5	13.0	65.0	22.5	0.089
Shawnee				Well Log	10	13	64	24					
Shawnee			23	Well Log	10	Not Given	34	15	10.0		34.0	15.0	0.200
Shawnee			24	Well Log	10	Not Given	34	15	10.0		35.3	15.0	0.193
Shawnee				Well Log	10	Not Given	34	15					
Shawnee				Well Log	11	Not Given	32	15					
Shawnee				Davis, et al, 1952	9	Not Given	41	Not Given					
Shawnee			25	Davis, et al, 1952	10	Not Given	38	Not Given	10.0		38.0		0.179
Shawnee			26	Davis, et al, 1952	10	Not Given	41	Not Given	9.0		20.5		0.298
Shawnee				Davis, et al, 1952	8	Not Given	0	Not Given					
Shawnee	11	16	22	Well Log	15	5	66	28	17.5	5.0	42.5	23.5	0.280
Shawnee				Well Log	20	Not Given	19	19					
Shawnee			23	Well Log	21	14	26	24	21.0	14.0	26.0	24.0	0.549
Shawnee			29	Davis, et al, 1952	9	Not Given	58	Not Given	9.0		58.0		0.105
Shawnee			30	Davis, et al, 1952	15	Not Given	56	Not Given	15.0		56.0		0.182
Shawnee			35	Well Log	27	Not Given	23	19	27.7		23.0	21.7	0.817
Shawnee				Well Log	34	Not Given	15	25					
Shawnee				Well Log	22	Not Given	31	21					
Shawnee	11	17	27	Well Log	0	19	55	9	0.0	19.0	66.0	9.0	0.000
Shawnee				Fader, 1974	0	Not Given	77	Not Given					
Shawnee			28	Well Log	19	Not Given	48	21	19.0		48.0	21.0	0.269
Jefferson	11	16	24	Well Log	18	Not Given	29	26	18.0		29.0	26.0	0.422
Jefferson			25	Well Log	2	7	49	23	4.7	7.0	49.0	18.3	0.065
Jefferson				Well Log	2	7	51	11					
Jefferson				Well Log	10	Not Given	47	21					
Jefferson		17	16	Well Log	33	Not Given	14	23	33.0		14.0	23.0	1.602
Jefferson			17	Well Log	1	15	59	28	1.0	15.0	59.0	28.0	0.012
Jefferson			18	Well Log	31	Not Given	36	28	29.5		45.0	28.0	0.446
Jefferson				Well Log	28	Not Given	54	Not Given					
Jefferson			19	Well Log	28	Not Given	12	22	28.0		12.0	22.0	1.586
Jefferson			20	Well Log	30	Not Given	36	21	30.0		36.0	21.0	0.566
Jefferson			21	Well Log	35	Not Given	18	25	35.0		18.0	25.0	1.321
Jefferson			22	Well Log	21	Not Given	12	10	21.0		12.0	10.0	1.189
Jefferson			23	Well Log	30	2	24	17	25.0	4.5	17.3	17.3	0.980
Jefferson				Well Log	25	Not Given	10	18					
Jefferson				Well Log	20	7	18	17					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Jefferson			24	Estimation					22.7	4.5	30.1	16.1	0.512
Jefferson			25	Well Log	9	Not Given	42	13	9.0		42.0	13.0	0.146
Jefferson			26	Estimation					17.9	6.3	28.5	15.5	0.428
Jefferson			27	Well Log	3	15	47	23	12.0	10.0	41.0	21.0	0.199
Jefferson				Well Log	21	5	35	19					
Jefferson			28	Well Log	1	9	59	19	1.0	9.0	59.0	19.0	0.012
Jefferson			29	Estimation					30.0		36.0	21.0	0.566
Jefferson			30	Well Log	24	7	16	21	24.0	7.0	16.0	21.0	1.019
Jefferson		18	8	Well Log	43	Not Given	8	7	43.0		8.0	7.0	3.653
Jefferson			16	Well Log	31	Not Given	57	12	26.5		55.0	12.0	0.327
Jefferson				Davis, et al, 1952	22	Not Given	53						
Jefferson			17	Well Log	27	3	46	14	27.0	3.0	46.0	14.0	0.399
Jefferson			18	Estimation					27.1	4.0	35.0	15.1	0.526
Jefferson			19	Well Log	34	Not Given	31	18	34.0		31.0	18.0	0.745
Jefferson			20	Well Log	28	Not Given	32	21	20.3	5.0	28.0	13.3	0.494
Jefferson				Well Log	31	Not Given	17	12					
Jefferson				Well Log	2	5	35	7					
Jefferson			21	Well Log	26	3	16	19	17.4	10.7	27.3	19.0	0.434
Jefferson				Well Log	12	Not Given	33	30					
Jefferson				Well Log	15	19	21	15					
Jefferson				Well Log	17	11	28	17					
Jefferson				Well Log	17	14	30	19					
Jefferson				Well Log	12	Not Given	39	14					
Jefferson				Well Log	15	10	28	16					
Jefferson				Well Log	27	7	20	22					
Jefferson				Davis, et al, 1952	16	Not Given	31	Not Given					
Jefferson			22	Well Log	30	Not Given	30	25	30.0		30.0	25.0	0.680
Jefferson				Davis, et al, 1952	30	6	50	Not Given					
Jefferson			25	Well Log	17	Not Given	54	15	19.3	13.0	54.0	15.0	0.243
Jefferson				Well Log	22	13	53	15					
Jefferson				Well Log	19	Not Given	55	15					
Jefferson			26	Well Log	16	Not Given	48	19	16.5		44.5	19.0	0.252
Jefferson				Well Log	17	Not Given	41	19					
Jefferson			27	Well Log	18	13	23	16	18.0	13.0	23.0	16.0	0.532
Jefferson			28	Well Log	12	10	17	10	12.0	10.0	17.0	10.0	0.480
Jefferson			34	Well Log	17	Not Given	41		17.0		41.0		0.282
Jefferson			35	Estimation					17.0		41.0		0.282
Jefferson			36	Well Log	13	Not Given	43	16	13.0		43.0	16.0	0.205
Jefferson		19	29	Well Log	28	10	29	21	29.5	6.5	36.5	20.0	0.549
Jefferson				Well Log	31	3	44	19					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Jefferson			30	Well Log	34	7	41	17	34.5	7.0	39.5	20.5	0.594
Jefferson				Well Log	35	Not Given	38	24					
Jefferson			31	Estimation					22.2	7.0	43.5	19.8	0.346
Jefferson			32	Well Log	19	Not Given	48	23	19.0		48.0	23.0	0.269
Jefferson			33	Well Log	30	12	14	22	26.0	17.0	25.3	22.0	0.697
Jefferson				Davis, et al, 1952	15	22	35	Not Given					
Jefferson				Davis, et al, 1952	33	Not Given	27	Not Given					
Jefferson			34	Well Log	40	Not Given	20	24	30.0	13.0	24.0	24.0	0.849
Jefferson				Davis, et al, 1952	20	13	28	Not Given					
Jefferson	12	19	5	Estimation					22.4	12.0	38.9	21.6	0.391
Jefferson			6	Estimation					18.1	7.0	44.8	19.6	0.274
Douglas	11	18	27	Estimation					11.0		40.3		0.186
Douglas			28	Davis, et al, 1952	5	Not Given	43	Not Given	5.0		39.5		0.086
Douglas				Davis, et al, 1952	5	Not Given	36	Not Given					
Douglas			29	Estimation					5.0		39.5		0.086
Douglas			30	Well Log	25	Not Given	16	13	25.0		16.0	13.0	1.062
Douglas	12	19	1	Well Log	39	Not Given	11	25	39.0		11.0	25.0	2.409
Douglas			2	Well Log	22	Not Given	18	14	22.0		18.0	14.0	0.831
Douglas			3	Estimation					30.0	13.0	24.0	24.0	0.849
Douglas			4	Estimation					13.5	15.3	39.7	18.0	0.231
Douglas			9	Well Log	2	19	48	14	1.0	13.5	54.0	14.0	0.013
Douglas				Davis, et al, 1952	0	8	60	Not Given					
Douglas			10	Well Log	9	5	24	14	9.0	5.0	24.0	14.0	0.255
Douglas			11	Estimation					14.0	11.0	37.5	18.0	0.254
Douglas			12	Well Log	19	17	51	22	19.0	17.0	51.0	22.0	0.253
Douglas			13	Well Log	11	7	42	12	11.0	7.0	42.0	12.0	0.178
Douglas			14	Well Log	34	Not Given	6	33	19.7	4.0	28.7	33.0	0.466
Douglas				Davis, et al, 1952	11	4	41	Not Given					
Douglas				Davis, et al, 1952	14	4	39	Not Given					
Douglas			15	Well Log	17	5	22	14	34.5	5.0	11.5	14.0	2.039
Douglas				Davis, et al, 1952	52	Not Given	1	Not Given					
Douglas			24	Well Log	23	Not Given	26	14	9.7		33.7	14.0	0.195
Douglas				Davis, et al, 1952	4	Not Given	44	Not Given					
Douglas				Davis, et al, 1952	0	10	48	Not Given					
Douglas				Davis, et al, 1952	8	Not Given	38	Not Given					
Douglas				Davis, et al, 1952	11	Not Given	38	Not Given					
Douglas				Davis, et al, 1952	12	Not Given	8	Not Given					
Douglas			25	Davis, et al, 1952	21	Not Given	24	Not Given	17.0		28.5		0.405
Douglas				Davis, et al, 1952	13	Not Given	33	Not Given					
Douglas	12	20	7	Well Log	44	5	15	21	22.5	29.0	21.0	22.5	0.728

Table A-1. Data summary (continued).

Location				Data Source	Measured Depth of				Average Depth of				
County	Township	Range	Section		Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Douglas				Davis, et al, 1952	0	40	43						
Douglas			8	Well Log	39	4	36	23	39.0	4.0	36.0	23.0	0.736
Douglas			9	Davis, et al, 1952	52	Not Given	11	Not Given	39.5		14.0		1.917
Douglas				Davis, et al, 1952	27	Not Given	17	Not Given					
Douglas			16	Well Log	21	7	21	Not Given	21.0	7.0	21.0		0.680
Douglas			17	Well Log	38	Not Given	40	22	25.8	5.0	44.3	22.0	0.395
Douglas				Davis, et al, 1952	9	5	59	Not Given					
Douglas				Davis, et al, 1952	26	Not Given	28	Not Given					
Douglas				Davis, et al, 1952	30	Not Given	50	Not Given					
Douglas			18	Well Log	9	Not Given	44	18	9.0		44.0	18.0	0.139
Douglas			19	Well Log	20	21	30	17	10.0	21.0	37.2	17.0	0.183
Douglas				Davis, et al, 1952	20	Not Given	31	Not Given					
Douglas				Davis, et al, 1952	0	Not Given	46	Not Given					
Douglas				Davis, et al, 1952	13	Not Given	32	Not Given					
Douglas				Davis, et al, 1952	12	Not Given	30	Not Given					
Douglas				Davis, et al, 1952	15	Not Given	40	Not Given					
Douglas				Davis, et al, 1952	2	Not Given	42	Not Given					
Douglas				Davis, et al, 1952	1	Not Given	49	Not Given					
Douglas				Davis, et al, 1952	10	Not Given	34	Not Given					
Douglas				Davis, et al, 1952	7	Not Given	38	Not Given					
Douglas			20	Well Log	12	5	38	22	14.0	6.5	43.0	22.5	0.221
Douglas				Well Log	33	Not Given	23	23					
Douglas				Davis, et al, 1952	6	8	44	Not Given					
Douglas				Davis, et al, 1952	11	Not Given	46	Not Given					
Douglas				Davis, et al, 1952	8	Not Given	64	Not Given					
Douglas			21	Well Log	23	12	46	16	23.7	8.0	41.3	18.7	0.389
Douglas				Well Log	37	Not Given	32	24					
Douglas				Well Log	11	4	46	16					
Douglas			26	Estimation					16.4	3.0	45.3	18.3	0.246
Douglas			28	Well Log	10	Not Given	50	19	10.0		50.0	19.0	0.136
Douglas			29	Davis, et al, 1952	13	3	37	Not Given	9.0	13.6	48.0		0.127
Douglas				Davis, et al, 1952	3	15	48	Not Given					
Douglas				Davis, et al, 1952	10	14	43	Not Given					
Douglas				Davis, et al, 1952	3	34	48	Not Given					
Douglas				Davis, et al, 1952	2	14	56	Not Given					
Douglas				Davis, et al, 1952	15	6	53	Not Given					
Douglas				Davis, et al, 1952	17	9	51	Not Given					
Douglas			30	Davis, et al, 1952	10	Not Given	38	Not Given	11.7	7.0	33.7		0.236
Douglas				Davis, et al, 1952	13	Not Given	24	Not Given					
Douglas				Davis, et al, 1952	14	Not Given	34	Not Given					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Douglas				Davis, et al, 1952	8	Not Given	34	Not Given					
Douglas				Davis, et al, 1952	14	Not Given	31	Not Given					
Douglas				Davis, et al, 1952	18	7	29	Not Given					
Douglas				Davis, et al, 1952	8	Not Given	33	Not Given					
Douglas				Davis, et al, 1952	11	Not Given	41	Not Given					
Douglas				Davis, et al, 1952	10	Not Given	37	Not Given					
Douglas				Davis, et al, 1952	13	Not Given	31	Not Given					
Douglas				Davis, et al, 1952	10	Not Given	39	Not Given					
Douglas			32	Well Log	22	10	27	29	22.0	10.0	27.0	29.0	0.554
Douglas			33	Well Log	4	14	44	16	9.5	14.0	40.0	17.0	0.161
Douglas				Well Log	15	Not Given	36	18					
Douglas			34	Well Log	19	Not Given	35	17	19.0		35.0	17.0	0.369
Douglas			35	Well Log	22	Not Given	56	26	16.5	4.0	48.0	19.0	0.234
Douglas				Well Log	11	4	40	12					
Douglas			36	Dufford, 1958	16	Not Given	40	Not Given	16.0		40.0		0.272
Douglas	13	20	1	Well Log	20	5	37	20	11.5	5.0	50.0	20.0	0.156
Douglas				Dufford, 1958	3	Not Given	63	Not Given					
Douglas			2	Well Log	28	9	52	38	28.0	9.0	52.0	38.0	0.366
Douglas			3	Well Log	44	10	10	31	44.0	10.0	10.0	31.0	2.990
Douglas			10	Well Log	12	0	0	46	12.0	0.0	0.0	46.0	
Douglas			11	Estimation					29.7	3.3	23.7	37.0	0.852
Douglas			12	Well Log	49	1	19	27	49.0	1.0	19.0	27.0	1.753
Douglas	12	21	27	Well Log	2	16	50	24	2.0	10.5	35.5	24.0	0.038
Douglas				Dufford, 1958	2	5	21	Not Given					
Douglas			28	Well Log	21	15	27	25	21.0	15.0	27.0	25.0	0.529
Douglas			31	Well Log	21	Not Given	49	22	16.5		42.0	22.0	0.267
Douglas				Dufford, 1958	12	Not Given	35	Not Given					
Douglas			34	Well Log	17	Not Given	33	16	17.0		33.0	16.0	0.350
Leavenworth	12	20	27	Well Log	14	2	58	19	14.0	2.0	58.0	19.0	0.164
Leavenworth			34	Well Log	17	Not Given	33		17.0		33.0		0.350
Leavenworth	12	21	23	Estimation					18.3	5.5	26.5	20.3	0.470
Leavenworth			24	Well Log	30	2	21	31	30.0	2.0	21.0	31.0	0.971
Leavenworth			25	Well Log	25	1	26	9	12.5	9.0	26.5	15.0	0.321
Leavenworth				Well Log	0	17	27	21					
Leavenworth			26	Well Log	13	Not Given	32	21	12.5		32.0	15.0	0.265
Leavenworth				Well Log	12	4	32	9					
Leavenworth			28	Estimation					21.0	15.0	27.0	25.0	0.529
Leavenworth			32	Well Log	1	21	49	22	1.5	13.5	33.0	22.0	0.031
Leavenworth				Dufford, 1958	2	6	17	Not Given					
Leavenworth			33	Well Log	18	Not Given	30	26	18.0		30.0	26.0	0.408

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Leavenworth	12	22	13	Well Log	20	3	33	24	20.0	3.0	33.0	24.0	0.412
Leavenworth			18	Well Log	20	10	30	12	20.0	10.0	30.0	12.0	0.453
Leavenworth			21	Well Log	11	13	46	24	10.7	13.3	44.3	22.0	0.164
Leavenworth				Well Log	23	11	19	20					
Leavenworth				Well Log	11	12	40	22					
Leavenworth				Dufford, 1958	13	7	38	Not Given					
Leavenworth				Dufford, 1958	10	15	46	Not Given					
Leavenworth				Dufford, 1958	10	16	49	Not Given					
Leavenworth				Dufford, 1958	5	Not Given	50	Not Given					
Leavenworth				Dufford, 1958	13	13	50	Not Given					
Leavenworth				Dufford, 1958	2	24	61	Not Given					
Leavenworth				Dufford, 1958	9	9	44	Not Given					
Leavenworth			22	Well Log	37	Not Given	19	32	37.0		19.0	32.0	1.323
Leavenworth			24	Estimation					20.7	6.8	32.9	29.4	0.427
Johnson	12	21	24	Dufford, 1958	19	Not Given	38	Not Given	19.0		38.0		0.340
Johnson			25	Dufford, 1958	13	18	32	Not Given	9.0	17.5	32.0		0.191
Johnson				Dufford, 1958	4	17	35	Not Given					
Johnson				Dufford, 1958	10	Not Given	29	Not Given					
Johnson	12	22	19	Well Log	31	4	28	25	18.1	12.5	35.9	17.0	0.343
Johnson				Well Log	24	Not Given	34	22					
Johnson				Well Log	11	17	37	22					
Johnson				Well Log	2	13	50	8					
Johnson				Well Log	17	13	37	8					
Johnson				Dufford, 1958	9	11	41	Not Given					
Johnson				Dufford, 1958	39	Not Given	30	Not Given					
Johnson				Dufford, 1958	1	9	41	Not Given					
Johnson				Dufford, 1958	31	10	28	Not Given					
Johnson				Dufford, 1958	10	20	47	Not Given					
Johnson				Dufford, 1958	22	18	35	Not Given					
Johnson				Dufford, 1958	5	15	41	Not Given					
Johnson				Dufford, 1958	33	Not Given	23	Not Given					
Johnson				Dufford, 1958	19	7	31	Not Given					
Johnson			20	Well Log	11	11	41	21	8.7	12.9	39.1	22.8	0.152
Johnson				Well Log	12	12	38	20					
Johnson				Well Log	14	9	42	28					
Johnson				Well Log	16	16	36	24					
Johnson				Well Log	7	14	38	21					
Johnson				Dufford, 1958	1	22	50	Not Given					
Johnson				Dufford, 1958	10	Not Given	38	Not Given					
Johnson				Dufford, 1958	5	Not Given	39	Not Given					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Johnson				Dufford, 1958	2	Not Given	44	Not Given					
Johnson				Dufford, 1958	8	6	33	Not Given					
Johnson				Dufford, 1958	10	Not Given	31	Not Given					
Johnson			21	Well Log	16	Not Given	30	20	16.0		30.0	20.0	0.362
Johnson			23	Well Log	24	2	24	30	11.1	12.9	39.6	30.0	0.191
Johnson				Well Log	17	4	31	30					
Johnson				Dufford, 1958	14	Not Given	41	Not Given					
Johnson				Dufford, 1958	8	7	43	Not Given					
Johnson				Dufford, 1958	9	22	40	Not Given					
Johnson				Dufford, 1958	7	15	52	Not Given					
Johnson				Dufford, 1958	2	24	45	Not Given					
Johnson				Dufford, 1958	8	16	41	Not Given					
Johnson			24	Well Log	13	5	40	29	20.7	6.8	32.9	29.4	0.427
Johnson				Well Log	15	9	36	30					
Johnson				Well Log	25	3	25	30					
Johnson				Well Log	21	10	29	29					
Johnson				Well Log	27	Not Given	33	34					
Johnson				Well Log	24	Not Given	38	31					
Johnson				Well Log	22	Not Given	29	26					
Johnson				Well Log	22	Not Given	29	26					
Johnson				Fader, 1974	17	Not Given	37	Not Given					
Johnson			25	Well Log	23	Not Given	39	31	16.0	11.0	47.0	29.5	0.231
Johnson				Well Log	9	11	55	28					
Johnson			26	Dufford, 1958	2	12	65	Not Given	12.0	12.0	54.0		0.151
Johnson				Dufford, 1958	22	Not Given	43	Not Given					
Johnson			29	Well Log	19	13	23	25	13.5	13.0	29.5	25.0	0.311
Johnson				Dufford, 1958	8	Not Given	36	Not Given					
Johnson			30	Dufford, 1958	5	29	50	Not Given	5.0	29.0	50.0		0.068
Johnson	11	23	32	Estimation					16.0	25.0	47.0	32.0	0.231
Johnson			33	Dufford, 1958	10	Not Given	43	Not Given	11.7		35.3		0.224
Johnson				Dufford, 1958	20	Not Given	43	Not Given					
Johnson				Dufford, 1958	19	Not Given	37	Not Given					
Johnson				Dufford, 1958	7	Not Given	44	Not Given					
Johnson				Dufford, 1958	6	Not Given	36	Not Given					
Johnson				Dufford, 1958	8	Not Given	9	Not Given					
Johnson			34	Estimation					11.7		35.3		0.224
Johnson			35	Estimation					6.3	54.0	49.7	38.0	0.087
Johnson			36	Estimation					1.0	54.0	64.0	38.0	0.011
Johnson	12	23	5	Well Log	12	25	50	32	16.0	25.0	47.0	32.0	0.231
Johnson				Well Log	20	Not Given	44	32					

Table A-1. Data summary (continued).

Location					Measured Depth of				Average Depth of				
County	Township	Range	Section	Data Source	Over-burden = OVBD (ft)	Fine Sand=FS (ft)	Pay Zone=PZ (ft)	water level=wl (ft)	OVBD (ft)	FS (ft)	PZ (ft)	wl (ft)	OVBD Ratio (yd^3/ton)
Johnson			8	Estimation					16.0	25.0	47.0	32.0	0.231
Wyandotte	12	23	7	Estimation					16.0	25.0	47.0	32.0	0.231
Wyandotte			18	Estimation					20.0	3.0	33.0	24.0	0.412
Wyandotte			19	Estimation					20.7	6.8	32.9	29.4	0.427
Wyandotte	11	23	28	Well Log	42	Not Given	36	49	35.8	18.0	35.8	49.0	0.680
Wyandotte				Dufford, 1958	43	18	46	Not Given					
Wyandotte				Dufford, 1958	40	Not Given	28	Not Given					
Wyandotte				Dufford, 1958	22	Not Given	49	Not Given					
Wyandotte				Dufford, 1958	48	Not Given	20	Not Given					
Wyandotte				Dufford, 1958	20	Not Given	36	Not Given					
Wyandotte			35	Estimation					3.7	54.0	56.8	38.0	0.044
Wyandotte			36	Well Log	1	54	64	38	1.0	54.0	64.0	38.0	0.011
Wyandotte	11	24	13	Well Log	28	Not Given	53	38	28.5		45.0	38.5	0.430
Wyandotte				Well Log	29	Not Given	37	39					
Wyandotte			14	Well Log	15	15	53	38	15.0	15.0	53.0	38.0	0.192
Wyandotte			22	Well Log	18	Not Given	57	30	18.0		57.0	30.0	0.215
Wyandotte			27	Well Log	9	Not Given	42	28	9.0		42.0	28.0	0.146
Wyandotte			28	Estimation					17.5		41.0	33.0	0.290
Wyandotte			29	Well Log	26	Not Given	40	38	26.0		40.0	38.0	0.442
Wyandotte			30	Well Log	15	5	35	Not Given	15.0	5.0	35.0		0.291
Wyandotte			31	Estimation					16.5	5.5	39.0	30.0	0.288
Wyandotte			32	Well Log	18	6	43	30	18.0	6.0	43.0	30.0	0.284

The estimation technique for the counties indicated above are as follows (listed as county-township-range-section):

Riley 11-6-13=AVERAGE(Geary 11-6-22+Riley11-6-12+11-6-14+11-7-7)
Riley 11-6-15=AVERAGE(Geary 11-6-22,+Riley11-6-14+11-6-23)
Riley 10-7-25=AVERAGE(Riley 10-7-26+10-8-30+10-8-19+10-8-31)
Riley 10-8-14=AVERAGE(Riley 10-8-23+Pott.10-8-13+10-8-14+10-8-24)
Riley 10-9-15=AVERAGE(Riley10-9-16+10-9-21+10-9-22+Pott.10-9-14+10-9-23)
Riley 10-9-18=AVERAGE(Riley 10-9-17+10-9-19+Pott.10-8-13+10-8-24)
Pott. 10-8-22=AVERAGE(Pott. 10-8-14+10-8-15+Riley 10-8-22+10-8-23+10-8-21)
Pott. 10-8-23=AVERAGE(Pott. 10-8-14+10-8-15+10-8-13+Riley 10-8-22+10-8-23+10-8-24)
Pott. 9-10-27=AVERAGE(Pott. 9-10-26+9-10-34+9-10-35)
Pott. 10-10-1=AVERAGE(Pott. 10-10-2+10-10-11+10-10-12+10-11-6+Wabaunsee 10-11-6
Pott. 10-11-10=Wabaunsee 10-11-10
Pott. 10-12-8=Wabaunsee 10-12-8

Wabaunsee 10-9-24=AVERAGE(Wabaunsee 10-9-23+Pott. 10-9-13+10-9-14+10-9-23+10-10-18+10-10-19)
Wabaunsee 10-9-25=AVERAGE(Wabaunsee 10-9-25+Pott. 10-10-19)
Wabaunsee 10-11-3=Pott.10-11-3
Wabaunsee 10-11-4=Pott.10-11-4
Wabaunsee 10-11-8=AVERAGE(Pott. 10-11-4+10-11-5+10-11-6)
Wabaunsee 10-11-9=AVERAGE(Wabaunsee 10-11-8+10-11-10+10-11-4+10-11-3+Pott. 10-11-3+10-11-4+10-11-5+10-11-10)
Wabaunsee 10-11-11=Pott. 10-11-11
Wabaunsee 10-12-7=Pott. 10-12-7
Wabaunsee 10-12-9=AVERAGE(Wabaunsee 10-12-8+10-12-17+Pott. 10-12-9+10-12-8+10-12-10)
Wabaunsee 10-12-34=AVERAGE(Wabaunsee 10-12-33+10-12-28+Pott. 10-12-27+10-12-26+10-12-28)
Wabaunsee 10-12-35=AVERAGE(Wabaunsee 10-12-34+Pott. 10-12-27+10-12-26)
Wabaunsee 11-13-5=Shawnee 11-13-5
Wabaunsee 11-13-6=AVERAGE(Wabaunsee 11-13-7+Shawnee 11-13-5)
Shawnee 11-12-1=Wabaunsee 11-13-6
Shawnee 10-13-20=AVERAGE(Shanwee 10-13-19+10-13-29+10-13-30)
Shawnee 11-14-21=AVERAGE(Shawnee 11-14-20+11-14-22+11-14-15+11-14-16+11-14-17)
Jefferson 11-17-24=AVERAGE(Jefferson 11-17-23+11-17-25+11-18-19)
Jefferson 11-17-26=AVERAGE(Jefferson 11-17-27+11-17-22+11-17-23+11-17-24+11-17-25)
Jefferson 11-17-29=Jefferson 11-17-20
Jefferson 11-18-18=AVERAGE(Jefferson 11-18-17+11-18-19+11-18-20)
Jefferson 11-18-35=Jefferson 11-18-34
Jefferson 11-19-31=AVERAGE(Jefferson 11-19-30+11-19-32+11-18-36)
Jefferson 12-19-5=AVERAGE(Jefferson 11-19-31+11-19-32+11-19-33)
Jefferson 12-19-6=AVERAGE(Jefferson 11-19-31+11-19-32+11-18-36)
Douglas 11-18-27=AVERAGE(Douglas 11-18-28+Jefferson 11-18-34)
Douglas 11-18-29=Douglas 11-18-28
Douglas 12-19-3=Jefferson 11-19-34
Douglas 12-19-4=AVERAGE(Douglas 12-19-9+Jefferson 11-19-33)
Douglas 12-20-26=AVERAGE(Douglas 12-20-34+12-20-35+12-20-36+Leavenworth 12-20-27)
Douglas 12-19-11=AVERAGE(Douglas 12-19-10+12-19-12)
Douglas 13-20-11=AVERAGE(Douglas 13-20-2+13-20-10+13-20-12)
Leavenworth 12-21-23=AVERAGE(Leavenworth 12-21-24+12-21-25+12-21-26)
Leavenworth 12-21-28=Douglas 12-21-28
Leavenworth 12-22-24=Douglas 12-22-24
Johnson 11-23-32=Johnson 12-23-5
Johnson 11-23-34=Johnson 11-23-33
Johnson 11-23-36=Wyandotte 11-23-36

Johnson 11-23-35=AVERAGE(Johnson 11-23-34+11-23-36)
Johnson 12-23-8=Johnson 12-23-5
Wyandotte 12-23-7=Johnson 12-23-8
Wyandotte 12-23-18= Leavenworth 12-22-13
Wyandotte 12-23-19=Leavenworth 12-22-24
Wyandotte 11-23-35=AVERAGE(Wyandotte 11-23-36+ Johnson 11-23-35)
Wyandotte 11-24-28=AVERAGE(Wyandotte 11-24-27+11-24-29)
Wyandotte 11-24-31=AVERAGE(Wyandotte 11-24-30+11-24-32)

Abbreviations used in Table A-1 include:

FS=Fine Sand
PZ=Pay Zone=Fine-Coarse Sand and Gravel (Includes FS)
wl=Water Level
OVBD=Overburden