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Impacts of Commercial Navigation on Water Quality in the Illinois River Channel

by
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ILLINOIS STATE WATER SURVEY
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Indexing Terms: Water quality, water pollution effects, water pollution abatement, water management, Illinois, Illinois River, navigation channel, commercial navigation impacts, transport, barge tows, barge traffic.

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IMPACTS OF COMMERCIAL NAVIGATION ON WATER QUALITY IN THE ILLINOIS RIVER CHANNEL

by Thomas A Butts and Dana B. Shackleford

ABSTRACT

The U.S. Army Corps of Engineers shut down the navigation locks at the LaGiange and Peoria dams on the Illinois River for repairs during summer 1987. This effectively prevented commercial tows from traversing a 151-mile reach of the waterway for 58 days from July 13 through September 8, 1987. During the closing, high-flow conditions persisted for 23 days from August 17 to the reopening on September 8. The closing provided a rare opportunity to study and observe the river in the absence of commercial navigation.

A study was designed to collect water quality and benthic data from the main channel during a 30-day preshutdown period, during the shutdown period, and again during a 30-day postshutdown period. After the study progressed into the shutdown stage, high flows required the division of the shutdown period into low- and high-flow periods. Similar calendar periods were sampled during 1988 for comparative/control purposes.

Statistical testing procedures were used to determine whether water quality conditions improved in the absence of commercial navigation. Analysis of variance and *t* tests were used at a 5 percent level of significance to identify differences in means between periods within a given year and between similar periods in both years. The parameters examined were turbidity, suspended solids, pH, alkalinity, hardness, orthophosphate, ammonia, nitrite, nitrate, dissolved oxygen, temperature, Secchi disk readings, algae and benthos identification and enumeration, and subjective sediment analysis.

The results indicate that at the present traffic rates, tows do not cause permanent or long-term changes in water quality and benthic conditions in the main navigation channel. In comparison to present tow traffic influence, natural phenomena such as rapid flow increases or extended periods of low flow during warm weather cause major water quality changes of long duration. However, tows can create significant transient changes lasting up to several hours. If future traffic increases much above the present rates, overlapping of the transient changes could occur. This could result in continuous, long-term water quality changes and/or degradation.

INTRODUCTION

The Illinois River or Waterway is the single most significant waterresource in the state. The waterway runs from Lake Michigan to Grafton, a distance of approximately 327 miles. Its watershed drains 29,010 square miles, 24,810 of which are in Illinois. Before development by the white man, no direct connection existed between the waterway and Lake Michigan. Consequently, Native Americans and early European explorers had to make a relatively short portage between the two. During these early times, the river was free flowing and free of pollution. The river, its shores, and backwaters were blessed with an extreme abundance of fish and wildlife. Probably no other river in the country was characterized by the wealth and extentofbackwater areas relatively evenly distributed throughout its length. Backwaters such as these constitute a great natural resource, since the life cycles of most fish and wildlife are governed by the condition, nature, and abundance of habitat.

With the advent of modem times, priorities concerning river usage, attitudes toward the river ecosystem as a whole, and the exploitation of natural resources have changed drastically. The waterway is no longer a free-flowing river, as demonstrated in figure 1. It has been levied, straightened, drained, and dammed to such an extent that it now consists of eight "stepped" navigation pools. These physical alterations have placed serious constraints on the ability of the waterway system to assimilate organic, oxygen-consuming wastes and to purge itself of inorganic and organic silt loads. Water velocities have been reduced and channel water depths have been increased, both of which are detrimental to natural waste assimilative processes. Although the dams initially increased the depths of the backwater lakes, the overall result in the last 40 years has been a significant net loss in both the water depth and the surface areas of the lakes due to sedimentation (Demissie and Bhowmik, 1985).

Cause of the Problem

If a period of time could be designated as the beginning of the degradation of the Illinois River, it would have to be the opening of the waterway to steamboats in 1828. This led to large-scale development along the river, as well as some limited man-made physical changes in the river. With the opening of the waterway to steam-powered commercial craft came a large white population and the quick disappearance of much of the wildlife population along and near the river. The opening of the Illinois and Michigan (I&M) Canal in 1848 spurred additional growth in the river valley by connecting Chicago-area water courses directly to the river at LaSalle-Peru. More importandy, however, the I&M Canal provided an avenue by which organic pollution could reach the lower river from the rapidly expanding Chicago area. The continued growdi of Chicago in the late 1800s prompted

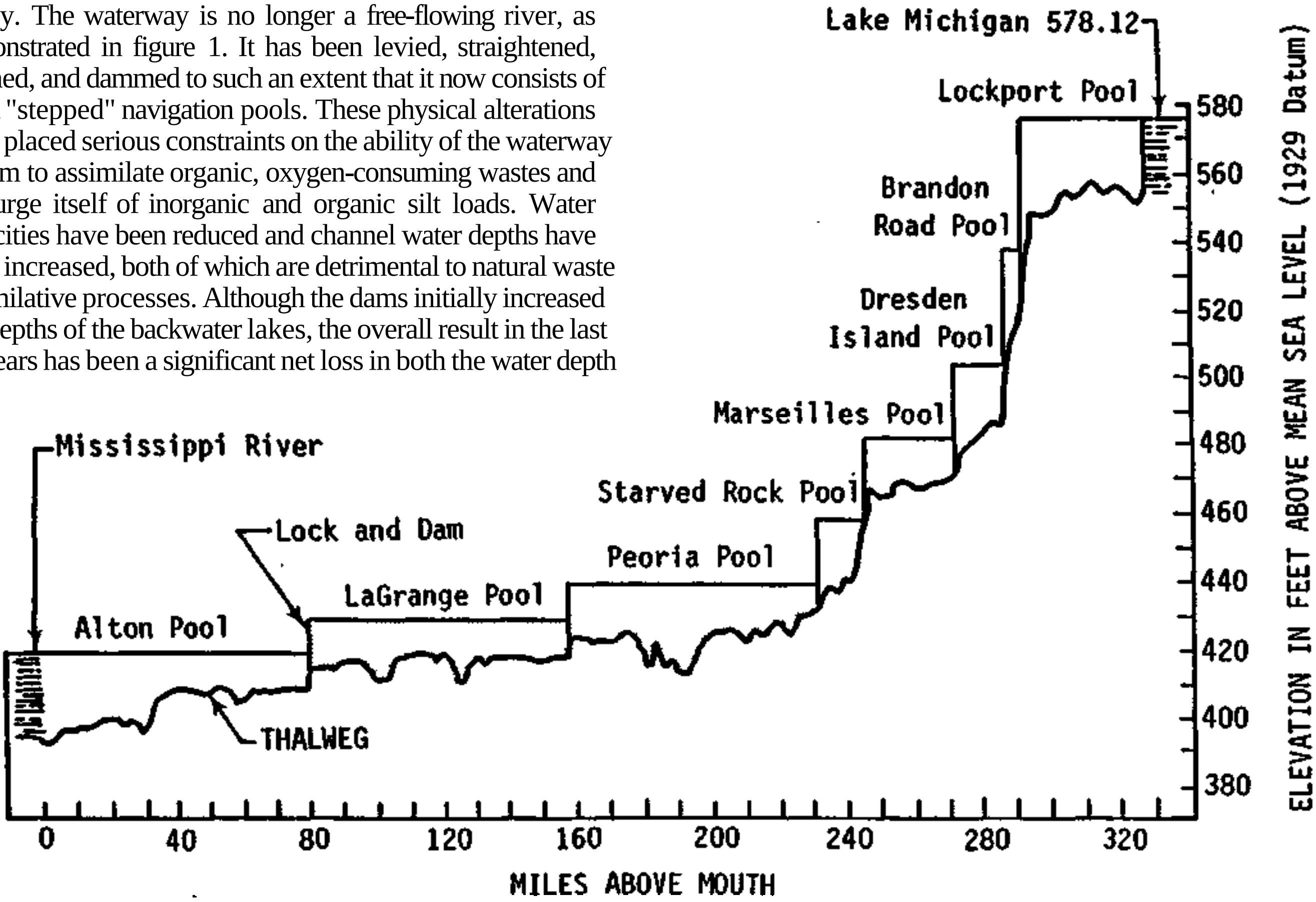


Figure 1. Profile of the Illinois Waterway indicating the study area in the LaGrange and Peoria pools

the building of what is now known as the Chicago Sanitary and Ship Canal. It was opened on January 17, 1900, and provided ahydraulically efficient means of pouring Chicago-area wastes downstream. With the completion of the lock and dam system during the late 1930s and a subsequent increase in commercial traffic, the river's self-purification capacity became stressed beyond its maximum. The stage was set for long-term deterioration in water quality and in the fish and wildlife indigenous to the lower river wetlands. This deterioration has been slowed significantly in most reaches, and in some areas marked improvements have been realized, especially in water quality.

Water quality has improved tremendously over the last 80 years. These improvements, however, have not been commensurate with the money and effort expended, due to the growth of commercial navigation and physical and structural changes to the river. Limited dissolved oxygen (DO) surveys conducted in the Peoria pool (between Peoria and Starved Rock) by the former Water Quality Section of the Illinois State Water Survey (ISWS) during the summers of 1982 and 1983 show that DO concentrations often dropped below S.O milligrams per liter (mg/L),even duringrelatively high summer flows. In the LaGrange pool below Peoria, concentrations as low as 3.5 mg/L were observed during summer low-flow conditions in 1983.

Computerized DO model simulations have clearly demonstrated that significant improvements in DO levels cannot be achieved by requiring additional reductions in organic waste loads, as measured by the biochemical oxygen demand (BOD) test at point sources. Most treatment plants along the waterway are presently achieving 90 to 95 percent BOD reductions. In addition, since 1971 ammonia input to the waterway (another cause of oxygen depletion) has been reduced more than SO percent Additional treatment would not produce a commensurate improvement in DO levels. The only plant along the waterway amenable to a large-scale upgrade is the Calumet Plant of the Metropolitan Water Reclamation District of Greater Chicago. Butts et al. (1983) have shown that upgrading the effluent of this plant to 7 mg/L BOD and 2 mg/L ammonia would improve the DO level in the critical reach of the Peoria pool by only 0.6 mg/L during low-flow conditions.

As mentioned above, the Illinois Waterway has been physically altered to a great degree to accommodate commercial barge traffic. Over the years questions have been raised by the general public, environmentalists, and professionals concerning the effects of barge traffic on water quality. A rare opportunity to directly study the possible effects of commercial barge movement on water quality in the Illinois River navigation channel occurred during two months in summer 1987 when the U.S. Army Corps of Engineers (COE) shut the Peoria and LaGrange navigation locks for 50-year repairs and rehabilitation.

Study Area

The study area, shown as the shaded portion in both figures 1 and 2, comprises the LaGrange and Peoria pools. The

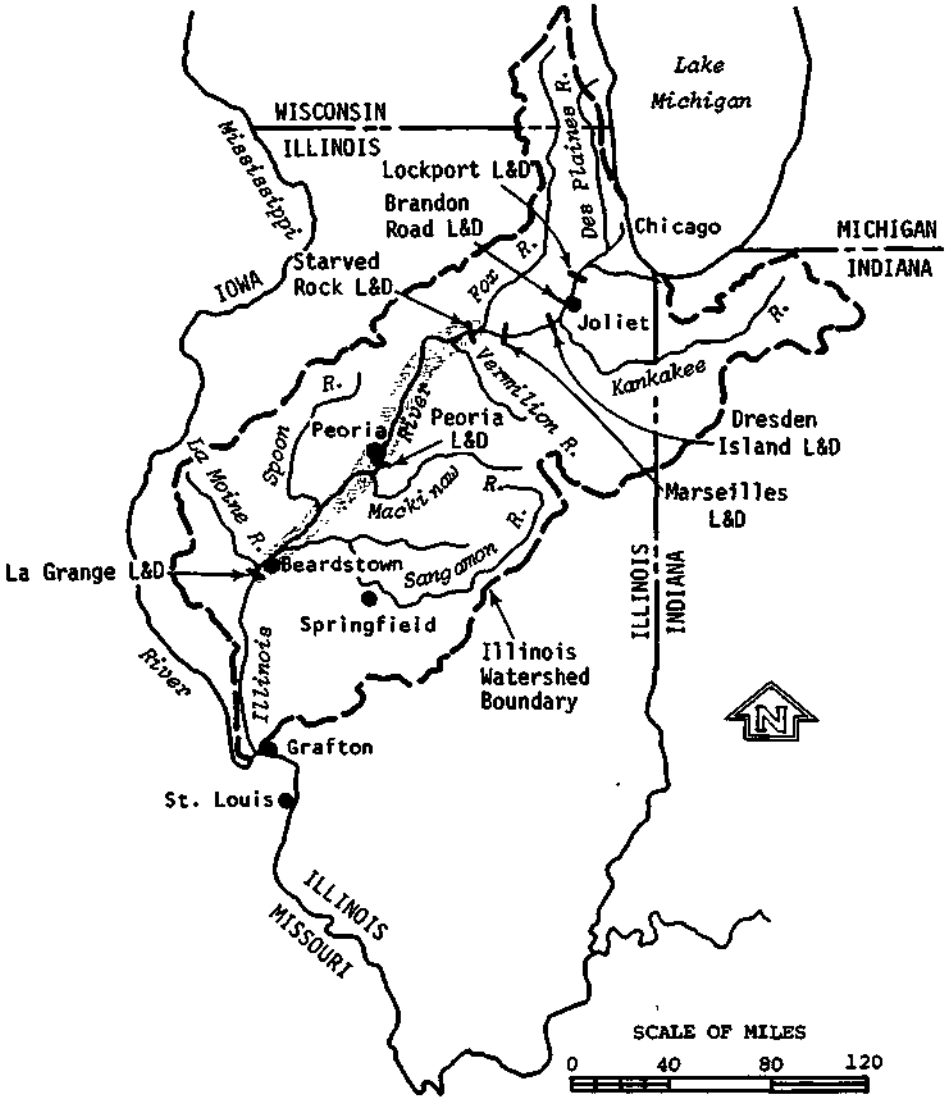


Figure 2. Plan view of the Illinois Waterway showing the study area shaded

LaGrange pool is 7756 miles long, starting at the LaGrange dam (river mile 80.19) and ending at the Peoria dam (river mile 157.75). The Peoria pool is 73.34 miles long, beginning at the Peoria dam and ending at the Starved Rock dam (river mile 231.09). Figure 1 shows that both pools are relatively shallow and flat At low flows of about 95 percent duration, the river flows through the study area at a rate of about 0.40 mile per hour (mph), while at medium flows of about 40 percent duration, it flows at a rate of about 0.90 mph. The 95 and 40 percent flow durations at the U.S. Geological Survey (USGS) gage at Marseilles (river mile 246.37) are 4,060 cubic feet per second (cfs) and 10,400 cfs, respectively.

Although both pools are bordered by or connected to backwater lakes along most of their lengths, the bulk of the water flows down the navigation channel, even in wide-pooled areas like the lower and upper Peoria Lake regions and the pooled stretch above Starved Rock (Zuehls, 1987).

The general water quality of these two pools was studied extensively by the Water Survey's former Water Quality Section from 1965 through 1987 (Butts et al., 1970; Butts, 1974; Butts et al., 1974; Butts et al., 1975; Butts and Evans, 1980; Butts et al., 1981; Butts et al., 1983; Butts and Adkins, 1987; Butts and Shackleford, 1987). The reports of these studies contain a plethora of information related to the physical, biological, and chemical conditions observed in the pools over the past 22 years. Although the present study is unique in its objectives, it will nonetheless add to the existing general knowledge of water quality conditions in the Illinois River.

Study Objectives

The basic objective of this study was to identify and quantify the effects of commercial barge traffic on the water quality of the main-channel flow of the Illinois River. Specific questions addressed were:

1. Does barge traffic contribute to the substandard dissolved oxygen concentrations routinely observed in the navigation channel during low, warm-weather flows?
2. Does barge traffic have any effect on biological activities, such as algal growth and benthos (benthic macro-invertebrate) existence in the navigation channel?
3. Can mitigation measures be found for any undesirable effects of increased commercial traffic that could be fostered by future structural alterations along the waterway?

This study became possible when the COE decided to postpone the lock rehabilitation projects from January/February 1987 to July/August 1987 (appendix A). This amounted to a "once-in-a-lifetime opportunity" to perform the study, since such rehabilitation work occurs only once every 50 years. This provided a chance to try to answer, in a scientific and factual manner, some of the subjective and speculative questions that have been raised concerning the effects of barge traffic on water quality. Presendy, commercial navigation interests, pleasure boating interests, and other special-interest groups are actively promoting several physical changes along the river, such as raising the height of the Peoria dam (appendix B), which could be detrimental to water quality.

Regulatory Relevance

The results produced by this study are relevant to four different regulatory or reviewing agencies: the Illinois Environmental Protection Agency (IEPA), the U.S. Army Corps of Engineers, the Division of Water Resources of the Illinois Department of Transportation, and the Federal Energy Regulatory Commission (FERC). The IEPA needs information, as presented in this report, for input into environmental impact statements (EIS) concerning proposals and projects promoting commercial navigation (appendix C) or the installation of hydropower facilities at dams along the Illinois Waterway.

The DO and temperature data generated during mis study supplement and complement similar data generated during a 1986 study, which was funded by the Illinois Department of Energy and Natural Resources (ENR). That study addressed dissolved oxygen resources in the Peoria pool. The data generated during the 1986 study are shown in appendix D. The 1986 DO-temperature data, along with those generated during this study, can greatly aid the IEPA and the FERC in environmental impact assessments for the development of hydropower facilities.

Acknowledgments

This study was funded by a contract from the Research Unit of the Illinois Department of Energy and Natural Resources, which was administered by Linda Vogt. The research was conducted as part of the work of the former Water Quality Section of the Illinois State Water Survey, under the general administrative guidance of Richard G. Semonin, Chief. Thanks are extended to Donald "Buzz" Byzinski, Starved Rock dam lockmaster, and his staff, all of whom were helpful in providing routine dam operation information and in allowing the Water Survey to store equipment at the dam site. Thanks are also extended to Starved Rock State Park officials for permitting the storage of the Peoria pool sampling boat on park grounds and to the Beardstown Marina operator for allowing the LaGrange pool sampling boat to be stored at the marina.

The project could not have been carried to fruition without the help of all the college students who spent many long (and often frustrating) hours on the road and on the water during both summers. Dave Hullinger and Dave Green performed most of the chemistry analyses. Tom Hill and Jeff Port identified and enumerated the benthos. Most of all, however, Dave Beuscher is singled out and recognized for the endless hours he spent peering through the microscope, relentlessly identifying and counting— without fear — killer algae. He truly deserves to be named "phycologist of the decade."

The manuscript was prepared by Linda Dexter and edited by Laurie Talkington.

METHODS AND PROCEDURES

For the proposed study plan, sampling and data gathering were divided into three periods during 1987. These were the preclosing period, the closed period, and the postclosing period. Sampling and data gathering for 1988 were conducted during the sametime periods used during 1987.This periodic sampling design was intended to provide data that could be used to ascertain statistically any differences in water quality between periods of commercial navigation and the period during which virtually no commercial navigation occurred in the two pools.

Field Sampling Chronology

A schematic representation of the sampling chronology as originally proposed is shown in figure 3a. However, heavy rains occurred over the upper reaches of the waterway midway between the closing and the reopening of the dams. Consequently, the study scheme was modified to accommodate the extreme change in hydraulic/hydrologic conditions in the study area. The revised plan is shown in figure 3b.

The rainfall began the evening of August 13, 1987, in northeastern Illinois. The heavy rains persisted for several days, and by noon on August 16, 12.84 inches had been recordedatO'Hare Airport in Chicago (ISWS, 1987a). Of this total, 9.3S inches fell between 9:16 p.m. on August 13 and 2:45 p.m. on August 14(ISWS, 1987b). Severe flooding occurred in waterways in the immediate Chicago area during this period, and these floodwaters eventually caused flows to be much higher than normal in the study area on the Illinois River.

Flows in the Peoria and LaGrange pools reached levels near flood stage, butover-bank conditions never occurred. The massive runoff resulting from the Chicago-area rainfall became very noticeable at Starved Rock at the head of the Peoria pool around August 14. The flow at the Starved Rock dam on August 13, the first day of the big rains in the Chicago area, was about 6,300 cfs. By August 17,it had increased to 28,000 cfs. This surgeof waterreached Peoria around August 15. Here the flow increased from 9,000 cfs on August 14 to approximately 25,000 cfs on August 17. The peak surge of water began to be dampened out by the time it reached the LaGrange dam. The August 14 flow at the LaGrange dam was approximately 8,800 cfs, reaching a maximum value of 23300 cfs on August 18.

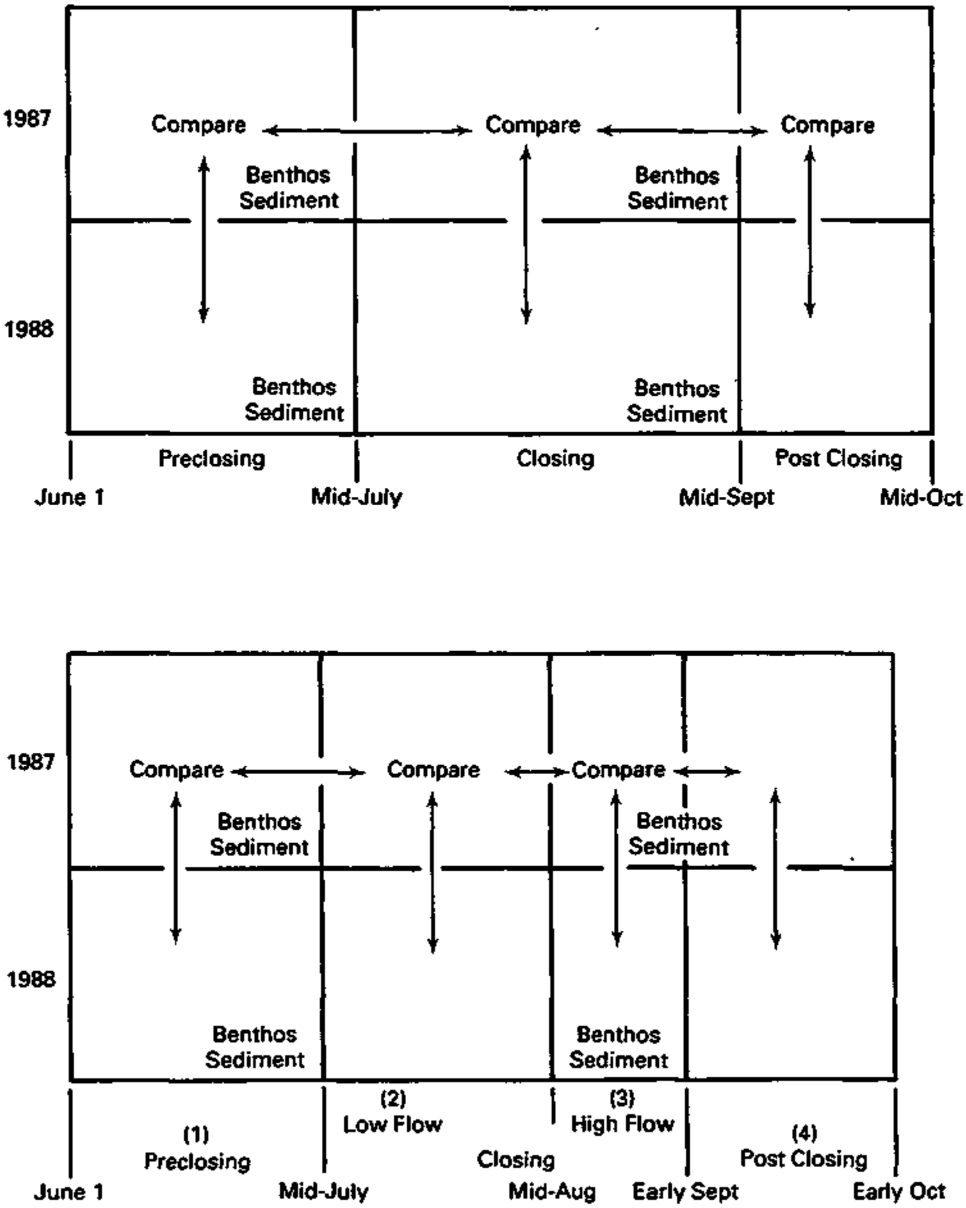


Figure 3. Study plan for grouping data for analysis

These abrupt increases in flow were sustained for several weeks while these pools were closed to commercial navigation. As a consequence, the closing period of the study had to bebroken into two subperiods:oneof low flow and oneofhigh flow. Therefore, the data for statistical comparisons had to be regrouped as shown by figure 3b.

Sampling Parameters and Frequencies

The water quality parameters sampled and their sampling frequencies are outlined in table 1. Physical, chemical, and biological samples were collected. Dissolved oxygen content, temperature, clarity (Secchi disk), and pH were measured in the field. Samples of water, sediment, and benthos were also collected for laboratory analyses.

The water quality parameters were selected somewhat intuitively, relative to their possible variance in magnitude with various degrees of water disturbance due to barge traffic. For example, with reduced traffic, water clarity might increase and turbidity and suspended material might decrease. This in turn would increase light penetration into the water column, thus increasing algal productivity. Algal growth can subtly impact various water quality parameters and exert a dynamic effect on the dissolved oxygen, pH, alkalinity, orthophosphate, and ammonia-N of surface waters. Increased algal activity produces wider fluctuations in daily DO concentrations, and this activity can increase the average daily pH levels in water; carbon dioxide is removed from water by algae during photosynthesis, and that carbon is used for cellular development

The sampling frequency of each parameter was selected on the basis of the sensitivity of that parameter to abrupt changes in aquatic environmental conditions. Dissolved oxygen can be affected immediately by various physical, chemical, and biological factors. In contrast, changes in benthic sediments and benthos communities occur much more slowly. On the other hand, algae numbers and population characteristics can change relatively quickly, often within a few days or a week, though not instantaneously. Because an improvementin water clarity was anticipated during the period without commercial navigation, an attendant increase in algae diversity and numbers was also anticipated. Algal activity in the Illinois River has intensified in the last several years commensurate with gradual water quality improvements over the past two decades. Consequently, the study of algal dynamics was emphasized as a primary means of detecting changes in the aquatic environment as a result of barge traffic.

Sampling Procedures and Regimen

The stations at which various water quality samples and/or measurements were taken are listed in table 2 for both pools. Dissolved oxygen and temperature readings were taken at the surface, at 3 feet deep, at mid-depth, and at the bottom in the center of the navigation channel. This sequence was followed at 29 stations in the LaGrange pool and at 28 stations in the Peoria pool. In addition, DO/temperature measurements were taken in the Starved Rock pool 400 feet above the Starved Rock dam at 2-foot depth increments starting at the surface. The measurements were taken on verticals in line with the center of all open Tainter gates.

DO, temperature, and Secchi disk readings were measured daily. A three-man crew made the sampling runs. Their time was evenly divided between the two pools during each workweek. Over the course of the study each pool was traversed an average of *25* times per week. During a given week, one pool would be traversed three times, the other only twice. Then the following week, the reverse would occur, the pool traversed three times the previous week would be traversed only twice, while the one traversed twice would be traversed three times. This systematic approach accounts for the "two-to-three-times per week" sampling frequency listed for DO, temperature, and Secchi disk readings in table 1.

Field Measurements

The DO and temperature measurements were made with YSI model 58 digital DO/temperature meters equipped with YSI model 5795A submersible stirrers and YSI model 5739 dissolved oxygen probes. Calibration was done in the field immediately before the commencement of a run, using Winklers run on tap or well water. The Standard Methods reference numbers and the minimum detection limits for theparameters analyzed in the field are given in table 1. The probe membranes were routinely changed on aweekly basis. Temperature probes were matched on all meters for a maximum difference of 0.2°C between readings.

The DO/temperature stirrer/probe assembly was attached to the end of a fishing downrigger cable weighted with a 6-pound cannonball. The sampling depth positions were controlled with heavy-duty downriggers fitted with depth counters. An assembled stirrer/probe was lowered to the bottom, and the total depth was recorded. DO/temperature readings were then taken at the bottom, mid-depth, 3-foot, and surface positions.

Secchi disk readings were taken at ten selected locations in each pool (table 2) using standard black-and-white quadrant Wildco limnological disks. The disks were attached to 3/16-inch nylon ropes that were graduated into inches.

ThepH was measured both in the field and in the laboratory. Differences in pH occur over time, due principally to biological activity in the water. Field pH was determined using small hand-held pH meters. During 1987, Hanna model 8114 meters were used. They were fitted with epoxy electrodes with glass bulbs and ceramic junctions. These meter/probes had to be manually adjusted to compensate for temperature differences. Coming model 107 pH/temperature meters were also used in 1987. They were fitted with glass electrodes with glass bulbs and ceramic junctions, which compensated for temperature automatically. Both the Hanna and Corning instruments were accurate to ± 0.01 pH unit The instruments were calibrated at the beginning of each run using standardized pH buffers of 4.00 and 7.00.

Laboratory Analyses of Samples

One-liter samples of water were collected at ten selected locations in each pool (table 2) at 3-foot depths using a one-liter Kemmerer water sampler. These samples were stored in one-liter plastic bottles and placed on ice for laboratory analysis of turbidity, suspended solids,pH,alkalinity, hardness, orthophosphate, dissolved ammonia, nitrite, and nitrates. All water chemistry analyses in the laboratory used Standard Methods (American Public Health Association, 1985). Reference numbers and minimum detection limits are given in table 1.

Benthic sediments and macroinvertebrate samples for laboratory analyses were collected at the ten stations listed for each pool in table 2. The samples were collected using a 9-inch Ponar dredge attached to a power winch mounted on a crane. The sediments collected for benthos processing were emptied into a flat tray and then washed through a Wildco model 190 plastic biological bucket fitted with a No. 30 sieve using a DC-powered electric pump. Sieved residues were preserved in plastic bottles using 95 percent ethyl alcohol. Three Ponar dredge samples were taken per station, and the washed residues were composited for laboratory examination and analysis.

Benthos samples were prepared for examination using salt flotation. Salt was added to a 5-gallon bucket of water and left to dissolve until a 100 percent salt solution developed. A preserved field sample was added to the brine and thoroughly mixed. The liquid portion was then passed through a 30-mesh sieve. The sieve residue was washed into a picking tray where the organisms were removed and preserved in vials containing 95 percent ethanol. The sediment residue that remained after the brine was decanted was thoroughly examined for heavy nonflotable organisms such as clams and crustaceans. Such organisms were removed and preserved in vials.

Organisms were separated and examined under a Wild M8 Zoom Stereomicroscope with a magnification of 6X to 50X. The scope was fitted with a Volpi AG Intralux 150 light source. All organisms from all the samples were picked and sorted; subsampling techniques were not used. Most organisms were identified to genus and species; a few were identified only to genus.

About 65 to 75 grams of homogenized sediment at each station were retained in sealed plastic bags for laboratory analyses for moisture content and volatile solids. These samples were iced in the field and refrigerated at all other times until laboratory analyses were completed. The quality of the sediments was subjectively described at each location, both at the time of collection and in the laboratory.

The analyses for moisture content and volatile solids were initiated by refrigerating a benthic sediment sample for 24 hours to allow excess water to separate from the solids. Any excess water was decanted and the remaining material was homogenized. From 25 to 50 grams of the homogenized sample were retained and prepared for determining dried solids and volatile solids, all according to Standard Methods (American Public Health Association, 1985). A drying temperature of approximately 103°C and a volatizing temperature of approximately 550°C were used. Subjective descriptions of the physical condition of the wet sediment and the ash residual from the muffle furnace were recorded.

A 400-milliliter (mL) plankton sample was collected one foot below the water surface at the ten stations listed for each pool in table 2. The algae samples were placed in glass bottles and preserved with 10 mL of formalin.

The preserved algae samples were prepared for microscopic examination by vacuum filtering a 50-mL aliquot of the 400-mL field sample through a Millipore type HA 0.45-micrometer filter. The filter residue was washed into a vial using 10 mL of formalin. One milliliter was pipetted from the tube onto a Sedgwick-Raffter (S-R) counting cell for microscopic examination. Cells were counted and identified using a differential-interface, contrast microscope equipped with 10X or 20X eyepieces, 20X and 100X objective lenses, and a Whipple disc. Six counting factors were used. The counting factor selection was based on an initial subjective evaluation of cell densities. A random width was selected, and counts were made for a number of these widths at various locations on the S-R cell. Low cell densities required wider widths and more counting locations. Enumeration was done at 200X magnification; identification was done at either 200X or 1.000X.

Phytoplankton species were identified using several keys (Smith, 1950;TiffanyandBritton, 1952; Palmer, 1959;Prescott, 1962; Patrick and Reimer, 1966). Organisms were separated and categorized as either blue-greens, greens, diatoms, flagellates, or desmids.

Sampling Regimen

A systematic sampling regimen was used to ensure that the sampling results were not biased due to hourly differences in sampling times during the day. Each pool was alternately sampled in upstream and downstream directions. Typically, a boat started sampling between 9:00 and 9:30 a.m. at the Peoria lock and dam in the LaGrange pool and ended sampling between 1:00 and 1:30 p.m. at the LaGrange lock and dam. The boat then would be left at the Beardstown Marina. Two days later or after a weekend, the next run would begin at the LaGrange dam between 9:30 and 10:00 a.m. and end at the Peoria dam between 1:30 and 2:00 p.m.

A similar routine was used for the Peoria pool. A run would begin at the Peoria dam between 9:00 and 9:30 a.m. and end at the Starved Rock lock and dam between 1:30 and 2:00 p.m. The boat would then be trailered and left at the Starved Rock State Park maintenance headquarters parking lot A boat left on the Corps of Engineers property at the Starved Rock dam would be launched immediately above the dam to make DO/temperature measurements at a transect 400 feet upstream of the dam. These measurements were usually completed between 2:30 and 3:30 p.m. At this time, information relative to the number of gates open, their respective opening heights, and the upstream and downstream pool elevations was obtained from the lockmaster. In the downstream direction, sampling was initiated above the Starved Rock dam between 10:30 and 11:00 a.m. and ended at the Peoria dam between 3:00 and 4:00 p.m.

Standardized field sheets were developed to record field-measured parameters and various other physical observations made while traversing each pool. The field sheets in the LaGrange and Peoria pools are shown as appendix E. Weather conditions at the beginning, midpoint, and end of each run were recorded. Information relative to barge traffic was also recorded, such as the name of the tow, its direction, the number of barges, the full or empty condition of the barges, and the river mile at which the tow and/or barges were encountered. If a tow was observed at a sampling station just prior to the sampling, a minimum often minutes was allowed to elapse for the water disturbance to subside.

Data Reduction and Analyses

Data reduction, computations, and analyses involved both hydraulic and water quality information collected during the study. River flows were computed at the three dam sites on the basis of flow-release control settings. Two U.S. Geological Survey gaging stations are located within the study area: one at Henry (river mile 196.1) and the other at Kingston Mines (river mile 145.6). However, flows computed at the dam sites were used in place of those potentially available at the gages because of the intermediate location of the gages between dams and because official flows at the gages would not be readily available during the period of the study or even for months after its completion.

Tests employing mathematical statistics were used to determine whether differences in water quality could be detected between the dam-closure period and the other periods with various degrees of commercial navigation, as presented in figure 3.

Flow Computations

Flowrates at the upper end of the study area are controlled by the manipulation of ten Tainter gates at the Starved Rock lock and dam. In a closed position, the gates rest on an ogee spillway with a crest elevation of 441.5 feet above mean sea level (msl). The gates are 60 feet wide and 19 feet high and are used to maintain a minimum upstream pool elevation of 458.5 feet msl.

During each daily sampling run, information on the number of open gates, gate opening heights, and the location of open gates was obtained at the dam control building. Also, the upper and lower pool elevations were recorded. This information was used to compute flow releases through the dam gates with the methodology developed by Mades (1981).

Flow control at the Peoria and LaGrange dams is more complicated. The principal flow-control structures at these two locations consist of navigable Chanoine wickets. The wickets consist of wooden plates one foot thick by 3.75 feet wide. They are 16.42 feet high at Peoria and 14.92 feet high at LaGrange. Both are positioned at a 20-degree angle from the vertical and are hinged at the base. These plates can be pivoted around the hinge and lowered to the riverbottom to allow river traffic to pass unobstructed during flows greater than 14,000 cfs at Peoria and 22,000 cfs at LaGrange. In a 3-inch gap between the plates, 4 x 4 timbers (needles) are inserted at very low flows to maintain minimum upstream pool elevations of 440.0 and 429.0 feet msl in the Peoria and LaGrange pools, respectively. The Peoria dam consists of 134 wickets, while the LaGrange dam consists of 135.

Flow releases at both dams are also controlled by butterfly valves. When fully open, they provide 29.5 square feet (sq ft) of flow area. Peoria has six valves, and LaGrange has 12.

The flow releases through or across the dams at these two sites are therefore contingent upon the combination of up and down wickets, the number of needles in place, and the number of butterfly valves open. All of these contingencies are dependent on the upstream and downstream pool elevations.

The methods and procedures outlined by Mades (1981) for computing flow releases take into consideration all these factors, and they were used to compute the daily flows at the two dams during the study periods. At the end of the 1988 sampling period, the operating records for both dams were obtained from the lockmasters, and flows were estimated with the methods suggested by Mades (1981). During the 1987 periods of June 1-10 andAugust l-2and 18-24,all the wicketsweredownatLaGrange because of near flood-flow conditions. Similarly, during the 1987 periods of June 1-11 and August 17-September 4, all the wickets were down at Peoria. Because of this, flows for these dates could not be computed directly and had to be estimated.

Water Quality Data Reduction and Analyses

Mathematical statistical tests were used to determine whether significant differences existed between the average values of specific parameters for each of the time periods presented in figure 3b. The analysis of variance (ANOVA) test was used as a broad screening tool to identify any differences. This test is only an indicator of differences; it does not pinpoint them. The differences can be directly ascertained using the Student's *t* test Before the advent of the high-capacity personal computer, indirect means such as Duncan's multiple-range test were generally used to pinpoint differences between data groupings.

Analysis of Variance Test

These statistical tests are based on the hypothesis (referred to as the "null hypothesis") that the average values foreach group of data are equal at a given confidence level (CL). For this study, a confidence level of 95 percent was used. Type I and Type II errors are associated with this sort of statistical testing. A Type I error, denoted as a, occurs when the null hypothesis is rejected, when in fact it should not have been. In other words, the conclusion is that differences exist between a set of means. However, this conclusion is incorrect because in reality, the means are equal. The risk of incurring a Type I error is equal to 100 percent minus the CL. It is equal to α a and referred to as the "level of significance." Consequently, for a CL of 95 percent, a = 5 percent Therefore, by setting the confidence level at 95 percent, a 5 percent chance exists that a Type I error will occur. Certain experimental designs may warrant guarding against Type I errors by setting a very low, such as at 1 or 0.5 percent. The experimental design associated with the objectives of this study, however, did not warrant this.

A Type II error occurs when a false hypothesis is not rejected. This occurs when the null hypothesis (that the means are equal) is accepted, when in fact the means are not equal. The probability of committing a Type II error, denoted as β, is reduced as the sample size increases. The sample sizes used during this study were limited because sampling was constrained by the time frames shown on figure 3b.

The variability of data is measured by a statistic, the standard deviation. It is expressed mathematically for a sample of *N* (number) of observations as:

$$s = [\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2]^{1/2}$$

where s - standard deviation

x_t = individual observations; a total *of N*

$\bar{x}$ = average or mean of the individual observations

The square of *s* is defined as the variance of a sample.

Simply comparing the mean values of samples without considering the variability in sample values can lead to erroneous conclusions about the equality of the samples. For example, a sample consisting of three values of 1,50, and 99, and another of 49, 50, and 51 both have means of 50. However, the first sample has a standard deviation of 49.0, while the second has a standard deviation of 1.0. A high probability exists that these two samples probably would not come from the same computation of values. The name of the analysis of variance test indicates that the variances *(s^2)* of a number of independent sample collections are to be analyzed and compared. If a high probability exists that the variability between samples is great and the null hypothesis is consequently rejected, the differences can be isolated using the *t* test to distinguish any differences between the means.

The F-ratio statistic is used to determine if the null hypothesis for the ANOVA is valid. For simple testing of two independent samples, this ratio is defined as:

$$F = \frac{s_1^2}{s_2^2} \tag{2}$$

where F = the F statistic

s_1^2 = variance of sample number 1

s_2^2 = variance of sample number 2

For one-way (one-factor) ANOVA testing, s_1^2 is replaced by the mean squares (variance) among the various treatments, and s^2 is replaced by the mean square (variance) within individual treatments. For this study, the treatments are represented by the four sampling periods designated on figure 3b. For easily understood methods for computing these factors consult the statistical manual by Crow et aL (1960).

If an unlimited number of samples was taken from a normal population of values, and F-ratios were computed for the resultant infinite number of pairs, a frequency distribution curve of F-values would result The exact shape of the curve would vary based on the level of significance used. A sample generalized *F*-distribution curve, along with a table of the theoretical distribution of F-values for a 2.5 percent level of significance, is presented as figure 4 (Crow et al., 1960). The degrees of freedom (f-values) are computed as:

$$f_1 = r-1 \tag{3}$$

$$f_2 = N-r \tag{4}$$

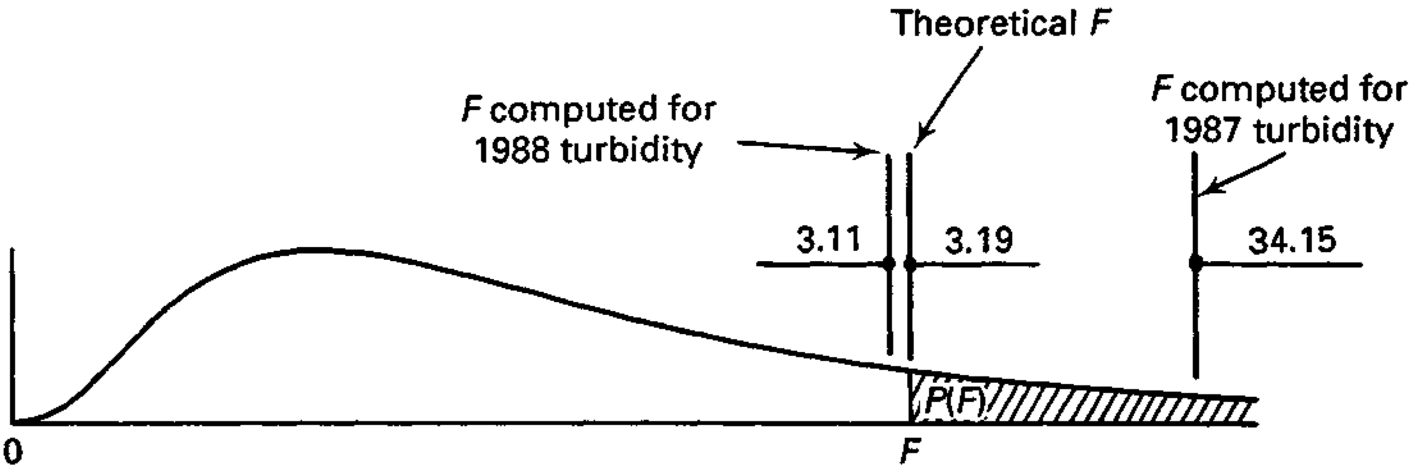
where f_1 = degrees of freedom of numerator of equation 2

r = number of treatments

f_2=degrees of freedom of denominator of equation 2

N=the total number of observations for all treatments combined

A specific example, the turbidity results observed for the Peoria pool during 1987 and 1988, will demonstrate the statistical procedures used to make a conclusion relative to the acceptance or rejection of the null hypothesis. These results are schematically represented and summarized in figure 5. The number of samples for periods 1,2,3, and 4 are 60, 50, 30, and 50, respectively, for both years. Consequently, *r* in equations 3 and 4 = 4, *and N* = 190. Substitution of these values in equations 3 and 4 yields $f_1 = 3$ and $f_2 = 186$. Since comparisons are being made between computed variances rather than a given or prespecified variance (or mean) and computed variances, a two-tailed *F* test is used. Consequently, α=0.05/2=0.025, and the theoretical F-value extrapolated from the table in figure 5 for $F_{(0.025,3,186)} = 3.19$.



P{F) = 0.025

f_2 f_1	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	647.79	799.50	864.16	888.58	821.85	937.11	948.22	856.66	863.28	968.63	976.71	984.87	993.10	997.25	1001.4	1005.6	1009.8	1014.0	1018.3
2	38.51	39.00	39.16	39.25	39 30	39.33	39.36	39.37	39.39	39.40	39.42	39.43	39.45	39.46	39.46	39.47	39.48	38.49	39.50
3	17.44	16.04	15.44	15.10	14 88	14.74	14.62	14.54	14.47	14.42	14.34	14.25	14.17	14.12	14.08	14.04	13.99	13.85	13.90
4	12.22	10.65	9.98	9.60	9.36	9.20	9.07	8.98	8.90	8.84	8.75	8.66	8.56	8.51	8.46	8.41	8.36	8 31	8.26
5	10.01	8.43	7.76	7.38	7.15	6.98	6.85	6.76	6.68	6.62	6.52	6.43	6.33	628	6.23	6.18	6.12	6.07	6.02
6	8.81	7.26	6.60	6.23	5.99	5.82	5.70	5.60	5.52	5.46	5.37	5.27	5.17	5.12	5.07	5.01	4.96	4.90	4.85
7	8 07	6.54	5.89	5.52	5.29	5.12	4.99	4.90	4.82	4.76	4.67	4.57	4.47	4.42	4.36	4.31	4.25	4.20	4.14
8	7.57	6.06	5.42	5.05	4.82	4.65	4.53	4.43	4.36	4.30	4.20	4.10	4.00	3.95	3.89	3.84	3.78	3.73	3.67
B	7.21	5.71	5.08	4.72	4.48	4.32	4.20	4.10	4.03	3.96	3.87	3.77	3.67	3.61	3.56	3.51	3.45	3.39	3.33
10	6.94	5.46	4.83	4.47	4.24	4.07	3.95	3.85	3.78	3.72	3.62	3.52	3.42	3.37	3.31	3.26	3.20	3.14	3.08
11	6.72	5.26	4.63	4.28	4.04	3.88	3.76	3.66	3.59	3.53	3.43	3.33	3.23	3.17	3.12	3.06	3.00	2.94	2.68
12	6.55	5.10	4.47	4.12	3.89	3.73	3.61	3.51	3.44	3.37	3.28	3.18	3.07	3.02	2.96	2.91	2.85	2.79	2.72
13	6.41	4.97	4.35	4.00	3.77	3.60	3.48	3.39	3.31	3.25	3.15	3.05	2.95	2.89	2.84	2.78	2.72	2.66	2.60
14	6.30	4.86	4.24	3.89	3.66	3.50	3.38	3.29	3.21	3.15	3.05	2.95	2.84	2.79	2.73	2.67	2.61	2.55	2.49
15	6.20	4.76	4.15	3.80	3.58	3.41	3.29	320	3.12	3.06	2.96	2.86	2.76	2.70	2.64	2.58	2.52	2.46	2.40
16	6.12	4.69	4.08	3.73	3.50	3.34	3.22	3.12	3.05	2.99	2.89	2.79	2.68	2.63	2.57	2.51	2.45	2.38	2.32
17	6.04	4.62	4.01	3.66	3.44	3.28	3.16	3.06	2.98	2 92	2.82	2.72	2.62	2.56	2.50	2.44	2.38	2.32	2.25
18	5.98	4.56	3.95	3.61	3.38	3.22	3.10	3.01	2.93	2.87	2.77	2.67	2.56	2.50	2.44	2.38	2.32	2.26	2.19
19	5.92	4.51	3.90	3.58	3.33	3.17	3.05	2.96	2.88	2.82	2.72	2.62	2.51	2.45	2.39	2.33	2.27	2.20	2.13
20	5.87	4.46	3.86	3.51	3.29	3.13	3.01	2.91	2.84	2.77	2.68	2.57	2.48	2.41	2.35	2.29	2.22	2.16	2.09
21	5.83	4.42	3.82	3.48	3.25	3.09	2.97	2.87	2.80	2.73	2.64	2.53	2.42	2.37	2.31	2.25	2.18	2.11	2.04
22	5.79	4.38	3.78	3.44	3.22	3.05	2.93	2.84	2.78	2.70	2.60	2.50	2.39	2.33	2.27	2.21	2.14	2.08	2.00
23	5.75	4.35	3.75	3.41	3.18	3.02	2.90	2.81	2.73	2.67	2.57	2.47	2.36	2.30	2.24	2.18	2.11	2.04	1.97
24	5.72	4.32	3.72	3.38	3.15	2.99	2.87	2.78	2.70	2.64	2.54	2.44	2.33	2.27	221	2.15	2.08	2.01	1.94
25	5.69	4.29	3.69	3.35	3.13	2.97	2.85	2.75	2.68	2.61	2.51	2.41	2.30	2.24	2.18	2.12	2.05	1.98	1.91
26	5.66	4.27	3.67	3.33	3.10	2.94	2.82	2.73	2.65	2.59	2.49	2 39	2.28	2.22	2.16	2.09	2.03	1.85	1.88
27	5.63	4.24	3.65	3.31	3.08	2.92	2.80	2.71	2.63	2.57	2.47	2.36	2.25	2.19	2.13	2.07	2.00	1.93	1.85
28	5.61	4.22	3.63	3.29	3.06	2.90	2.78	2.69	2.61	2.55	2.45	2.34	2.23	2.17	2.11	2.05	1.98	1.91	1.83
29	5.59	4.20	3.61	3.27	3.04	2.88	2.76	2.67	2.59	2.53	2.43	2.32	2.21	2.15	2.09	2.03	1.96	1.89	1.81
30	5.57	4.18	3.59	3.25	3.03	2.87	2.75	2.65	2.57	2.51	2.41	2.31	2.20	2.14	2.07	2.01	1.94	1.87	1.79
40	5.42	4.05	3.46	3.13	2.90	2.74	2.62	2.53	2.45	2.39	2.29	2.18	2.07	2.01	1.94	1.88	1.80	1.72	1.64
60	5.29	3.93	3.34	3.01	2.79	2.63	2.51	2.41	2.33	2.27	2.17	2.06	1.94	1.88	1.82	1.74	1.67	1.58	1.48
120	5.15	3.80	3.23	2.89	2.67	2.52	2.38	2.30	2.22	2.16	2.05	1.94	1.82	1.76	1.69	1.61	1.53	1.43	1.31
∞	5.02	3.69	3.12	2.79	2.57	2.41	2.29	2.19	2.11	2.05	1.94	1.83	1.71	1.64	1.57	1.48	1.39	1.27	1.00

Figure 4. Computed versus theoretical *F*-values comparing period-2 turbidity data from the Peoria pool, 1987 and 1988 (table from Crow et al., 1960)

Computed F-values for 1987 and 1988, using the appropriate computed mean squares in equation 2, are 34.15 and 3.11, respectively. The relationship between the theoretical and the computed F-values is shown on the *F*-distribution curve of figure 4. Since the computed 1987 value is greater than the theoretical value, the null hypothesis cannot be accepted. This indicates that turbidity must have varied a great deal during the four designated sampling periods. The opposite appears to be true for the 1988 data. The computed F-value is less than the theoretical value; therefore, the null hypothesis cannot be rejected.

The Student's t Test

This example demonstrates that the ANOVA test can only determine, collectively, if a difference in mean values occurs among treatments. Sophisticated statistical testing is not needed to conclude that during 1987 the means for periods 1 and 3 were much higher than those for period 2. However, after making this initial and obvious conclusion, the reaching of additional clear-cut conclusions is difficult. For instance, are the 1987 means for periods 1 and 3 equal? Similarly, are the 1987 means for periods 2 and 4 equal? Possibly the 1987 means for periods 1 and 4 are equal. Statistical testing can answer these questions and suppositions. The Student's *t* test, commonly referred to simply as the "*t* test," is a widely accepted and powerful statistical method of comparing the variability and means between two independent samples.

The null hypothesis associated with the *t* test is that $\bar{x}_1 = \bar{x}_2$. The *t*-statistic is defined as:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sigma\sqrt{1/n_1 + 1/n_2}} \tag{5}$$

where $\bar{x}_1 =$ the mean of sample 1 of n_1 values
$\bar{x}_2 =$ the mean of sample 2 of n_2 values

		Turbidity values (NTUs) for periods			
		1	2	3	4
		x1	*x1*	*x1*	*x1*
		x2	*x2*	*x2*	*x2*
		x3	*x3*	*x3*	*x3*
		·	·	·	·
		·	·	·	·
		·	·	·	·
		·	·	*x30*	·
		·	·		·
		·	*x50*		*x50*
		·			
		x60			
Average ($\bar{x}$):	1987	66.5	40.4	86.3	51.5
	1988	39.0	38.6	41.6	47.9

Null hypothesis: $\bar{x}_1 = \bar{x}_2 = \bar{x}_3 = \bar{x}_4$ during both 1987 and 1988

Degrees of freedom = *f1* = number of treatments -1 = *r* -1
J2 = *n1* +*n2* + *n3* + *n4*-*r*
= 60 + 50 + 30 + 50-4=186

F(a/2, f1,f2=F(0.05/2,3,186)	1987	1988
Calculated (equation *2):*	34.15	3.11
Theoretical (figure 4):	3.19	3.19

Conclusions: Reject hypothesis that $\bar{x}_1 = \bar{x}_1 = \bar{x}_3 = \bar{x}_4$ during 1987
Accept hypothesis that $\bar{x}_1 = \bar{x}_1 = \bar{x}_3 = \bar{x}_4$ during 1988

Figure 5. Schematic representation of ANOVA test procedure using turbidity results from the Peoria pool, 1987 and 1988

$$\sigma = \sqrt{n_1 s_1 + n_2 s_2 / f} \qquad (6)$$

where s_1 = standard deviation of sample 1
s_2= standard deviation of sample 2
f = degrees of freedom = $n_1 + n_2 - 2$

The turbidity data for periods 1 and 2 for the Peoria pool in 1987 and 1988 will illustrate the mechanics of employing the *t* test to determine whether differences exist between sample means. The means for period 1 for 1987 and 1988 are 66.5 and 39.0, respectively. The standard deviations are computed using equation 1, and the /-statistic is computed using equation 5. The computed /-values for the data for periods 1 and 2 are 8.09 and 0.78, respectively. The degrees of freedom *(f)* associated with these data are computed using the expression n_1+n_2-*2* or 60+60 -2= 118 for period 1, and 50+50 - 2 = 98 for period 2. For *a/2* = 0.05/2 = 0.025 and the appropriate/-values, the theoretical *t*-values for periods 1 and 2 are 1.98 and 1.99, respectively. Figure 6 diagrammatically shows the relationship between these results. The computed /-value for the data for period 2 falls well inside the theoretical limit, while the period-1 *t*-value falls well outside. The results of comparing turbidity data for periods 1 and 2 and for periods 3 and 4 are summarized in figure 7.

The results derived using the statistical methods and procedures outlined in figures 4-7 were instrumental in arriving at conclusions relative to the effects of barge traffic and natural phenomenon on water quality in the Illinois River navigation channel. These statistical tests were performed on the data generated for the various parameters listed in table 1 for the Peoria and LaGrange pools, which were viewed as whole units, and for specific river mile points within each pool. River mile 179.0 was selected for the Peoria pool, and mile 113.3 was selected for the LaGrange pool. These two mile-points were selected because they are centrally located within each pool, and consistently exhibit the poorest water quality under stressful conditions.

Treating a pool as a unit in terms of sampling produced large sample sizes, which increased the power of the statistical tests used. Sample sizes greater than 32 are considered large and adhere to large sampling theory. Conversely, sample sizes smaller than 32 are subjected to the limitations of small sampling theory. Since DO was measured at 28 locations in the Peoria pool, ten runs would produce 280 values, which could be subjected to statistical analyses. On the other hand, only ten values could be generated at river mile 179.0.

All the statistical analyses were done on an IBM Model 70 PC fitted with a math coprocessor using the proprietary program *Number Cruncher Statistical System (NCSS) - Version 5.01,* as developed by Dr. Jerry L. Hintze of Kaysville, Utah. The ANOVA segment of the program utilized the weighted means concept developed to accommodate the unequal sample sizes encountered during this study.

Biological Data Analyses

The algae data were tabulated and analyzed on a pool-wide basis, rather than by individual stations within each pool. Pool-averaged cell counts were determined for four phyla. The benthic macroinvertebrate data were tabulated by station and date for each pool. The tabular data for both algae and benthos were summarized by listing the total number of organisms counted per given unit (a square meter for benthos and a milliliter for algae), the number of taxa identified, the Shannon-Weiner Diversity Index, and the Illinois Macroinvertebrate Biotic Index (MBI).

A biological diversity index provides a means of evaluating the richness of species within a biological community through a mathematical computation. A community consisting solely of one species has no diversity or richness and takes on a value of unity. As the number of species increases and as long as the species are nearly numerically equal, the diversity index increases. A diversity index would approach infinity when a large number of individual organisms are present and each one of these organisms belongs to a different species.

The Shannon-Weiner Diversity Index formula is given by Smith (1980) in computational form as:

$$H = 3.322\left(\log N - \frac{\Sigma n_i \text{ x } \log n_i}{N}\right) \qquad (7)$$

where H = the Shannon-Weiner Diversity Index
N = the total number of all organisms
n_i = the number of organisms for a given species

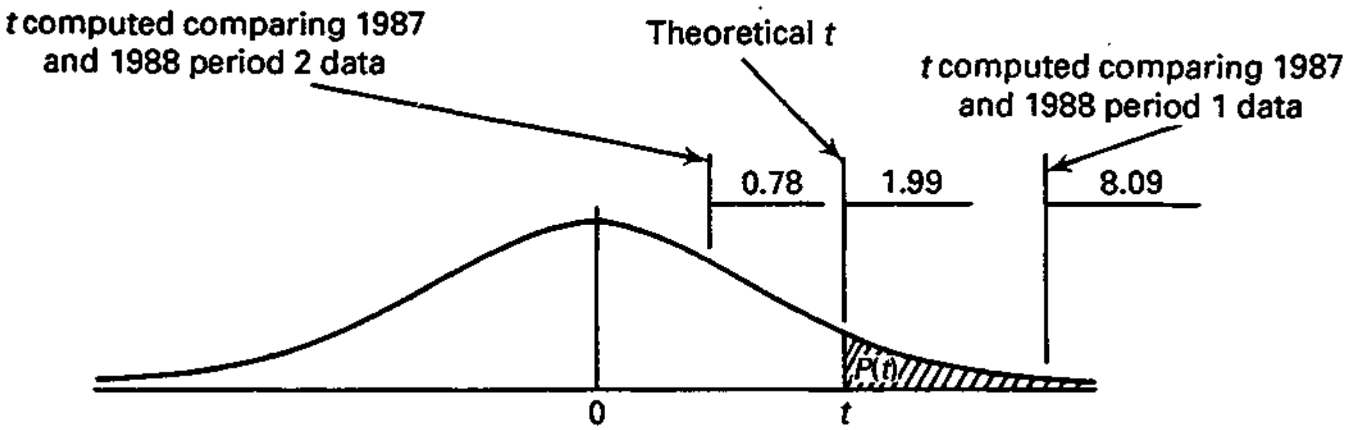
The purpose of using the Shannon-Weiner Diversity Index in this study is to determine if barge traffic affects the diversity of either algae or benthos communities. However, no in-depth evaluation or comments will be made relative to the state or condition of either of these biological communities.

A methodology developed by the IEPA (Hite and Bertrand, 1988) is used to assess the health of benthic macroinvertebrate communities. It assigns various benthic organisms a numerical pollution tolerance value ranging from 0 for totally intolerant organisms to 10 for the most tolerant to produce the Macroinvertebrate Biotic Index. The MBI can be expressed mathematically as:

$$\text{MBI} = \frac{\Sigma (n_i)(t_i)}{N} \qquad (8)$$

where n_i = number of organisms per taxa
t_i = tolerance value assigned to a taxa
N = total number of all organisms

As with the Shannon-Weiner Diversity Index, the MBI index will only be used to assess relative conditions from sampling



$P(t)$ f	.40	.30	.25	.20	.15	.10	.05	.025	.01	.005	.0005
1	.325	.727	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.657	636.619
2	.289	.617	.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	31.598
3	.277	.584	.765	.978	1.250	1.638	2.353	3.182	4.541	5.841	12.924
4	.271	.569	.741	.941	1.190	1.533	2.132	2.776	3.747	4.604	8.610
5	.267	.559	.727	.920	1.156	1.476	2.015	2.571	3.365	4.032	6.869
6	.265	.553	.718	.906	1.134	1.440	1.943	2.447	3.143	3.707	5.959
7	.263	.549	.711	.896	1.119	1.415	1.895	2.365	2.998	3.499	5.408
8	.262	.546	.706	.889	1.108	1.397	1.860	2.306	2.896	3.355	5.041
9	.261	.543	.703	.883	1.100	1.383	1.833	2.262	2.821	3.250	4.781
10	.260	.542	.700	.879	1.093	1.372	1.812	2.228	2.764	3.169	4.587
11	.260	.540	.697	.876	1.088	1.363	1.796	2.201	2.718	3.106	4.437
12	.259	.539	.695	.873	1.083	1.356	1.782	2.179	2.681	3.055	4.318
13	.259	.538	.694	.870	1.079	1.350	1.771	2.160	2.650	3.012	4.221
14	.258	.537	.692	.868	1.076	1.345	1.761	2.145	2.624	2.977	4.140
15	.258	.536	.691	.866	1.074	1.341	1.753	2.131	2.602	2.947	4.073
16	.258	.535	.690	.865	1.071	1.337	1.746	2.120	2.583	2.921	4.015
17	.257	.534	.689	.863	1.069	1.333	1.740	2.110	2.567	2.898	3.965
18	.257	.534	.688	.862	1.067	1.330	1.734	2.101	2.552	2.878	3.922
19	.257	.533	.688	.861	1.066	1.328	1.729	2.093	2.539	2.861	3.883
20	.257	.533	.687	.860	1.064	1.325	1.725	2.086	2.528	2.845	3.850
21	.257	.532	.686	.859	1.063	1.323	1.721	2.080	2.518	2.831	3.819
22	.256	.532	.686	.858	1.061	1.321	1.717	2.074	2.508	2.819	3.792
23	.256	.532	.685	.858	1.060	1.319	1.714	2.069	2.500	2.807	3.767
24	.256	.531	.685	.857	1.059	1.318	1.711	2.064	2.492	2.797	3.745
25	.256	.531	.684	.856	1.058	1.316	1.708	2.060	2.485	2.787	3.725
26	.256	.531	.684	.856	1.058	1.315	1.706	2.056	2.479	2.779	3.707
27	.256	.531	.684	.855	1.057	1.314	1.703	2.052	2.473	2.771	3.690
28	.256	.530	.683	.855	1.056	1.313	1.701	2.048	2.467	2.763	3.674
29	.256	.530	.683	.854	1.055	1.311	1.699	2.045	2.462	2.756	3.659
30	.256	.530	.683	.854	1.055	1.310	1.697	2.042	2.457	2.750	3.646
40	.255	.529	.681	.851	1.050	1.303	1.684	2.021	2.423	2.704	3.551
60	.254	.527	.679	.848	1.046	1.296	1.671	2.000	2.390	2.660	3.460
120	.254	.526	.677	.845	1.041	1.289	1.658	1.980	2.358	2.617	3.373
∞	.253	.524	.674	.842	1.036	1.282	1.645	1.960	2.326	2.576	3.291

° Use explained in Sec. 2.2.2. FoR a two-sided (equal-tails) test the significance levels are twice the above column headings. The reciprocals of the numbers of degrees of freedom, rather than the numbers themselves, should be used for linear interpolation. To calculate the upper 0.5% point for *f — 34,* use

$$2.704 + \frac{(1/34) - (1/40)}{(1/30) - (1/40)} (0.04\dot{6}) = 2.728$$

which is correct to 3 decimal places, whereas ordinary linear interpolation would **give 2.732. This** table was adapted, with the permission of the authors and the publishers, from R. A. Fisher and F. Yates, Statistical Tables, 4th rev. ed., Edinburgh, Oliver & Boyd, Ltd., 1053, p. 40. (The original table is given in terms of the two-sided test probabilities.)

Figure 6. Computed versus theoretical *t*-values comparing turbidity data from the Peoria pool, periods 1 and 2,1987 and 1988 [P*(t)* table from Crow et al., 1960]

period to sampling period. It will not be used for critical assessment of specific Illinois River benthic environmental problems. The t_i-values for most organisms associated with Illinois River bottom substrates are given by Hite and Bertrand (1988). Relative assessments will be predicated upon the results achieved by subjecting the index values to the ANOVA and the *t*-test statistical tests, as was done with the water quality data.

1989 Peoria Pool DO/Temperature Data

During summer 1986, between July 1 and September 30, daily runs were made (Monday through Friday) to take DO/ temperature measurements at the 28 Peoria pool stations utilized during this study. Two earlier runs, on August 15 and 16,1985,arealsoincludedinthe 1986 data summary. The DO/ temperature sampling methodology and the equipment used in that study were also used for this study. No direct statistical comparisons have been made between the two sets of data, but some subjective discussion and conclusions will be presented.

The 1986 data will be summarized in tables according to mile point The minimum value, mean value, maximum value, standard deviation (equation 1), 95 percent and 99 percent confidence intervals of the mean value, and standard error of the mean will be given for the DO data. Only the minimum, mean, and maximum will be given for the temperature data. The confidence interval (CI) of a mean value $(\bar{x})$ is represented by:

$$CI = \bar{x} \pm Zs \tag{9}$$

where Z depends on the particular level of confidence desired. The Z-values are derived on the basis of a normal bell-shaped distribution and are published in tabular form in most statistical texts. The Z-values for the 95 and 99 percent confidence intervals for the mean are 1.96 and 2.58, respectively. Consequently, a 95 percent probability exists that the true population mean $(\bar{x})$ lies between $\bar{x} \pm$ 60s, while a 99 percent chance exists that it lies between $\bar{x} \pm$ 2.576s.

The standard error of the mean $(\sigma_{\bar{x}})$ is represented by the equation:

$$\sigma_{\bar{x}} = \frac{s}{n} \tag{10}$$

This expression represents the standard deviation of a sampling distribution of means. It is useful in determining the minimum number of samples needed during future sampling to ensure, with some degree of confidence, that any new data are comparable to the historical data.

	Turbidity values (NTUs) for periods							
	1		2		3		4	
	1987	1988	1987	1988	1987	1988	1987	1988
	x1	*x1*	*x1*	*x1*	*x1*	*x1*	*x1*	*x1*
	x2	*x2*	*x2*	*x2*	*x2*	*x2*	*x2*	*x2*
	x3	*x3*	[illegible]	[illegible]	*x3*	*x3*	*x3*	[illegible]
	·	·	·	·	·	·	·	·
	·	·	·	·	·	·	·	·
	·	·	·	·	*x30*	*x30*	·	·
	·	·	*x50*	*x50*			*x50*	*x50*
	x60	*x60*						
Average $(\bar{x})$:	$\overline{66.5}$	$\overline{39.0}$	$\overline{40.4}$	$\overline{38.6}$	$\overline{86.6}$	$\overline{41.6}$	$\overline{51.5}$	$\overline{47.9}$
Null Hypothesis:	$\bar{x}_1(87)=\bar{x}_1(88)$		$\bar{x}_2(87)=\bar{x}_2(88)$		$\bar{x}_3(87)=\bar{x}_3(88)$		$\bar{x}_4(87)=\bar{x}_4(88)$	
Degrees of: Freedom	*f=n1 +H2-2* 118		98		58		98	
t(a/2,f) = *t(0.05/2, f)*								
Calc. (Eq. 5):	8.09		0.78		6.79		0.81	
Theo. (fig. 6):	1.98		1.99		2.00		1.98	
Conclusion:	Reject		Accept		Reject		Accept	

Figure 7. Schematic representation of the f-test procedure using turbidity results from the Peoria pool, 1987 and 1988

RESULTS

As previously noted, the results were greatly influenced by weather conditions, which caused significant variations in streamflows, especially during the 1987 phase of the study. These variations necessitated subdividing the original dam-closure period (as shown in figure 3a) into a low-flow dam-closure period and a high-flow dam-closure period (shown in figure 3b). Consequently, the hydrologic/hydraulic information generated during the study will be presented first because it greatly influenced how the parametric data had to be analyzed and displayed.

Hydrologic/Hydraulic Data

The flow conditions during the 1987 and 1988 study periods are summarized in table 3 and are diagrammadcally shown on figures 8, 9, and 10. The flow duration percentages given in table 3 are from curves developed for the warm summer months of June, July, August, and September (Butts et al, 1989a, 1989b). A comparable curve has not been developed for the river reach near the LaGrange dam. The duration percentages represent the proportion of a given time period, in this case 132 days, during which a given flow is equaled or exceeded. For instance, the minimum flow of 6,285 cfs observed at Starved Rock during the 1987 sampling period is exceeded 79.5 percent of the time, or about 105 days out of a total of 132 summer days. The values presented for Starved Rock are based only on flows recorded at the dam while sampling runs were made on the Peoria pool. The data used to develop the flow statistics for the Peoria and LaGrange dams include all the study period days, whether or not sampling runs were made on the LaGrange pool or the Peoria pool.

Two facts stand out relative to the hydraulic/hydrologic conditions during the study periods. First, the summer 1987 flows were much higher than the summer 1988 flows. Second, the 1987 flows were unstable, and the study area was dramati-

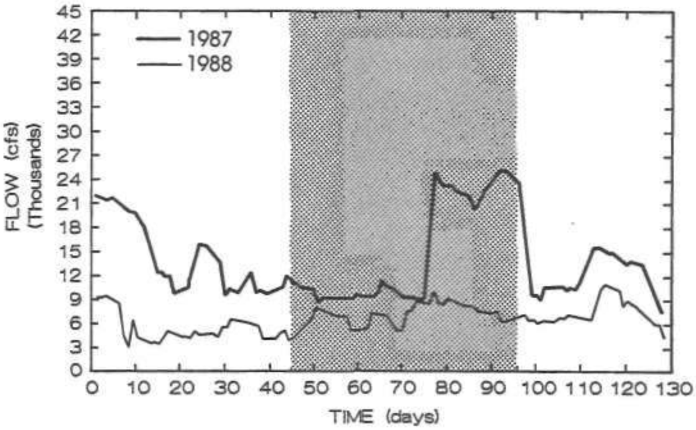


Figure 9. Discharge at the Peoria lock and dam during the study periods, June 2-October 6, 1987, and June 2-October 3, 1988

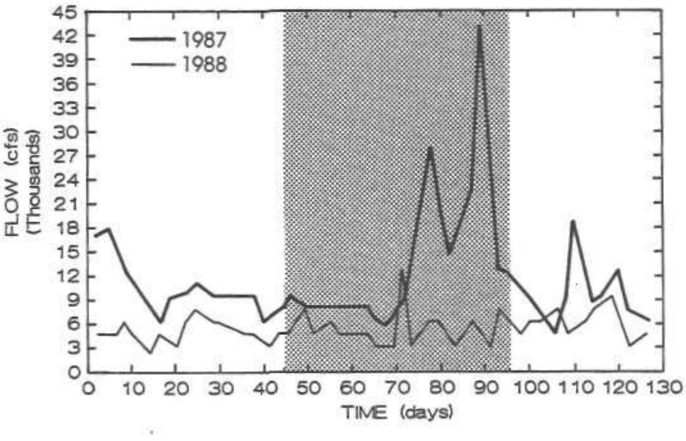


Figure 8. Discharge at the Starved Rock lock and dam during the study periods, June 2-October 6, 1987, and June 2-October 3,1988

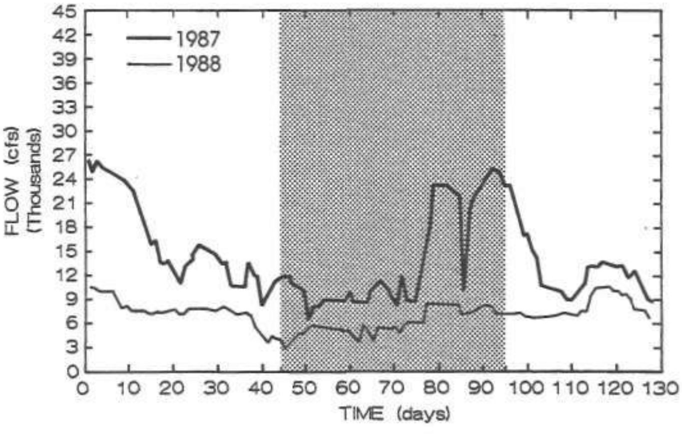


Figure 10. Discharge at the LaGrange lock and dam during the study periods, June 2-October 6,1987, and June 2-October 3,1988

cally affectedby the heavy mid-August rainfall in the Chicago area. The summer 1988 flows were persistently low and stable. Note from table 3 that the minimum flow-duration percentages ranged from 98.5 to 99.9+. The average flow at the Peoria dam during this period had a remarkably high duration value of 99.8 percent. This means that a lower average flow could be expected to occur only 0.2 percent of the time during the summer.

The sudden increase in flow during the shutdown period (shown as the shaded area in the figures) necessitated dividing this period into low-flow and high-flow periods. The inclusive dates for the resultant four sampling periods are given in table 4. The "number of trips" refers to complete passes made for each pool. During these passes, all field measurements were made; however, the water quality samples collected for laboratory analyses were collected at the frequency outlined in table 1. Consequently, the number of water quality samples taken from each station in each pool for laboratory analyses such as ammonia-nitrogen were six, five, three, and five for periods 1,2,3, and 4, respectively. Similarly, twelve, ten, six, and nine sets of algae data were collected per station for periods 1 through 4, respectively, in both pools.

The barge traffic conditions observed within each pool during each period are summarized in tables S and 6. From table 5, note that immediately before the shutdown of both dams (1987, period 1), barge traffic was significantly heavier than normal (1988, period 1). Undoubtedly, shippers were trying to complete last-minute business in anticipation of the closing of the locks.

Some local commercialbargemovement occurred within the confines of the Peoria pool during both the high- and low-flow shutdown periods. No barge movement was observed in the LaGrange pool during period 2, although some was observed during the high-flow period (period 3) during the shutdown. The commercial barge traffic observed in both pools during periods 2 and 3 was probably primarily local fleeting and transfer operations. The significantly lower number of barges per tow (table 6) during the shutdown periods could reflect this. Some local traffic could have originated above the Starved Rock dam, since the lock at Starved Rock was in operation.

Because of the high flows during the last two weeks of August 1987 (period3),all 134 wickets at the Peoria dam were down for 17 continuous days. Similarly, all 135 wickets were down at the LaGrange dam for 28 continuous days. Theoretically, this created the potential for opening both pools to "normal" commercial barge traffic. As table 5 shows, both pools did experience increased traffic, but this increase was very small. The average tow passage per day increased from 0.8 to 1.3 per day for the Peoria pool, while it increased from 0 to 0.7 per day for the LaGrange pool. Both daily averages were much lower than those of 7.6 and 8.6 for the Peoria and LaGrange pools, respectively, during the preshutdown period (table 5). Usage was probably not significantly higher because the barge operators and shippers were not prepared for this act of nature. Therefore, they could not readily or economically take advantage of it.

The highest density of tows and barges recorded during any run occurred in the LaGrange pool on September 23, 1988. On that date, 15 tows were observed pushing a total of 161 barges for an average of almost 11 barges per tow. During the sampling run prior to that on September 21, 1988, only three tows pushing a total of 25 barges were observed.

Water Quality

Over the course of the study 22,406 DO and temperature readings and 1,740 pH and S ecchi disk measurements were taken in the field. Approximately 760 chemical analyses were performed in the laboratory. Because of the magnitude of the data, the raw data will not be presented in this report. However, the data will be available on either 3.5- or5.25-inch diskettes using ASCII character files, comma delimited. The data are grouped according to periods for each year for both pools. Furthermore, these groupings are subdivided into field, laboratory chemistry, algae, and benthos categories. The information cannot be readily retrieved by river mile stations, but requests for data by station could be honored with some extra effort.

Analyses by Pool

Summaries of the results of the Peoria pool field tests and laboratory analyses are given in tables 7 and 8, respectively. Similar summaries for the LaGrange pool are given in tables 9 and 10. Presented are the sample mean *(x)* or average value for each parameter, the sample standard deviation (a measure of the variability of the data as expressed by equation 1), the calculated *F*-values (Calc), and the theoretical or book *F*-values (Theo) as referenced to the degrees of freedom. The f_1-values were equal to 3 in all cases since the number of treatments, i.e., the periods *(r)* were equal to 4 (f_1=4-l). The f_2-values for both the field pH and Secchi disk readings were 426 and 436 for the Peoria and LaGrange pools.respectively; f_2 was equal to 1,200 for the Peoria pool DO and temperatures, and 1,272 for the LaGrange pool DO and temperature data. The f_2-values for all the laboratory parametric analyses were equal to 186. Consequently, theoretical values for $F(0.025, 3, 426) = F(0.025,3,436) = 3.15$; $F(0.025, 3,1200) = F(0.025,3,1272) = 3.13$; and $F(0.025,3,186) = 3.19$ were obtained from the appropriate *F*-table in Crow et al. (1960).

The ANOVA results, as presented in tables 7 through 10, indicate that with only three exceptions, significant differences occurred between the means of each parameter for the different periods. The only situations in which the hypothesized equality in means could be accepted were the 1988 Peoria pool Secchi disk, turbidity, and suspended solids measurements. Intuitively, turbidity, suspended solids, and Secchi disk transparency could be suspected of being the most sensitive to barge movement and the most indicative of short- and long-term effects on water quality, since they are measures of water clarity. Note from table 7b that although the means for the Secchi disk readings vary from a low of 11.86 inches for period 4 to a high of 13.74 inches for period 2, these values show no statistically significant differences.

The data in tables 7 through 10 yield a number of interesting observations and results. The mean pH values appear to vary little, although in each case, statistically significant different values seem to occur within the groupings. This probably results from the fact that the pH unit is a logarithm, and small changes in pH represent relatively large numerical changes. The Secchi disk, turbidity, and suspended solids values are directly correlated with each other for both pools during both seasons. An increase or decrease in one value is accompanied by a corresponding increase or decrease in the others.

Large differences occurred in the temperature means between periods for both pools for both years. At this point in the analyses, these temperature differences appear to be more seasonal in nature than barge-related. The DO values varied greatly between periods, between years, and even within the location on the water column. For example, the 1988 Peoria pool DO averaged 7.08 mg/L at the surface during period 2, but it averaged only 5.50 mg/L at the bottom. Similarly, in the LaGrange pool, the surface value average for period 2 in 1988 was 5.23 mg/L; whereas the bottom average was only 4.38 mg/L. Evidently, barge traffic does not promote "well-mixed" conditions in the channel waters, as evidenced by this extensive DO stratification.

A wide range in the averages for the chemical parameters also occurred. Differences will have to be isolated using the *t* test, and judgments made as to the causes of these differences.

The results of the *t* test comparing periods within each year for the Peoria pool are presented in tables 11 and 12. The results of the *t* test comparing corresponding periods in 1987 and 1988 for the Peoria pool are given in table 13. Similarly, the r-test results comparing periods within each year for the LaGrange pool are given in tables 14 and 15; the results comparing corresponding periods in 1987 and 1988 are given in table 16.

The *t*-test results for both the Peoria and LaGrange pools for 1987 show that all the periodic means for suspended solids and turbidity are statistically significantly different; i.e., in all probability, each mean came from a different population of values. Note from tables 8 and 10 that during 1987 the lowest turbidity and suspended solids values in both pools occurred in period 2, during low flow and in the absence of barge traffic. Taken at face value, this tends to indicate that water clarity improves in the absence of barge traffic. However, the results of the *t* test comparing the 1987 and 1988 period-2 turbidity and suspended solids values (table 13b, Peoria pool; table 16b, LaGrange pool) negate this conclusion. The means for both parameters for both pools were actually lower during 1988 when barge traffic returned to normal. Although the 1988 averages were slightly lower for the Peoria pool, the differences were not statistically significant However, the 1988 averages were considerably lower for the LaGrange pool, and these differences proved to be statistically significant

A cursory examination of the 1987 results of the Secchi disk measurements taken in the field (tables 7 and 9) also tends to indicate better water clarity during period 2 in the absence of barge traffic. However, this was probably not the case since the values for both pools for period 2 in 1988 were significantly greater (tables 13b and 16b). The average visually measured transparency in the Peoria pool increased 2.S7 inches in 1988 over that observed during 1987; the 1988 LaGrange pool average increased 2.03 inches over the 1987 observation. Moreover, the 1987 Secchi disk readings for periods 2 and 4 in the Peoria pool were equal (table 11e). Similarly, these two 1987 periods were also equal for the LaGrange pool (table 14e). The fact that the means for periods 2 and 4 proved to be equal is significant, since flow conditions during these two periods were comparable (table 3), and barge traffic returned to near-normal conditions during period 4 (table S).

Other comparative situations appear contrary to intuition. For example, an examination of the /-values in tables 13b and 16b comparing DO for period 2 in 1987 and 1988 shows that the 1988 values are decidedly lower than the 1987 values. Barge tows violently mix and chum the water as they pass. Consequently, elevated DO levels usually occur in the wake of barge tows. Evidently, though, this effect is transient, based on the results presented in tables 13b and 16b.

Some of the chemical parameter differences observed between the commercial and noncommercial navigation periods appear to be caused by factors other than the presence or absence of barge traffic. Differences in alkalinity, hardness, phosphorus, and the nitrogens probably resulted from the extreme hydraulic, hydrologic, and weather conditions that persisted throughout the study periods. During 1987, flows were higher and much more erratic than during 1988. Record low flows and hot weather prevailed during the summer of 1988. Period 3 average surface temperatures for the Peoria pool were 23.53°C and 26.75°C, respectively, for 1987 and 1988. Similar 1987 and 1988 averages for the LaGrange pool were 23.93°C and 27.04°C, respectively. Extremes in temperatures and flows have a profound effect on biological activity within the pools. This in turn influences water quality to a very great extent. The interactions between biologic, hydrologic, and meteorologic conditions as they were observed during the study will be discussed in more detail later.

Analyses by Station

Water quality data for two sampling stations, at river mile 179.0 in the Peoria pool and river mile 113.3 in the LaGrange pool, were selected for in-depth statistical analyses. These two stations were selected on the basis of their central locations within the poorest quality water in each pool.

The ANOVA results for bom stations for bom years are presented in tables 17 through 20. During 1987, with the sole and minor exception of orthophosphate at river mile 179.0 in the Peoria pool (compare tables 8a and 18a), the two stations produced results representative of each of the respective pools as a whole. During 1988, the ANOVA results for the field data, with the exception of pH in both pools, mirrored those of the respective pools overall (compare tables 7b and 17b and tables 9b and 19b). However, the pH results as measured in the laboratory for both pools exhibited numerous differences (compare tables 8b and 18b and tables 10 and 20b).

The r-test results used to ascertain differences in the means between the groupings within each year for river mile 179.0 are presented in tables 21 and 22. The results comparing the same periods in 1987 and 1988 at river mile 179.0 are presented in table 23. Similar information is tabulated in tables 24 through 26 for river mile 113.3.

The results outlined in table 21e indicate that the 1987 means for turbidity and suspended solids at river mile 179.0 for period 2 are lower than those for period 4. This apparently indicates that barge traffic contributes to long-term elevated turbidity and suspended sediment levels in the navigation channel at this location. However, the r-test results for Secchi disk readings in table 21e show no significant difference in the means between the two periods, although water clarity during period 4 was slightly better than during period 2. Furthermore, as the results in table 23b show, no significant differences existed between the 1987 and 1988 means for turbidity, suspended solids, and Secchi disk measurements. This strongly indicates that water clarity at river mile 179.0 is probably not affected by commercial navigation over a relatively long period of time. In fact, except for the two minor parameters, alkalinity and nitrite-nitrogen, none of the other parameters showed significant differences in means for period 2 in 1987 and 1988 (table 23b). As with the Peoria pool as a whole (table 13b), the return of barge traffic and the accompanying turbulence resulted in higher induced DO levels at this station.

The 1987 results observed for the LaGrange pool at river mile 113.3 (table 24) are similar, but not identical, to those observed at the same time at river mile 179.0 in the Peoria pool (table 21). Of the three primary parameters (turbidity, suspended solids, and Secchi disk measurements), only turbidity showed a statistically significant difference between periods 2 and 4 (table 24e). No differences were ascertained between the suspended solids and Secchi disk means for periods 2 and 4. These results indicate, somewhat more strongly than the period-2 and-4 results at river mile 179.0, that barge traffic has minimal long-term effects on channel water clarity at specific locations along the river. The results presented in table 26b support this almost conclusively. Note that the 1987 and 1988 means for all parameters except turbidity and Secchi disk measurements can only be assumed to be equal. Furthermore, the suspicion grows even stronger that long-term water quality at a given location is little affected by barges: turbidities were significantly lower and Secchi disk readings significantly higher during 1988 than during 1987 (table 26b).

Algae

Algal counts, together with turbidity, suspended solids, Secchi disk readings, and dissolved oxygen measurements, were to be the primary parameters around which the water quality effects of barge traffic would be evaluated. The hypothesis was that persistent barge movement would reduce water clarity. This in turn would reduce light transparency and thus hinder algal productivity and photosynthetic oxygen production. The results of the statistical analyses of the water quality parameters outlined in the previous section clearly show that no discernable long-term differences in general water quality (within season) could be attributed to barge traffic.

During 1987 and 1988, 370 and 360 algae samples were examined, respectively, in each pool. The ANOVA results are presented in table 27 for the Peoria pool and in table 28 for the LaGrange pool. Note that the theoretical /-"-values contained in tables 27 and 28 are somewhat higher than those contained in tables 7-10. The theoretical *F*- and *t*-values for the algae statistical comparisons are higher because fewer algae samples were analyzed. As the number of samples goes down, the reliability of the statistical tests is reduced. Therefore, to guard against a Type I error, the *F*- and /-values increase.

The mean values presented in tables 27 and 28 represent the average logarithm of the individual algal cell counts. Algal cell counts ranged from a few cells per milliliter (cell/mL) to more than a thousand per milliliter. This produced a skewed arithmetic mean and sampling distribution. Consequently, to "normalize" the data for use in conjunction with standard statistical tables, the biological data were subjected to a $\log_{10}$ transform. The mean values presented for the algae *t* tests have been converted to the antilog_{10} values of the mean $\log_{10}$ values given in tables 27 and 28. For example, the mean $\log_{10}$ value of blue-green algae in the Peoria pool for period 1, 1987, was 1.657 (table 27a). The geometric mean *(Mg)* or antilog_{10} of 1.657 is 45.39 cell/mL, as shown in table 29a.

The algae statistical test results are less definitive than those for the general water quality parameters. The results of the total counts, the number of taxa, and the Shannon-Weiner Diversity Index are deemed most important and will be examined first Note from table 27 that for these three parameters, the Peoria pool results for 1987 and 1988 are identical. For both years, no differences in periodic means were evident for total counts and the diversity index, although differences occurred in the number of taxa. This indicates that some natural or human element caused significant periodic changes in algal numbers during both summers. With those changes came an attendant change in diversity, although the taxa numbers remained unchanged.

For the LaGrange pool the periodic means of the three primary algal parameters exhibited no differences during 1987 (table 28a); whereas, the periodic means for the total counts were different in 1988 (table 28b). The fact that none of the three primary indicators changed significantly over the four 1987 periods demonstrates that barge traffic probably has little or no effect on overall algal growth in the pool However, the types of organisms making up the total population of cells appears to have changed somewhat from period to period during both years. This is evidenced by the rejection of the hypothesis for the greens and flagellates during 1987 and for the blue-greens, diatoms, and flagellates during 1988.

The 1987 Peoria pool results (table 29e) show that the total count geometric mean for period 2 was almost double that of period 4. This in itself indicates that barge traffic may have a detrimental effect on algal productivity. However, the results in table 29d show that the total algae count geometric mean for period 2 was more than double that of period 3. This is significant because barge traffic virtually ceased during both these periods. This indicates that natural phenomena may play a more significant role than barge traffic in algal productivity in the Peoria pool. An examination of the geometric means of the total counts and the arithmetic means of the number of taxa and diversity index between periods in 1988 (table 30) reveals significant variability in these parameters when barge traffic returned to normal.

This bifurcation carries over in the *t*-test results comparing corresponding periods in 1987 and 1988 in the Peoria pool (table 31). The total geometric mean for 1987 period 2 (table 31b) is more than twice that for the same period in 1988. However, the reverse is true for period 3 (table 3lc); the 1987 period-2 total mean is only 62 percent of that observed for the 1988 period-2 mean.

Mixed signals as to the principal cause of the variability of the total algal counts also appear in the LaGrange pool *t*-test results (tables 32 and 33). Comparison of the geometric means for the total algal counts for periods 2 and 4 in 1987 indicates that the hypothesis that both are equal must be accepted (table 32e). However, comparison of the geometric means for the total algal counts for periods 2 and 3 in 1987 indicates that the hypothesis must be rejected (table 32d). At this point, an apparent anomaly in these two conclusions must be clarified. Note that the period-2, -3, and -4 geometric means for total counts are 775, 426, and 493, respectively. The results indicate that the 775 and 493 came from the same population; whereas, the 775 and 426 did not This may seem strange; 426 does not appear to differ much from 493 and in fact, both appear "on the surface" to be significantly less than 775.

However, the discussion in the Methods and Procedures section of this report, which detailed the reasons for using statistical testing for making decisions, addresses this ambiguity. The variability of the data plays a critical role in deciding if two means are generated from the same population. In this instance, the standard deviations, in terms of the $\log_{10}$ transform for the M_g-values of 775, 426, and 493, are 0.263, 0.096, and 0.206, respectively (table 28a). The standard deviations of 0.263 and 0.206 correspond sufficiently well with their respective means to produce the results presented in table 32e. However, the standard deviations of 0.263 and 0.096 are widely separated and correspond poorly with their respective means to produce the results shown in table 32d.

The geometric means for the number of taxa and the diversity index appear to be equal for all paired combinations for 1987 (table 32). During 1988, similar results occurred, although the diversity index geometric means for periods 1 and 4 were different (table 33c).

Table 34 presents the LaGrange pool f-test results comparing corresponding 1987 and 1988 periods. Except for the minor grouping of flagellates, all parameter geometric and arithmetic means appear to be equal for the critical period-2 comparisons. This strongly indicates that natural environmental conditions, rather than the influence of barge traffic, dictated the degree of algal productivity.

Barges and Benthic Sediments

The benthic macroin vertebrates identified and enumerated during the two 1987 sampling periods are listed in tables 35 and 36 by station. The organisms identified and enumerated during the two 1988 sampling periods are given in tables 37 and 38 by station. Also presented in the tables by station are the total number of organisms, total number of taxa, the IEPA macroinvertebrate biotic index, and the Shannon-Weiner Diversity Index. These four parameters will be used to ascertain whether barge traffic effectively hinders the growth and retards thediversity of bottom-dwelling (benthic) organisms in the channel of the river.

As mentioned earlier, the purpose of this phase of the study was to compare relative conditions, not to pass judgment on the absolute health and richness of the benthic communities. In the past 25 to 30 years, the channel portion of the river has not been able to sustain a large benthic biomass. Moreover, the biomass that does develop at specific locations in either pool usually consists of only two to five organisms. Of all the entities studied, the benthos was expected to exhibit the leastchange. Generally, a response time longer than the shutdown period is needed for benthos to react to stable environmental changes. Unfortunately, the stability of the shutdown period was also disturbed by the high flows during August 1987. However, a steady, progressive change in the benthic environment can, at times, quickly precipitate the development of some benthic organisms. Mathis and Butts (1981) witnessed such an event when a sudden, massive hatch of *Chaoborussp.* developed in a Kaskaskia River backwater cutoff meander.

Table 39 lists the f-test results for both the Peoria and LaGrange pools, comparing means within each year and between years. A cursory examination of these results shows that few changes occurred between periods within each year (tables 39a and 39b) or for corresponding periods between years (tables 39c and 39d). In terms of absolutes, the 1988 Peoria pool means for the total number of organisms, number of taxa, and the IEPA MBI are actually greater (albeit not significantly) than those during the 1987 shutdown period (table 39c, September). Similarly, the 1988 means for these three parameters for the LaGrange pool were equal to or greater than their 1987 counterparts (table 39d, September). Obviously, a sudden massive hatch of benthic organisms did not materialize during the shutdown, as was hoped.

The benthic sediment conditions, as observed at each benthos collection station during each period, are subjectively described in appendix F for the Peoria pool and in appendix G for the LaGrange pool. The measured water and volatile solids content of each benthic sediment sample are also presented by station and period in appendices F and G. Statistical comparisons of the means of the two measured parameters are presented in table 39. Note that in all cases, the hypothesis of equal means has to be accepted, i.e., no change could be detected in the water content or the volatile solids during any of the periods in either individual year or for like periods between the two years.

Although the sediment characteristics of each pool as a whole changed little over the course of the study, some localized changes were apparent, particularly immediately above both dams. At river mile 158.0 above the Peoria dam, the sediment just prior to the shutdown (July 1987) was relatively clean. It consisted mostly of pulverized shell, large clam half-shells, sand, and a thin layer of silt. However, just prior to the reopening of the dam to navigation (September 1987), 2 to 3 inches of gray-black silt had accumulated on top of the sand. The water content of the sediment in July was 15.8 percent, compared to 63.3 percent in September. In concert with the change in water content, the volatile solids content rose from 1.3 to 6.4 percent (appendix F).

The area of the river immediately above the Peoria dam is relatively deep (25 to 30 feet) compared to most places in the pool (10 to 15 feet). Consequently, this localized section of the river can trap and retain sediments under the right conditions. Evidently conditions were right while the pool was closed to commercial barge traffic. The apparent scenario was that the high flows that occurred during the shutdown carried a large load of suspended solids into the area (table 8), and some of that load was deposited. Much of this deposition remained and became so consolidated in the absence of barge traffic that it remained intact even with the return of normal barge traffic. The July and September 1988 sediment sampling results show that much of the silt-clay layer remained a year later. The water content remained high (55.1 to 64.0 percent), as did the volatile solids content (5.3 to 7.0 percent), as shown in appendix F.

A similar scenario, albeit to a lesser degree, appears to have occurred above the LaGrange dam. At river mile 80.2 above the dam, the preshutdown (July 1987) sediment sample consisted principally of a little silt and fine sand on top of coarse sand, small shells, shell fragments, pulverized shells, and woody detritus. During the shutdown (September 1987) a thick layer of black-gray silt was deposited on top of the sand, shells, and woody detritus. The water and volatile solids contents, however, did not change significantly, although both values were less than the July values, as shown by the data in appendix G.

Most of the silt remained through July 1988, and the sediment water content and volatile solids remained essentially as they were when observed during September 1987. However, by September 1988, the sediments in this area appeared to have returned to the condition observed prior to shutdown during 1987. Only a one-inch layer of watery gray silt-clay remained on top of the sand, shells, shell fragments, and woody detritus. Furthermore, the July 1987 and September 1988 water and volatile solids percentages were almost identical: 42.0 and 42.4 percent, respectively, for water, and 3.6 and 4.1 percent, respectively, for volatile solids.

1986 Peoria Pool DO/Temperature Data

The dissolved oxygen and temperature data collected in the Peoria pool during July, August, and September 1986 are summarized in appendix D. Normal summer flows and weather conditions persisted throughout the 1986 sampling period. Consequently, the dissolved oxygen data can be considered normal or typical of most summers. Therefore, these data provide a baseline for determining the deviation of the 1987 and 1988 Peoria pool DO values from the normal.

A close examination of the data presented in appendix D reveals DO concentrations below 5.0 mg/L only at river mile 174.9 during 1986. Furthermore, the DO at this location fell below 5.0 mg/L only twice in 42 sampling days. During both 1987 and 1988, however, DO fell below 5.0 mg/L 14 times for 43 sampling days during each year. The minimum 1986, 1987, and 1988 DOs were 4.61, 3.40, and 2.10 mg/L, respectively. The respective average DOs were 6.72, 6.01, and 6.18 mg/L. Sophisticated statistical analyses are not needed in this case to conclude that significant deterioration in water quality began during 1987, and that this deterioration continued into summer 1988.

DISCUSSION

The study was conceived and designed around the assumption that commercial barge traffic has a significant long-term effect on Illinois River water quality. The study was not initiated to prove that commercial barge traffic causes water quality problems. On the contrary, the subconscious mind, coupled to some degree with worldly bias, had already declared that barge traffic does impair water quality. This was a foregone conclusion held by most river observers. To have carried this bias and/or declaration through the implementation and analysis stages of the study and to have permitted it to influence the outcome would have resulted in a spurious scientific endeavor. However, a good sampling program designed to produce data amenable to rigid analysis using mathematical statistical tests produced essentially unbiased results.

In the end, commercial barge movement was found to have limited—if any—measurable effects on long-term water quality conditions in the main river channel. This does not mean that short-term or transient effects do not occur—they do. However, if long-term effects do occur, they appear to be completely masked or overshadowed by natural phenomenon.

Statistical Test Results versus Data Plotting and Curve Fitting

In the previous section, many permutations and combinations of data were analyzed through statistical testing. Conclusions were drawn by comparing mean values of various water quality indicators (derived during commercial and noncommercial navigation periods) and accepting or rejecting a fact of equality between the two periods at a 5 percent level of significance. When statistical testing is used for decision making, the user must unequivocally accept the result of the test. The acceptance or rejection of a hypothesis must also be an absolute decision. The results of the ANOVA and *t* tests, as presented in the preceding section, were addressed in this manner. However, those unwilling to accept statistical testing as the quintessential approach in decision making may accept more simplistic, indirect approaches that produce similar but less definite conclusions. An indirect approach will be discussed in this section.

The means of the various parameters listed in tables 7 through 10 can be presented as dependent variables *(y)* in simple *x* versus y plots. These dependent variables can be plotted with either of the two independent variables: flow (table 3) or barge traffic (table 5). These plots should show direct or indirect trends if thedependent variables are correlated with eitherof the two independent variables. Plots were developed using turbidity, suspended solids, Secchi disk, surface DO, bottom DO, and total algae counts as dependent variables. These parameters were plotted for each pool in conjunction with 1) the mean daily flow at the Peoria dam and 2) the appropriate unit daily barge traffic observed during sampling runs (table 5).

Plots showing the casual relationships between the six dependent variables and the unit barge traffic for each pool are presented as figures 11-16. In no case did a definitive trend appear between barge traffic and any of the selected dependent variables. Similar plots using the Peoria dam flow as the independent variable are presented in figures 17-22. In this case, definite trends are readily apparent for several of the dependent variables. Both turbidity and suspended solids show direct, lin-

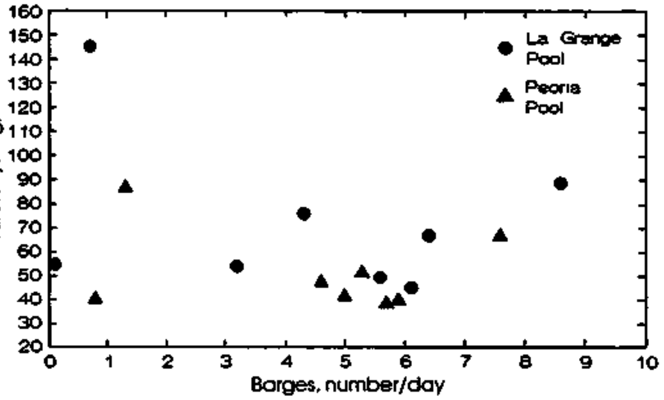


Figure 11. Relationship between barge movement and turbidity

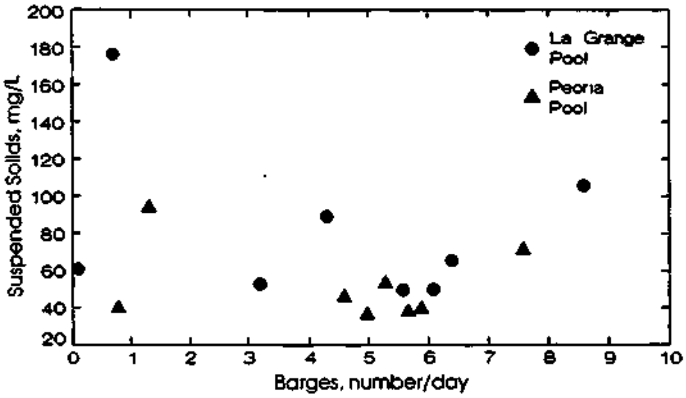


Figure 12. Relationship between barge movement and suspended solids

ear relationships with flow (figures 17 and 18); i.e., increases in flow cause corresponding proportional increases in both turbidity and suspended solids. Turbidity and suspended solids in the LaGrange pool appear to be more sensitive to changes in flow than in the Peoria pool. Two factors indicate this: 1) the LaGrange pool data points plot above the Peoria pool points and 2) the LaGrange pool plots exhibit a greater positive slope.

The Secchi disk readings exhibit an inverse relationship with flow. This is notunexpected since these readings indicate that water clarity is reduced as turbidity and suspended solids increase. Again, the LaGrange pool appears more sensitive to changes in water clarity with changes in flow than does the Peoria pool.

The LaGrange pool is probably more sensitive because the navigation channel is narrower and constrained throughout its length. The wider areas in the Peoria pool, such as the upper and lower Peoria Lake reaches, would tend to dampen out some of the hydraulically and hydrologically induced changes in water quality. Since the LaGrange pool is more sensitive than the Peoria pool to long-term, natural changes in water clarity-related parameters caused by flow, one could reasonably assume that the LaGrange pool is also more sensitive to transient hydraulic disturbances, such as those caused by barge movements.

The relationships between DO and flow are particularly interesting. The surface DO concentration in the Peoria pool appears to fall slightly as flow increases (figure 20); however, flow appears to have little or no effect on riverbottom DO conditions(figure21). The probable reason for this dichotomy is that low flows are more suitable for algal activity, resulting in higher surface DOs during low flows due to photosynthetic oxygen production. For example, on July 11, 1988, at river mile 174.9(with a flow of only 4,285 cfs at the Peoria dam) the surface, 3-foot, mid-depth, and bottom DO concentrations were 13.33, 4.56, 2.25, and 2.10 mg/L, respectively. In contrast, on August 28, 1987, at river mile 174.9 (with a flow of 22,778 cfs at the Peoria

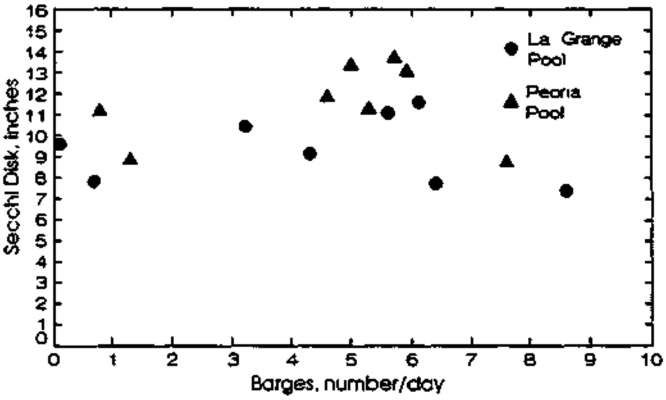


Figure 13. Relationship between barge movement and Secchi disk readings

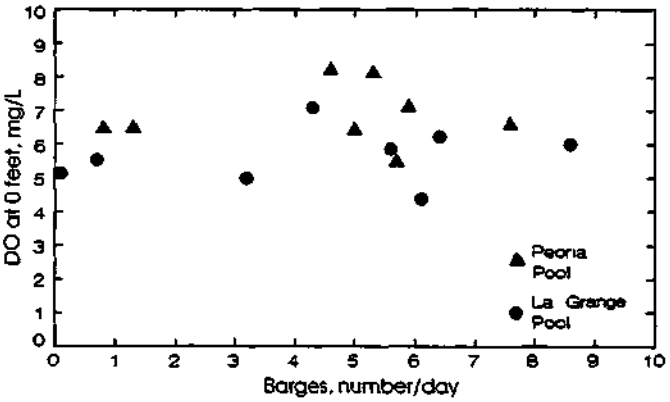


Figure 15. Relationship between barge movement and bottom DO

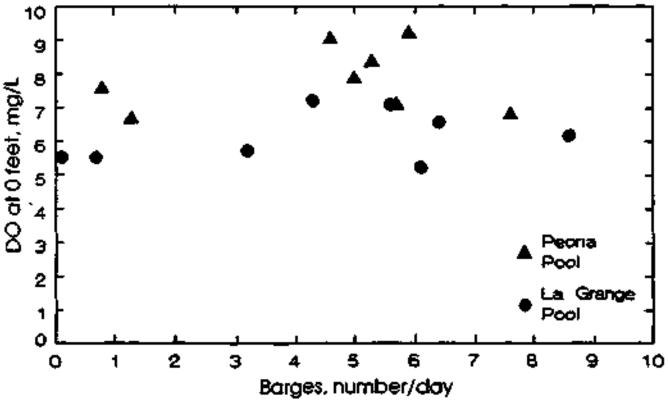


Figure 14. Relationship between barge movement and surface DO

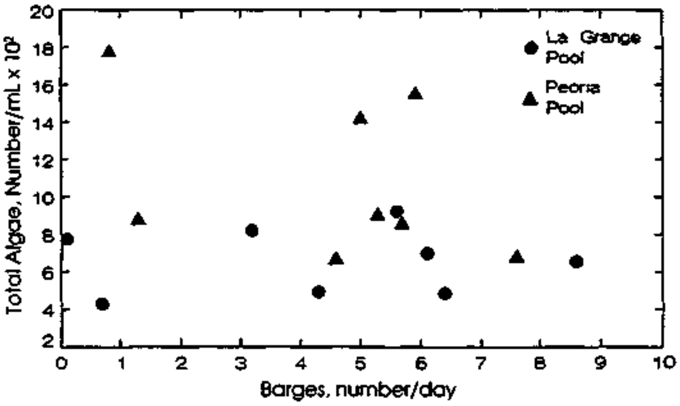


Figure 16. Relationship between barge movement and total algae counts

dam) the surface, 3-foot, mid-depth, and bottom DO concentrations were 5.00, 4.90,4.61, and 4.57 mg/L, respectively.

Rapidly increasing flows during warm summer conditions tend to "wash out" standing algal blooms that may have developed during low flows. Also, the higher turbidities (figure 17) and higher velocities associated with high flows retard algal growth. At the same time, high flows create turbulent mixing, which results in a more uniform DO distribution in a cross section, as was exemplified by the August 28, 1987, results. Note from figure 22 that algae counts tend to be lower during very high flows for both pools.

Mathematical Models and Formulations

Thedata presented graphically in figures 11 through 22 can be reduced to specific mathematical models and formulations to better define trends and relationships. Trend or regression equations can be developed using statistical, least-square methods of curve or line fitting. A linear equation using the x-axis as the independent variable is represented by the expression:

$$y = a + bx \qquad (11)$$

where y = dependent variable
x = independent variable
a = y-axis intercept
b = slope of curve; i.e., $(y_2-6_1)/(x_2-x_1)$
where (x_1, y_1) and (x_2, y_2) are coordinates

Similarly, a linear equation using they-axis as the independent variable is represented by the expression:

$$x=a'+b'y \qquad (12)$$

where x = dependent variable
y = independent variable
a' = x-axis intercept
b' = slope of curve; i.e., $(x_2-x_1)/(y_2-y_1)$

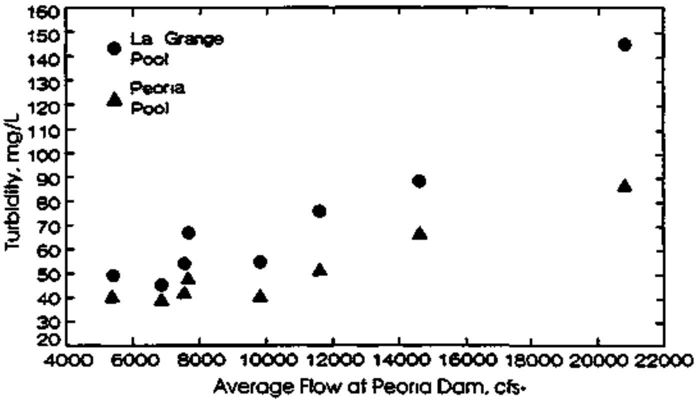


Figure 17. Relationship between flow and turbidity

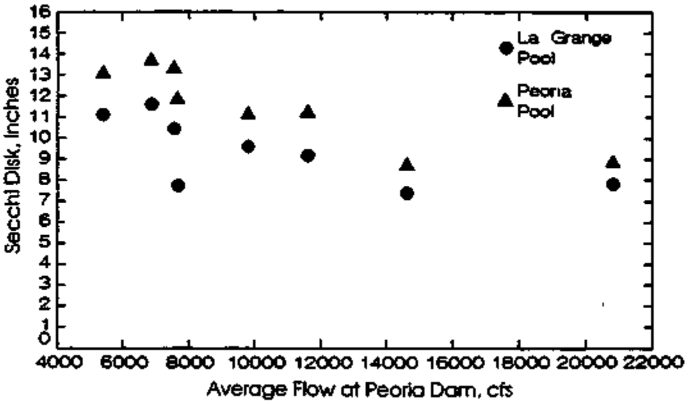


Figure 19. Relationship between flow and Secchi disk readings

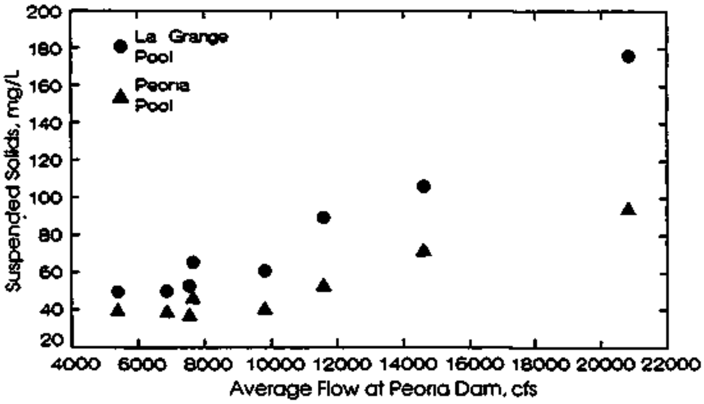


Figure 18. Relationship between flow and suspended solids

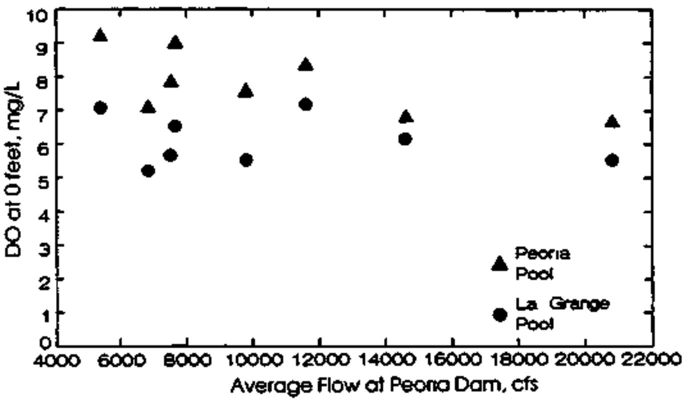


Figure 20. Relationship between flow and surface DO

The correlation coefficient is a mathematically derived number that indicates how well the observed data used to generate a regression equation or line actually fit the line. The correlation coefficient *(r)* can be mathematically represented by:

$$r = (b)(b') \qquad (13)$$

Consequently, to achieve a perfect fit (e.g., $r=\pm1$) all the data sets would have to fall on a line, either rising or falling, at a 45-degree angle or slope. In other words, equations 11 and 12 would have identical slopes. Horizontal lines represent zero correlations since in equation 11, b=0, making *y equal* to a constant a; similarly vertical lines represent zero correlations since in equation 12, b'=0, making *x* equal to a constant a'. In terms of equation 13, a perfect direct correlation is $r=(1)(1)=1$, while a perfect indirect correlation is $r=(-1)(1)=-1$. For a horizontal line $r=(0)(\infty)=0$, while for a vertical line $r=(\infty)(0)=0$, where ∞ equals an infinite slope. The coefficient of determination r^2 is defined as the portion of the total variance of y that is explained by *x* in equation 11. Therefore, if $r = 0.90$, then 81 percent ($0.90^2 \times 100$) of the variability observed in the dependent variable can be ascribed to the independent variable.

Table 40 lists regression coefficients as "a" and "b" (equation 11), as well as correlation coefficients and coefficients of determination for the data plots depicted in figures 11-22. The statistical results support the subjective analyses imposed upon the data plots. The correlation coefficients relating all the water quality parameters to barge traffic are low for both pools. In fact, the correlations between turbidity and suspended solids for both pools are negative, indicating that somewhat higher degrees of water clarity were observed at higher rates of barge traffic. Only the correlation coefficients for "total algal counts versus barge traffic" for the Peoria pool and "surface DO versus barge traffic" for the LaGrange pool were statistically significant at the 5 percent level. Even then, barge traffic explained less than 16 percent of the variability in eitherof these relationships, as evidenced by the r^2 values in table 40. However, the conclusions can be reached that barge traffic does tend to limit algal growth to a small degree in the Peoria pool, and that it appears to influence surface DO in a positive manner in the LaGrange pool.

Other water quality parameters appear to be highly correlated with flow. Both turbidity and suspended solids exhibit very high correlation coefficients for both pools (table 40). From 92.1 to 95.5 percent of the variability observed for these parameters is attributable to changes in flow (table 40). Furthermore, flow explains more than 80 percent of the variability observed in the Peoria pool Secchi disk readings. While flow accounts for only 48.6 percent of the observed variability in the LaGrange pool Secchi disk readings, this percentage is still highly significant at the 5 percent level. Flow also appears to have a moderate but significant negative effect on Peoria pool surface DO and LaGrange pool total algae counts, but only a small but significant effect on Peoria pool algae counts.

Overall the trends, inferences, and results derived from the data plotting/curve fitting procedures agree well with those produced by the ANOVA/*t*-test methodology, which analyzed for differences in mean values. Succinctly stated, barge traffic does not appear to have a major impact on long-term water quality conditions in either the Peoria or LaGrange pools.

Previous Studies

This study was not designed to investigate and evaluate short-term effects of barge traffic on limited or selected water quality parameters. However, a number of recent studies have been conducted relative to this subject on both the Mississippi and Illinois Rivers. Probably the first in-depth study generally available in report form was that conducted by Johnson (1976). He studied changes in water quality caused by the resuspension of benthic sediments in the Illinois and upper Mississippi Rivers.

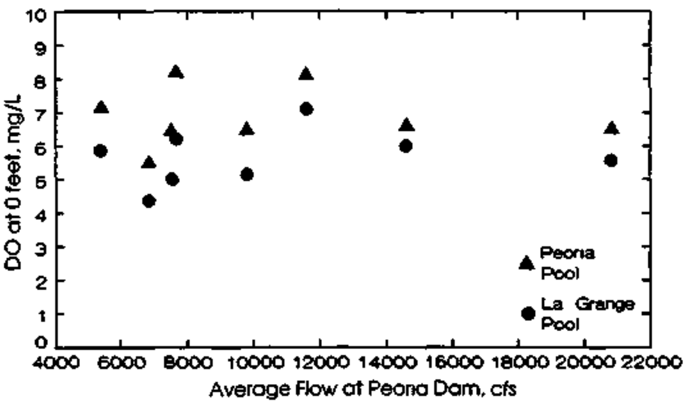


Figure 21. Relationship between flow and bottom DO

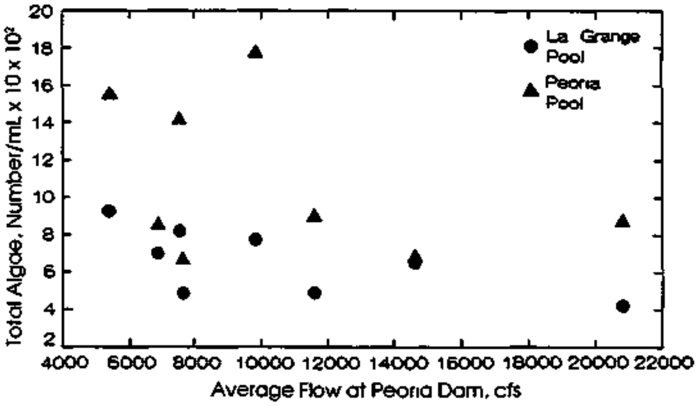


Figure 22. Relationship between flow and total algae counts

The water quality parameters studied were turbidity, suspended solids, and dissolved oxygen. The study was brief and intensified. *In situ* sampling was conducted from October 5 through November 2,1975, to provide data to meet five objectives, four of which were pertinent to this study.

1. To determine if tow traffic significantly increased concentrations of suspended solids and turbidity above ambient concentrations at sampling stations located on a transect within the river proper.
2. To estimate the time required for concentrations of suspended solids and turbidity to return to ambient concentrations in the immediate study areas.
3. To determine if multiple tow traffic events have an additive effect on elevating concentrations of suspended solids and turbidity in the immediate study area.
4. To estimate the magnitude and duration of the oxygen demand exerted (DO change) by riverbed sediments resuspended in the main channel by tow traffic.

Johnson used six monitoring stations, one located at river mile 113.5 in the LaGrangepool, andanother atriver mile215.8 in the Peoria pool. Sampling was limited specifically to periods of tow passage. It was initiated just prior to a tow passage and after the passage atintervals of 10,20,40,60,90,120,150,and 180 minutes. Overall, 15 tow traffic events were monitored.

The results of the Johnson study are summarized in table 41. The conclusions made by Johnson that are relevant to this study are:

1. Upper Mississippi and Illinois River tow traffic can raise turbidity and suspended sediment levels. However, these elevated levels return to ambient conditions after a certain amountof time, depending on the number of tow passages.
2. Elevated turbidity levels caused by tow traffic during normal pool and tow passage conditions are no higher than those caused by natural high flows along the Illinois River.
3. Continuous movement of tows past a point can create additive effects, i.e., multiple passings can cause suspended solids and turbidity levels to rise higher than would a single passing. The recovery time to ambient conditions is generally longer at the end of the final pass of a multiple pass than it is after a single pass.
4. In most instances, tow traffic did not affect dissolved oxygen concentrations in the main channel.

Conclusions 1, 3, and 4 can be deduced by perusing the information contained in table 41. The essential point to be gleaned from these tabular data is that the effects of tow passages on water quality are, at best, transient. This fact, along with Johnson's conclusion that naturally occurring high flows affect suspended solids and turbidity levels more than barges do, ostensibly supports the findings and attendant conclusions presented in this study.

Bhowmik et al. (1981a) conducted a study similar to Johnson's on the resuspension and lateral movement of sediment by tow traffic on the upper Mississippi and lower Illinois Rivers. Not surprisingly, their findings and conclusions paralleled those of Johnson. First, an assumption was made that the passing of tows increased suspended sediments. However, the resuspension was found to be greater along the channel borders than in the navigation channel. The suspended sediments concentration returned to ambient levels 60 to 90 minutes after tow passage. Similar to Johnson's findings relative to successive tow passages, Bhowmik et al. (1981a) found that multiple tow passings across a section in less than 90 minutes required a longer time to return to ambient conditions after the passing of the last tow than was required after thepassingofasingle tow. However, they found that the average increase in peak concentrations created by multiple passages was less than that created by a single passage.

A draft of the U.S. Army Corps of Engineers (1989) plan of study of the navigation effects of a second lock at the Melvin Price lock and dam refers to several previous works relative to the effects of barge traffic on water quality. Included are limited discussions of the Johnson and Bhowmik works also reviewed in this report. All the discussion of elevated suspended sediments due to barge movement in the COE draft plan refer to transient effects and not to long-term effects. Additional comments in the Corps' draft plan concern the effects of tow traffic on backwater or side channel water quality and on the mortality of larval fishes. Neither subject was addressed during this study, since it concerns only water quality and benthic conditions within the main channel.

Bhowmik et al. (1981b) also reported on a study of the effects of Illinois River traffic on water and sediment input to aside channel. Lubinski et al. (1981) also published a literature search relative to the physical, chemical, and biological effects of navigation.

Transient Effects of Barge Traffic

Although this study was not designed to address transient effects of commercial barge traffic on channel water quality, some of the data lends itself to such interpretation. On September 23, 1988, during a sampling run in the LaGrange pool, 15 tows were observed pushing a total of 161 barges. The pool is 77.4 miles long, which means a moving tow was encountered every 5 miles on average. Approximately 232 minutes were required to complete the sampling run, so a tow was encountered about every 15.5 minutes on average. Therefore, based on Johnson's work (table 41) and the results from Bhowmik et al. (1981b), disturbed and possibly turbulent conditions persisted throughout the LaGrange pool during the sampling run, since at least 60 minutes of nondisturbance would be needed for ambient conditions to return.

Because of these unusual traffic conditions, one would suspect that water quality throughout the pool would probably resemble that transiently imposed by barge movement, rather than normal ambient conditions. This suspicion was verified by comparing water quality results measured on September 23, 1988, with those measured two days previously when only three tows pushing 25 barges were encountered. The results are presented in table42. Unfortunately, September 23,1988, was not a day during which samples were collected for laboratory analyses of turbidity and suspended solids. Only field data were available for comparison. Nevertheless, these data are sufficient to show the transient nature of the results observed on September 23.

Secchi disk readings are a good indicator of water clarity. Note from table 42a that water clarity on September 21, in terms of inches, was almost twice that on September 23. Also, the sustained barge traffic appears to have produced statistically significantly lower DO. Indirectly this agrees with the findings of Johnson (1976). In some instances he observed slightly reduced DO levels during heavy tow traffic but not during normal barge traffic. Nevertheless, he concluded that the Illinois River is highly susceptible to sustained, elevated turbidity during high tow traffic because of a narrow navigation channel.

Increases in turbidity produce commensurate decreases in algal photosynthetic oxygen production. The Illinois River is a highly productive river, and the DO concentrations in the upper 3 feet of the water column are greatly influenced by algal activity. The difference in DO concentrations in the upper 3 feet of water observed between September 21 and September 23 was probably not weather-related. September 21 was sunny to partly cloudy; whereas September 23 was primarily partly cloudy.

Table 42b compares high and low traffic sampling days on the Peoria pool. The results are less conclusive than for the LaGrange pool. The highest tow traffic in the Peoria pool was noted on June 24, 1988, when 12 tows were observed pushing 76 barges. This date was compared to conditions on June 28, 1988, when four tows were observed pushing 23 barges. The differential between barge traffic was not nearly as great as for the LaGrange pool example. Even more important is the fact that weather conditions between the two Peoria pool dates were radically different On June 24, rain was falling under cloudy skies; whereas, on June 28, skies were clear. Winds on June 24 ranged from calm to 2 mph; winds on June 28 ranged from calm to 4 mph. The hypothesis of equal means for the Secchi disk readings for both dates could not be rejected. However, the mean DO concentrations at all depths were much different on the two dates. Those for June 28 were much higher and undoubtedly resulted from accelerated photosynthetic oxygen production due to the prevailing sunny, calm weather. On June 24, with higher traffic and cloudy, drizzly conditions, photosynthetic oxygen production was probably nil. Again this illustrates how natural phenomenon can easily "mask out" any marginal changes that may be caused by commercial barge traffic in either pool.

Transient versus Long-Term

Finally, a brief commentary should address the meaning of "long-term" used throughout this report. Basically the authors have used it as a convenience to distinguish between transient changes in water quality due to the passing of a barge tow and conditions averaged over a 30- to 40-day period. In reality, this study has shown that barge traffic, at the *existing average rate*, generally has little or no significant effect on navigation channel water quality, except for a "fleeting" few minutes after tows pass a given point.

If future traffic were allowed to increase to such an extent that a tow would pass a given point on the average of every 15 minutes, as was observed in the LaGrange pool on September 23, 1988, long-term (continuous) water quality problems would certainly develop. At mis time, however, me river system appears to be able to handle the existing traffic rate without any deleterious effects on channel water and benthic conditions. One can only speculate on how delicate this balance is or at what point in time recurrent or continuous degradation will become evident. However, the results of the Johnson (1976) and Bhowmik et al. (1981) studies, coupled with the information generated during this study, indicate to some degree that the system is now close to its maximum traffic accommodation capacity.

SUMMARY AND CONCLUSIONS

The U.S. Army Corps of Engineers shut down the navigation locks at the LaGrange and Peoria dams on the Illinois River during the summer of 1987 for repairs. This effectively prevented commercial tows from traversing a Sl-mile reach of the waterway for 58 days from July 13 to September 8, 1987. The closing provided a rare opportunity to study and observe the river without commercial navigation. During the closing, high-flow conditions persisted for 23 days, from August 17 to the reopening on September 8, 1987.

A study was designed to collect water quality and benthic data from the main channel during a 30-day preshutdown period, during the shutdown period, and during a 30-day postshutdown period. After the study progressed into the shutdown stage, high flows required the division of the shutdown period into low- and high-flow shutdown periods. Corresponding calender periods were sampled during 1988 for comparative/control purposes.

Statistical testing procedures were used to determine whether water quality conditions improved in the absence of commercial navigation. Analysis of variance and *t* tests were used at a 5 percent level of significance to ascertain any differences in means between periods in a single year and between corresponding periods in the two years. The parameters examined were turbidity, suspended solids, pH, alkalinity, hardness, orthophosphate, ammonia, nitrite, nitrate, dissolved oxygen, temperature, Secchi disk readings, algae and benthos identification and enumeration, and subjective sediment analysis. The resultant conclusions are:

1. Commercial navigation, at its present rate, does not appear to cause any significant sustained changes in water quality in either pool. At worst, barge traffic appears to hinder algal growth somewhat in the Peoria pool; at best, tows appear to improve surface DO levels slightly in the LaGrange pool. In terms of absolutes, water clarity (as gaged by turbidity, suspended solids, and Secchi disk readings) was actually better during the four 1988 periods than during comparable 1987 periods. The 1987 LaGrange pool turbidity, suspended solids, and Secchi disk means during period 2 (low-flow shutdown) were 54.8 nephelometric turbidity units (NTU). 61.0 mg/L, and 9.6 inches, respectively. Corresponding 1988 period-2 values were 45.4 NTU, 503 mg/L, and 11.6 inches.

2. Natural phenomena, such as rapidly rising flows and sustained low flows during warm summers, influence water quality for long periods to a far greater extent than does commercial barge traffic at present rates. During 1987, turbidity averages increased from 40.4 NTU during period-2 low-flow conditions to 86.6 NTU during period-3 high-flow conditions. Average water clarity was reduced by 2.3 inches. The sustained low flows and unusually hot weather during 1988 promoted algal blooms that resulted in DO concentrations significantly higher than those observed in LaGrange pool suspended solids concentrations, which could be attributed to changes in flow.

3. Tows cause intensified, transient changes in water quality to the extent that long-term water quality in the navigation channel could be degraded if growth in commercial barge traffic is unrestricted. This study was not specifically designed to study and analyze transient impacts of tows, but the opportunity to do so did arise. On September 23, 1988, 15 tows pushing 161 barges were observed traversing the LaGrange pool during a sampling run. The sampling boat passed a moving barge about every 15 minutes. Water clarity on this date was only 51.8 percent of that observed two days previously, when only three tows pushing 25 barges were present A mathematical model should be developed to help predict the optimal rate of traffic necessary to prevent sustained water quality degradation. Central to the development of such a model is the need to formulate an algorithm to predict or estimate the "rest time" needed between transient disturbances to prevent accelerated degradation under a wide range of hydraulic, hydrologic, weather, and water quality conditions.

4. No significant differences were found in the density and diversity of benthic macroinvertebrate (benthos) populations for samples collected during commercial navigation periods and those collected at the very end of the shutdown period. This was not entirely unexpected, since the channel substrate in most places in bom pools is not particularly well suited for benthos production and diversity. Also, unlike water quality per se and aquatic biological growths like algae, benthos respond much more slowly to physical changes in the aquatic environment. Only about two months of noncommercial navigation time were available for benthic macroinvertebrates to exhibit significant changes.

5. Overall, few changes were observed in the physical characteristics of the benthic sediments in the navigation channel throughout both pools, with the minor exception of areas situated immediately above both dams. Prior to the shutdowns the sediments above both dams consisted of some silt mixed with sand and shells. With the high flows during the shutdown, considerable amounts of fine, watery sediments were deposited at both locations, and a large portion of these depositions remained through 1988.

TABLES

Table 1. Water Quality Parameters and Their Sampling Frequencies

			Minimum	*Type*			*Analyses*		*Sampling frequency*			
	Std. Mthd.		*detectable*						*Per week*			*2 per*
Parameter	*reference*	*Units*	*limit*	*Phy*	*Chem*	*Bio*	*Field*	*Lab*	*1*	2	*2-3*	*summer*
Dissolved oxygen				X			X				X	
a. Winkler	421B	mg/L	0.05									
b. Electrode	421F	mg/L	0.01									
Temperature	421F	°C	0.01	X			X				X	
Secchi disk	-	in.	-	X			X				X	
Turbidity	214A	NTU	1	X				X	X			
Suspended solids	209C	mg/L	1	X				X	X			
pH	423	pH	0.01		X		X				X	
Alkalinity	403	mg/L	1		X			X	X			
Hardness	314B	mg/L	1		X			X	X			
Orthophosphate	424F	mg/L	0.01		X			X	X			
Dissolved ammonia	417C*	mg/L	0.01		X			X	X			
Nitrite	419	mg/L	0.01		X			X	X			
Nitrate	418D	mg/L	0.01		X			X	X			
Algae counts	1002	no./mL	0.45μm			X		X		X		
Benthos	1005D	no./sq.m	0.60mm			X		X				X

* modified as per Water Research, 1970, (4), 805-811

Table 2. Water Quality Sampling and Measurement Stations

	LaGrange pool							*Peoria pool*					
	Lab samples			*Field measure*				*Lab samvles*			*Field measure*		
River mile	*Algae*	*Water*	*Sed./ benthos*	*pH*	*Secchi disk*	*DO/ temp*	*River mile*	*Algae*	*Water*	*Sed./ benthos*	*pH*	*Secchi disk*	*DO/ temp*
80.2	X	X	X	X	X	X	158.0	X	X	X	X	X	X
82.3						X	159.4						X
85.5						X	160.7	X	X	X	X	X	X
89.2			X			X	161.6						X
93.6	X	X		X	X	X	162.8	X	X	X	X	X	X
97.0			X				164.4						X
97.2						X	165.3						X
99.5						X	166.1	X	X	X	X	X	X
103.4						X	167.0						X
106.9	X	X		X	X	X	170.9						X
110.2			X			X	174.9						X
113.3	X	X		X	X	X	177.4						X
116.3						X	179.0	X	X		X	X	X
119.7			X			X	183.0						X
121.1	X	X		X	X	X	183.2			X			
125.8						X	188.0						X
129.5	X	X		X	X	X	190.0						X
132.0			X			X	193.5			X			
135.7						X	196.9	X	X		X	X	X
139.0	X	X	X	X	X	X	200.4						X
143.2						X	205.4						X
145.5	X	X		X	X	X	209.4						X
147.3			X			X	213.4	X	X	X	X	X	X
148.2						X	217.1						X
150.0	X	X	X	X	X	X	219.8						X
151.0						X	222.6	X	X	X	X	X	X
152.0						X	224.7						X
153.0						X	226.9	X	X	X	X	X	X
155.0			X			X	229.6						X
157.6	X	X		X	X	X	231.0	X	X	X	X	X	X
							231.1	Starved Rock pool					X

Table 3. Flow Conditions at the Dams during the Study Periods, 1987 and 1988

		Minimum				*Average*				*Maximum*			
		Flow (cfs)		*Duration(%)*		*Flow (cfs),*		*Duration(%)*		*Flow (cfs)*		*Duration(%)*	
Period	*Dam*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*
1	Starved Rock	6,285	2,357	79.5	99.9+	10,490	5,009	30.5	95.0	17,830	6,295	8.0	79.5
	Peoria	9,594	3,087	64.0	99.9+	14,617	5,394	18.5	99.8	21,925	9,257	3.0	69.5
	LaGrange	8.057	7,253			16,773	8,194			26,917	10,531		
2	Starved Rock	6,295	3,145	80.0	99.8		5,386	52.5	92.5	9,438	12,578	34.0	26.5
	Peoria	8,987	3,980	75.0	99.9+	9,821	6,867	57.5	98.5	11,972	9,944	32.0	55.0
	LaGrange	8,295	2,801			10,218	5,395			17,653	8,538		
3	Starved Rock	12,423	3,146	27.5	99.8	21,840	5,406	52.0	90.0	43,215	6,319	0.1	81.0
	Peoria	9,211	6,364	70.0	98.5	20.834	7,546	4.0	95.5	25,211	9,158	1.0	72.5
	LaGrange	10,309	7,187			21,695	7,909			25,211	8,561		
4	Starved Rock	4,732	4,736	96.5	96.5	7,736	6,146	51.0	80.0	18,670	9,408	9.5	33.5
	Peoria	7,576	6,052	95.5	98.7	11,598	7,673	35.0	95.0	15,543	10.946	15.5	42.0
	LaGrange	8,714	6,799			11,678	8,251			15,242	10,651		

Table 4. Completed Sampling Schedules

Pool	*Sampling period*	*Period description*	*Number trips*	*Inclusive sampling dates*	
				1987	*1988*
Peoria	1	Commercial navigation	14	6/02-7/10	6/02-7/11
	2	Shutdown - low flow	12	7/14-8/13	7/13-8/12
	3	Shutdown - high flow	7	8/17-9/03	8/16-9/01
	4	Commercial navigation	10	9/08-10/05	9/06-10/04
LaGrange	1	Commercial navigation	14	6/01-7/09	6/01-7/08
	2	Shutdown - low flow	13	7/13-8/14	7/12-8/15
	3	Shutdown - high flow	7	8/18-9/04	8/17-9/02
	4	Commercial navigation	10	9/09-10/06	9/07-10/03

Table 5. Summary of Observed Barge Traffic

Period	*Barges*	*Peoria pool*		*LaGranse pool*	
		1987	*1988*	*1987*	*1988*
1	Total number	106	82	121	78
	Avg/day	7.6	5.9	8.6	5.6
2	Total number	9	68	0	79
	Avg/day	0.8	5.7	0	6.1
3	Total number	9	35	5	41
	Avg/day	1.3	5.0	0.7	3.2
4	Total number	53	46	43	64
	Avg/day	5.3	4.6	4.3	6.4

Table 6. Summary of Barge Movement Characteristics

		Average no. barges per tow		*Tow direction*				*Number of tows pushing barges which were*					
				Up		*Down*		*Full*		*Empty*		*Full/empty*	
Pool	*Period*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*
Peoria	1	8.4	6.8	62	50	44	32	62	42	27	28	17	12
	2	4.7	7.4	4	38	5	30	4	37	3	19	2	12
	3	2.9	7.5	8	14	1	21	3	15	6	10	0	10
	4	6.1	6.4	30	30	23	16	31	27	17	10	5	9
LaGrange	1	12.1	9.4	66	49	55	28	76	38	30	18	15	21
	2	0.0	7.9	0	55	0	24	0	43	0	18	0	18
	3	6.8	8.6	2	25	3	16	2	27	1	8	1	6
	4	6.1	8.8	29	37	14	27	22	34	16	18	5	12

Table 7. Field-Measured Water Quality Results, Analysis of Variance (ANOVA) Statistical Tests, Peoria Pool

	Mean for periods				*Standard deviation (s) for periods*				*F-value*		***Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$***	
Parameter	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	***Acc***	***Rej***
						7a. 1987 Results						
pH	8.09	8.10	7.62	8.11	0.359	0.289	0.272	0.185	51.88	3.15		X
Secchi disk	8.76	11.17	8.86	11.28	3.220	3.615	4.786	3.919	14.72	3.15		X
Temp.-0'	26.33	28.65	23.53	20.65	1.818	1.592	3.050	3.064	659.76	3.13		X
-3'	26.26	28.39	23.44	20.56	1.762	1.510	3.060	3.037	657.30	3.13		X
-mid	26.20	28.24	23.40	20.52	1.744	1.516	3.052	3.034	644.42	3.13		X
-btm	26.21	28.16	23.35	20.50	1.743	1.543	3.030	3.023	639.49	3.13		X
DO -0'	6.81	7.57	6.65	8.35	1.148	1.444	1.316	1.280	101.21	3.13		X
-3'	6.65	6.91	6.57	8.19	1.085	1.324	1.286	1.228	106.99	3.13		X
-mid	6.59	6.51	6.51	8.14	1.053	1.294	1.283	1.208	127.07	3.13		X
-btm	6.59	6.48	6.50	8.13	1.050	1.297	1.294	1.200	128.29	3.13		X
						7b. 1988 Results						
pH	8.46	8.25	8.23	8.35	0.234	0.306	0.260	0.413	13.98	3.15		X
Secchi disk	13.07	13.74	13.39	11.86	3.085	4324	5.847	6.173	3.03	3.15	X	
Temp.-0'	24.60	28.82	26.75	21.60	1.651	1.275	3.349	1.605	760.82	3.13		X
-3'	24.25	28.55	26.60	21.40	1.514	1.125	3.257	1.493	853.13	3.13		X
-mid	23.96	28.35	26.45	21.25	1.398	1.079	3.206	1.482	906.18	3.13		X
-btm	23.895	28.28	26.39	21.17	1.407	1.091	3.195	1.528	902.06	3.13		X
DO -0'	9.21	7.08	7.85	9.00	2.892	2.144	1.497	1.403	69.09	3.13		X
-3'	8.32	6.25	7.34	8.55	2.488	1.617	1.298	1.291	106.13	3.13		X
-mid	7.43	5.68	6.89	8.30	2.263	1.411	1.192	1.240	133.90	3.13		X
-btm	7.14	5.50	6.73	8.22	2.170	1.394	1.186	1.236	146.49	3.13		X

Note: DO is expressed in mg/L, temperature in degrees Celsius, and pH in pH units. Number of samples for pH and Secchi disk for periods 1, 2, 3, and 4, respectively, were 140, 120, 70, and 100; for all other parameters samples numbered 392, 336, 196, and 280, for periods 1, 2, 3, and 4, respectively.

Table 8. Laboratory-Measured Water Quality Results, Analysis of Variance (ANOVA) Statistical Tests, Peoria Pool

8a. 1987 Results

	Mean ($\bar{x}$) for periods				*Standard deviation (s) for periods*				*F-value*		**Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$**	
Parameter	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	***Acc***	***Rej***
Turbidity	66.50	40.40	86.63	51.46	23.541	8.393	32.018	19.377	34.15	3.19		X
Susp. solids	71.67	40.30	94.30	53.28	27.820	15.007	46.765	20.517	28.30	3.19		X
pH	8.18	8.35	7.98	8.27	0.120	0.166	0.159	0.092	50.11	3.19		X
Alkalinity	185.55	168.32	155.53	196.84	11.164	5.804	20.326	8.691	102.22	3.19		X
Hardness	261.43	230.18	207.70	259.48	16.974	9.913	27.215	12.087	97.44	3.19		X
Ortho-P	0.15	0.19	0.19	0.23	0.047	0.043	0.025	0.009	15.67	3.19		X
NH_3-N	0.18	0.09	0.12	0.08	0.203	0.084	0.084	0.005	6.13	3.19		X
NO3-N	4.19	2.16	2.51	2.83	1.083	0.638	0.416	0.387	78.14	3.19		X
NO2-N	0.30	0.20	0.18	0.15	0.080	0.072	0.073	0.050	46.19	3.19		X

8b. 1988 Results

	Mean ($\bar{x}$) for periods				*Standard deviation (s) for periods*				*F-value*		**Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$**	
Parameter	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	***Acc***	***Rej***
Turbidity	38.95	38.60	41.63	47.86	11.926	13.933	17.103	24.768	3.11	3.19	X	
Susp. solids	39.47	38.58	37.00	46.14	10.719	16.431	16.787	26.182	2.21	3.19	X	
PH	8.67	8.42	8.29	8.39	0.250	0.221	0.151	0.221	25.14	3.19		X
Alkalinity	174.97	149.52	137.80	140.02	12.216	13.515	6.042	5.000	138.94	3.19		X
Hardness	275.17	231.82	214.83	216.34	28.122	20.840	6.949	7.652	106.67	3.19		X
Ortho-P	0.16	0.22	0.24	0.24	0.071	0.648	0.062	0.075	17.12	3.19		X
NH3-N	0.05	0.12	0.08	0.07	0.052	0.114	0.066	0.062	13.70	3.19		X
NO3-N	2.18	1.96	2.37	2.69	0.580	0.707	0.448	0.556	13.70	3.19		X
NO2-N	0.11	0.10	0.10	0.06	0.037	0.024	0.022	0.021	25.26	3.19		X

Note: Turbidity is expressed in NTUs, pH in pH units, and all others in mg/L. Number of samples for all parameters for periods 1, 2, 3, and 4, respectively, were 60, 50, 30, and 50.

Table 9. Field-Measured Water Quality Results, Analysis of Variance (ANOVA) Statistical Tests, LaGrange Pool

Parameter	*Mean* ($\bar{x}$) *for periods*				*Standard deviation (s) for periods*				*F-value*		**Hypothesis:** $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$	
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	**Acc**	**Rej**
9a. 1987 Results												
pH	8.13	7.98	7.62	8.04	0.218	0.277	0.188	0.185	80.86	3.15		X
Secchidisk	7.40	9.60	7.83	9.18	2.504	2.420	2.787	2.536	20.99	3.15		X
Temp.-0'	26.56	29.04	23.93	20.75	1.989	1.610	2.773	3.371	698.47	3.13		X
-3'	26.51	28.86	23.91	20.69	1.907	1.575	2.769	3.343	701.74	3.13		X
-mid	26.48	28.82	23.90	20.68	1.908	1.571	2.771	3.336	698.26	3.13		X
-btm	26.51	28.79	23.89	20.66	1.866	1.569	2.762	3.336	706.87	3.13		X
DO -0'	6.16	5.53	5.53	7.20	1.055	1.576	1.097	1.143	114.29	3.13		X
-3'	6.01	5.18	5.51	7.13	0.989	1.539	1.101	1.169	14730	3.13		X
-mid	6.00	5.09	5.55	7.11	0.966	1.540	1.079	1.182	155.86	3.13		X
-btm	6.01	5.15	5.56	7.11	0.961	1.549	1.096	1.194	145.89	3.13		X
9b. 1988 Results												
pH	8.19	8.02	7.98	8.02	0.239	0.281	0.251	0.206	16.56	3.15		X
Secchi disk	11.12	11.63	10.46	7.75	2.120	2.231	2.454	2.091	66.80	3.15		X
Temp.-0'	25.05	29.32	27.04	22.29	1.709	1.313	3.399	1.075	821.26	3.13		X
-3'	24.46	29.06	26.83	22.16	1.594	1.202	3.349	1.046	882.09	3.13		X
-mid	24.51	29.01	26.75	22.12	1.563	1.170	3.345	1.048	896.93	3.13		X
-btm	24.47	28.97	26.72	22.10	1.563	1.184	3.346	1.052	891.93	3.13		X
DO -0'	7.09	5.23	5.71	6.55	2.226	1.454	1.364	1.103	91.64	3.13		X
-3'	6.28	4.60	5.21	6.31	1.823	1.147	1.395	1.100	121.68	3.13		X
-mid	5.94	4.42	5.05	6.25	1.510	1.069	1.397	1.108	144.60	3.13		X
-btm	5.88	4.38	5.01	6.23	1.493	1.067	1.393	1.109	145.30	3.13		X

Note: DO is expressed in mg/L, temperature in degrees Celsius, and pH in pH units. Number of samples for pH and Secchi disk for periods 1, 2, 3, and 4, respectively, were 140, 130, 70, and 100; for all other parameters 406, 377, 203, and 290, respectively, for periods 1, 2, 3, and 4.

Table 10. Laboratory-Measured Water Qualify Results, Analysis of Variance (ANOVA) Tests, LaGrange Pool

	Mean ($\bar{x}$) for periods				*Standard deviation (s) for periods*				*F-value*		**Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$**	
Parameter	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Cole*	*Theo*	***Acc***	***Rej***
					10a. 1987 Results							
Turbidity	88.47	54.82	145.27	75.98	26.975	11.535	76.381	22.174	40.68	3.19		X
Susp. solids	105.87	61.00	176.23	89.36	41.432	24.410	105.762	34.547	31.16	3.19		X
pH	8.18	8.26	8.03	8.26	0.084	0.103	0.058	0.094	54.35	3.19		X
Alkalinity	188.00	177.00	149.97	200.64	8.082	5.226	12.175	6.868	270.70	3.19		X
Hardness	264.98	239.70	199.17	26238	11.398	11.592	14.858	8.298	264.57	3.19		X
Ortho-P	0.12	0.17	0.16	0.17	0.012	0.029	0.014	0.026	60.12	3.19		X
NH_3-N	0.05	0.18	0.07	0.06	0.028	0.074	0.035	0.041	84.69	3.19		X
NO3-N	4.07	1.85	2.33	2.65	1.071	0.605	0.363	0.362	96.17	3.19		X
NO2-N	0.24	0.14	0.14	0.96	0.073	0.045	0.025	0.034	78.07	3.19		X
					10b. 1988 Results							
Turbidity	49.45	45.36	54.17	66.90	11.308	11.570	14.098	15.237	26.38	3.19		X
Susp. solids	49.73	50.32	52.97	65.92	14.433	26.068	23.397	23.397	6.18	3.19		X
pH	8.40	8.21	8.16	8.27	0.190	0.165	0.149	0.152	16.89	3.19		X
Alkalinity	182.13	171.20	146.03	148.68	8.154	12.944	4.445	3.502	203.29	3.19		X
Hardness	275.28	257.02	220.30	228.78	15.384	28.255	5.523	16.828	93.81	3.19		X
Ortho-P	0.13	0.21	0.21	0.18	0.052	0.067	0.035	0.020	35.87	3.19		X
NH3-N	0.17	0.24	0.23	0.14	0.115	0.145	0.114	0.082	8.74	3.19		X
NO3-N	1.62	1.28	1.82	2.25	0.393	0.255	0.302	0.467	59.54	3.19		X
NO2-N	0.08	0.13	0.20	0.09	0.025	0.044	0.108	0.635	35.44	3.19		X

Note: Turbidity is expressed in NTUs, pH in pH units, and all others in mg/L. Number of samples for all parameters for periods 1, 2 ,3 and 4, respectively, were 60, 50, 30, and 50.

Table 11. Water Qualify *t* test Results, Peoria Pool, 1987

Parameter	Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_1=\bar{x}_2$		Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_1=\bar{x}_3$	
	1	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods land 2						**b. Periods land 3**					
Turbidity	66.50	40.40	8.00	1.98		X	66.50	86.63	3.06	1.99		X
Susp. solids	71.67	40.30	7.52	1.98		X	71.67	94.30	2.44	1.99		X
pH(lab)	8.18	8.34	5.86	1.98		X	8.18	7.98	6.06	1.99		X
Alkalinity	185.55	168.32	10.39	1.98		X	185.55	155.53	7.54	1.99		X
Hardness	261.43	230.18	12.01	1.98		X	261.43	207.70	9.90	1.99		X
Ortho-P	0.15	0.19	3.94	1.99		X	0.15	0.19	4.33	1.99		X
NH_3-N	0.18	0.09	2.92	1.98		X	0.18	0.12	1.78	1.99	X	
NO_2-N	0.30	0.20	6.78	1.98		X	0.30	0.18	7.20	1.99		X
NO_3-N	4.19	2.16	12.20	1.98		X	4.19	2.51	10.57	1.99		X
pH (field)	8.09	8.10	0.41	1.97	X		8.09	7.62	10.39	1.97		X
Secchi disk	8.76	11.17	5.62	1.97		X	8.76	8.86	0.15	1.97	X	
Temp: 0'	26.32	28.65	18.37	1.96		X	26.32	23.53	11.84	1.96		X
3'	26.26	28.39	1734	1.96		X	26.26	23.44	11.94	1.96		X
Mid	26.21	28.24	16.87	1.96		X	26.21	23.40	11.94	1.96		X
Btm	26.21	28.16	16.04	1.96		X	26.21	23.35	12.21	1.96		X
DO: 0'	6.81	7.57	7.82	1.96		X	6.81	6.65	1.40	1.96	X	
3'	6.65	6.91	2.82	1.96	X		6.65	6.57	0.79	1.96	X	
Mid	6.59	6.51	0.88	1.96	X		6.59	6.51	0.73	1.96	X	
Btm	6.59	6.48	1.29	1.96	X		6.59	6.50	0.92	1.96	X	
	c Periods land 4						**d. Periods 2 and 3**					
	1	*4*			$\bar{x}_1=\bar{x}_4$		*2*	*3*			$\bar{x}_2=\bar{x}_3$	
Turbidity	66.50	51.46	3.68	1.98		X	40.40	86.63	7.75	1.99		X
Susp. solids	71.67	53.28	3.98	1.98		X	40.30	94.30	6.14	1.99		X
pH(lab)	8.18	8.27	4.36	1.98		X	8.34	7.98	9.74	1.99		X
Alkalinity	185.55	196.84	5.96	1.98		X	168.32	155.53	3.36	1.99		X
Hardness	261.43	259.48	0.70	1.98	X		230.18	207.70	4.35	1.99		X
Ortho-P	0.15	0.23	5.42	1.98		X	0.19	0.19	0.11	1.99	X	
NH_3-N	0.18	0.08	3.53	1.98		X	0.09	0.12	1.56	1.99	X	
NO_2-N	0.30	0.15	11.78	1.98		X	0.20	0.18	1.37	1.99	X	
NO3-N	4.19	2.87	8.78	1.98		X	2.16	2.51	136	1.99	X	
pH (field)	8.09	8.11	0.77	1.97	X		8.10	7.62	11.43	1.97		X
Secchi disk	8.76	11.28	5.27	1.97		X	11.17	8.86	3.50	1.97		X
Temp: 0'	26.32	20.65	27.72	1.96		X	28.65	23.53	21.84	1.96		X
3'	26.26	20.56	28.23	1.96		X	28.39	23.44	21.16	1.96		X
Mid	26.21	20.52	28.19	1.96		X	28.24	23.40	20.78	1.96		X
Btm	26.21	20.50	28.36	1.96		X	28.16	23.35	20.71	1.96		X
DO: 0'	6.81	8.35	16.09	1.96		X	7.57	6.65	7.50	1.96		X
3'	6.65	8.19	16.82	1.96		X	6.91	6.57	2.91	1.96		X
Mid	6.59	8.14	17.28	1.96		X	6.51	6.51	0.01	1.96	X	
Btm	6.59	8.13	17.24	1.96		X	6.48	6.50	0.14	1.96	X	

Note: For parameter units and number of samples, see notes in tables 7 and 8.

Table 11. Water Quality *t* test Results, Peoria Pool, 1987 (Continued)

Parameter	Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_2=\bar{x}_4$		Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_3=\bar{x}_4$	
	2	*4*	*Calc*	*Theo*	*Acc*	*Rej*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	40.40	51.46	3.70	1.98		X	86.63	51.46	5.45	1.99		X
Susp. solids	40.30	53.28	3.61	1.98		X	94.30	53.28	4.55	1.99		X
pH (lab)	8.34	8.27	2.86	1.98		X	7.98	8.27	9.03	1.99		X
Alkalinity	168.32	196.84	19.30	1.98		X	155.53	196.84	10.57	1.99		X
Hardness	230.18	259.48	13.25	1.98		X	207.70	259.48	9.85	1.99		X
Ortho-P	0.19	0.23	3.06	1.98		X	0.19	0.23	3.25	1.99		X
NH_3-N	0.09	0.08	0.85	1.98	X		0.12	0.08	2.47	1.99		X
NOVN	0.20	0.15	3.95	1.98		X	0.18	0.15	1.72	1.99	X	
NO_3-N	2.16	2.87	0.85	1.98		X	2.51	2.87	2.48	1.99		X
pH (field)	8.10	8.11	0.35	1.97	X		7.62	8.11	13.09	1.97		X
Secchi disk	11.17	11.28	0.22	1.97	X		8.86	11.28	3.49	1.97		X
Temp: 0'	28.65	20.65	39.48	1.96		X	23.53	20.65	10.12	1.97		X
3'	28.39	20.56	39.29	1.96		X	23.44	20.56	10.16	1.97		X
Mid	28.24	20.52	38.77	1.96		X	23.40	20.52	10.14	1.97		X
Btm	28.16	20.50	38.43	1.96		X	23.35	20.50	10.11	1.97		X
DO: 0'	7.57	8.35	7.10	1.96		X	6.65	8.35	14.02	1.97		X
3'	6.91	8.19	12.47	1.96		X	6.57	8.19	13.81	1.97		X
Mid	6.51	8.14	16.12	1.96		X	6.51	8.14	13.94	1.97		X
Btm	6.48	8.13	16.39	1.96		X	6.50	8.13	13.98	1.97		X

Note: For parameter units and number of samples, see notes in tables 7 and 8.

Table 12. Water Quality *t* test Results, Peoria Pool, 1988

	Mean ($\bar{x}$) for periods		*t-value*		*Hypothesis: $\bar{x}_1=\bar{x}_2$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_1=\bar{x}_3$*	
Parameter	*1*	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods 1 and 2						b. Periods 1 and 3					
Turbidity	38.95	38.60	0.14	1.98	X		38.95	41.63	0.77	1.99	X	
Susp. solids	39.47	38.58	0.33	1.98	X		29.47	37.00	0.73	1.99	X	
pH(lab)	8.67	8.42	5.39	1.98		X	8.67	8.29	8.85	1.99		X
Alkalinity	174.97	149.52	10.27	1.98		X	174.97	137.80	19.31	1.99		X
Hardness	275.17	231.82	9.27	1.98		X	275.17	214.83	15.69	1.99		X
Ortho-P	0.16	0.22	3.76	1.98		X	0.16	0.24	5.36	1.99		X
NH3-N	0.05	0.12	3.76	1.98		X	0.05	0.08	1.96	1.99	X	
NO2-N	0.11	0.10	1.46	1.98	X		0.11	0.10	0.59	1.99	X	
NO3-N	2.18	1.96	1.74	1.98	X		2.18	2.37	1.69	1.99	X	
pH (field)	8.46	8.25	6.16	1.97		X	8.46	8.23	6.46	1.97		X
Secchi disk	13.07	13.74	1.42	1.97	X		13.07	13.38	0.42	1.97	X	
Temp: 0'	24.60	8.82	38.88	1.96		X	24.60	26.75	8.50	1.96		X
3'	24.25	28.55	43.80	1.96		X	24.25	26.60	9.60	1.96		X
Mid	23.96	28.35	47.78	1.96		X	23.96	26.44	10.39	1.96		X
Btm	23.85	28.28	47.78	1.96		X	23.85	26.39	10.62	1.96		X
DO: 0'	9.21	7.08	11.40	1.96		X	9.21	7.85	7.50	1.96		X
3'	832	6.24	13.51	1.96		X	8.32	7.34	6.27	1.96		X
Mid	7.43	5.68	12.67	1.96		X	7.43	6.89	3.78	1.96		X
Btm	7.14	5.50	12.24	1.96			7.14	6.73	2.91	1.96		X
	c Periods l and 4						**d. Periods 2 and 3**					
	1	*4*			$\bar{x}_1=\bar{x}_4$		*2*	*3*			$\bar{x}_2=\bar{x}_3$	
Turbidity	38.95	47.86	2.33	1.98		X	38.60	41.63	0.82	1.99	X	
Susp. solids	39.47	46.14	1.69	1.98	X		38.58	37.00	0.41	1.99	X	
pH (lab)	8.67	839	6.15	1.98		X	8.42	8.29	3.20	1.99		X
Alkalinity	174.97	140.02	20.22	1.98		X	149.52	137.80	5.31	1.99		X
Hardness	275.17	216.34	15.53	1.98		X	231.82	214.83	5.29	1.99		X
Ortho-P	0.16	0.24	5.58	1.98		X	0.22	0.24	1.27	1.99	X	
NH3-N	0.05	0.06	1.08	1.98	X		0.12	0.08	1.94	1.99	X	
NO_2-N	0.11	0.06	7.69	1.98		X	0.10	0.10	0.91	1.99	X	
NO3-N	2.18	2.69	4.74	1.98		X	1.96	2.37	3.13	1.99		X
pH (field)	8.46	8.34	2.60	1.97			8.25	8.23	0.66	1.97	X	
Secchi disk	13.07	11.86	1.81	1.97	X		13.74	13.38	0.44	1.97	X	
Temp: 0'	24.60	21.60	23.61	1.96		X	28.82	26.75	8.31	1.96		X
3'	24.25	21.40	24.31	1.96		X	28.55	26.60	8.08	1.96		X
Mid	23.96	21.25	23.90	1.96		X	28.35	26.44	8.05	1.96		X
Btm	23.85	21.17	23.20	1.96		X	28.28	26.39	8.02	1.96		X
DO: 0'	9.21	9.00	1.25	1.96	X		7.08	7.85	4.90	1.96		X
3'	8.32	8.55	1.58	1.96	X		6.24	7.34	8.55	1.96		X
Mid	7.43	8.30	6.42	1.96		X	5.68	6.89	10.52	1.96		X
Btm	7.14	8.22	8.02	1.96		X	5.50	6.73	10.80	1.96		X

Note: For parameter units and number of samples, see notes in tables 7 and 8.

Table 12. Water Quality *t* test Results, Peoria Pool, 1988 (Continued)

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_2=\bar{x}_4$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_3=\bar{x}_4$*	
	2	*4*	*Calc*	*Theo*	*Acc*	*Rej*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	38.60	47.86	2.30	1.98		X	41.63	47.86	1.33	1.99	X	
Susp. solids	38.58	46.14	1.73	1.98	X		37.00	46.14	1.90	1.99	X	
pH (lab)	8.42	8.39	0.77	1.98	X		8.29	839	238	1.99		X
Alkalinity	149.52	140.02	4.66	1.98		X	137.80	140.02	1.69	1.99	X	
Hardness	231.82	216.34	4.93	1.98		X	214.83	216.34	0.90	1.99	X	
Ortho-P	0.22	0.24	1.32	1.98	X		0.24	0.24	0.01	1.99	X	
NH3-N	0.12	0.06	2.94	1.98		X	0.08	0.06	1.00	1.99	X	
NO2-N	0.10	0.06	7.69	1.98		X	0.10	0.06	7.79	1.99		X
NO3-N	1.96	2.69	18.99	1.98		X	2.37	2.69	28.12	1.99		X
pH (field)	8.25	8.34	1.83	1.97	X		8.23	8.34	2.30	1.97		X
Secchi disk	13.74	11.86	2.57	1.97		X	13.38	11.86	1.64	1.97	X	
Temp: 0'	28.82	21.60	60.96	1.96		X	26.75	21.60	20.00	1.97		X
3'	28.55	21.40	66.03	1.96		X	26.60	21.40	20.90	1.97		X
Mid	28.35	21.25	66.77	1.96		X	26.44	21.25	21.17	1.97		X
Btm	28.28	21.17	66.25	1.96		X	26.39	21.17	21.24	1.97		X
DO: 0'	7.08	9.00	19.69	1.96		X	7.85	9.00	10.06	1.97		X
3'	6.24	8.55	19.69	1.96		X	7.34	8.55	10.06	1.97		X
Mid	5.68	8.30	24.54	1.96		X	6.89	8.30	12.53	1.97		X
Btm	5.50	8.22	26.63	1.96		X	6.73	8.22	13.22	1.97		X

Note: For parameter units and number of samples, see notes in tables 7 and 8.

Table 13. Water Quality *t* test Comparison Results, Peoria Pool, 1987 and 1988

	Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$		Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$	
Parameter	**1987**	**1988**	**Calc**	**Theo**	**Acc**	**Rej**	**1987**	**1988**	**Calc**	**Theo**	**Acc**	**Rej**
			a. Period 1						**b. Period 2**			
Turbidity	66.50	38.95	8.09	1.98		X	40.40	38.60	0.78	1.99	X	
Susp. solids	71.67	39.47	837	1.98		X	40.30	38.58	0.55	1.99	X	
pH(lab)	8.18	8.67	13.57	1.98		X	8.34	8.42	2.00	1.99		X
Alkalinity	185.55	174.97	4.95	1.98		X	168.32	149.52	9.04	1.99		X
Hardness	261.43	275.17	3.24	1.98		X	230.18	231.82	0.50	1.99	X	
Ortho-P	0.15	0.16	0.77	1.98	X		0.19	0.22	3.96	1.99		X
NH_3-N	0.18	0.05	4.50	1.98		X	0.09	0.12	1.41	1.99	X	
NO_2-N	0.30	0.11	17.06	1.98		X	0.20	0.10	9.67	1.99		X
NO_3-N	4.19	2.18	12.68	1.98		X	2.16	1.96	1.47	1.99	X	
pH (field)	8.09	8.46	10.48	1.99		X	8.10	8.25	3.99	1.99		X
Secchi disk	8.76	13.07	11.23	1.99		X	11.17	13.74	5.01	1.99		X
Temp: 0'	26.32	24.60	13.93	1.98		X	28.65	28.82	1.55	1.98	X	
3'	26.26	24.25	17.11	1.98		X	28.39	28.55	1.57	1.98	X	
Mid	26.21	23.96	19.92	1.98		X	28.24	28.35	1.05	1.98	X	
Btm	26.21	23.85	20.90	1.98		X	28.16	28.28	1.13	1.98	X	
DO: 0'	6.81	9.21	15.41	1.98		X	7.57	7.08	3.49	1.98		X
3'	6.65	8.32	12.16	1.98		X	6.91	6.24	5.08	1.98		X
Mid	6.59	7.42	6.64	1.98		X	6.51	5.68	7.95	1.98		X
Btm	6.59	7.14	4.45	1.98			6.48	5.50	9.40	1.98		X
			c Period 3						**d. Period 4**			
Turbidity	86.63	41.63	6.79	2.00		X	51.46	47.86	0.81	1.99	X	
Susp. solids	94.30	37.00	6.32	2.00		X	53.28	46.14	1.52	1.99	X	
pH (lab)	7.98	8.29	7.72	2.00		X	8.27	8.39	3.58	1.99		X
Alkalinity	155.53	137.80	4.58	2.00		X	196.84	140.02	40.07	1.99		X
Hardness	207.70	214.83	1.39	2.00	X		259.48	216.34	21.32	1.99		X
Ortho-P	0.19	0.24	4.38	2.00		X	0.23	0.24	0.39	1.99	X	
NH3-N	0.12	0.08	2.12	100		X	0.08	0.06	1.41	1.99	X	
NCH-N	0.18	0.10	5.47	2.00		X	0.15	0.06	11.78	1.99		X
NO3-N	2.51	2.37	1.29	2.00	X		2.87	2.69	1.87	1.99	X	
pH(field)	7.62	8.23	13.41	2.00		X	8.11	8.37	5.15	1.99		X
Secchi disk	8.86	13.38	5.02	2.00		X	11.28	11.86	0.80	1.99	X	
Temp: 0'	23.53	26.75	9.97	1.99		X	20.65	21.60	4.60	1.98		X
3'	23.44	26.60	9.91	1.99		X	20.56	21.40	4.16	1.98		X
Mid	23.40	26.44	9.64	1.99		X	20.52	21.25	3.61	1.98		X
Btm	23.35	26.39	9.65	1.99		X	20.50	21.17	3.28	1.98		X
DO: 0'	6.65	7.85	8.45	1.99		X	8.35	9.00	5.74	1.98		X
3'	6.57	7.34	5.92	1.99		X	8.19	8.55	3.40	1.98		X
Mid	6.51	6.89	3.00	1.99		X	8.14	8.30	1.57	1.98	X	
Btm	6.50	6.73	1.89	1.99	X		8.13	8.22	0.86	1.98	X	

Note: For parameter units and number of samples, see notes in tables 7 and 8.

Table 14. Water Quality *t* test Results, LaGrange Pool, 1987

Parameter	Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_1=\bar{x}_2$		Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_1=\bar{x}_3$	
	1	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Turbidity	88.47	54.82	8.75	1.98		X	88.47	145.27	3.95	1.98		X
Susp. solids	105.87	61.00	7.05	1.98		X	105.87	176.23	3.51	1.99		X
pH(lab)	8.18	8.26	4.54	1.98		X	8.18	8.03	10.10	1.99		X
Alkalinity	188.00	177.00	8.60	1.98		X	188.00	149.97	15.49	1.99		X
Hardness	264.98	239.70	11.48	1.98		X	264.98	199.17	21.33	1.99		X
Ortho-P	0.12	0.17	10.47	1.98		X	0.12	0.16	13.42	1.99		X
NH_3-N	0.05	0.18	11.71	1.98		X	0.05	0.07	1.36	1.99	X	
NC_2-N	0.24	0.14	8.66	1.98		X	0.24	0.14	9.03	1.99		X
NO_3-N	4.07	1.85	13.62	1.98		X	4.07	2.33	11.32	1.99		X
pH (field)	8.13	7.98	4.82	1.97		X	8.13	7.62	17.44	1.97		X
Secchi disk	7.40	9.60	7.34	1.97		X	7.40	7.83	1.09	1.97		X
Temp: 0'	26.56	29.04	19.05	1.96		X	26.56	23.93	19.20	1.96		X
3'	26.51	28.86	18.84	1.96		X	26.51	23.91	12.01	1.96		X
Mid	26.48	28.82	18.84	1.96		X	26.48	23.91	11.88	1.96		X
Btm	26.51	28.79	18.52	1.96		X	26.51	23.89	12.20	1.96		X
DO: 0'	6.16	5.53	6.53	1.96		X	6.16	5.53	6.77	1.96		X
3'	6.01	5.18	8.86	1.96		X	6.01	5.51	5.42	1.96		X
Mid	6.00	5.09	9.73	1.96		X	6.00	5.55	4.96	1.96		X
Btm	6.01	5.15	9.23	1.96		X	6.01	5.56	4.97	1.96		X
	c Periods land 4						**d. Periods 2 and 3**					
	1	*4*			$\bar{x}_1=\bar{x}_4$		*2*	*3*			$\bar{x}_2=\bar{x}_3$	
Turbidity	88.47	75.98	2.66	1.98		X	54.82	145.27	6.42	1.99		X
Susp. solids	105.87	89.36	2.28	1.98		X	61.00	176.23	5.88	1.99		X
pH (lab)	8.18	8.26	4.77	1.98		X	8.26	8.03	12.81	1.99		X
Alkalinity	188.00	200.64	8.87	1.98		X	177.00	149.97	11.54	1.99		X
Hardness	264.98	262.38	1.38	1.98	X		239.70	199.17	12.79	1.99		X
Ortho-P	0.12	0.17	12.03	1.98		X	0.17	0.16	0.95	1.99	X	
NH3-N	0.05	0.06	0.04	1.98	X		0.18	0.07	9.77	1.99		X
NCb-N	0.24	0.10	13.67	1.98		X	0.14	0.14	0.52	1.99	X	
NO3-N	4.07	2.65	9.61	1.98		X	1.85	2.33	4.42	1.99		X
pH (field)	8.13	8.04	3.32	1.97		X	7.98	7.62	10.86	1.97		X
Secchi disk	7.40	9.18	5.39	1.97		X	9.60	7.83	4.49	1.97		X
Temp: 0'	26.56	20.75	12.07	1.96		X	29.04	23.93	26.27	1.96		X
3'	26.51	20.69	26.71	1.96		X	28.86	23.91	23.49	1.96		X
Mid	26.48	20.68	26.65	1.96		X	28.82	23.91	23.49	1.96		X
Btm	26.51	20.66	27.04	1.96		X	28.79	23.89	23.32	1.96		X
DO: 0'	6.16	7.20	72.22	1.96		X	5.53	5.53	4.44	1.96		X
3'	6.01	7.13	13.35	1.96		X	5.18	5.51	2.98	1.96		X
Mid	6.00	7.11	13.27	1.96		X	5.09	5.55	4.17	1.96		X
Btm	6.01	7.11	13.01	1.96		X	5.15	5.56	3.68	1.96		X

Note: For parameter units and number of samples, see notes in tables 9 and 10.

Table 14. Water Quality *t* test Results, LaGrange Pool, 1987 (Continued)

	Mean ($\bar{x}$) for periods		*t-value*		*Hypothesis: $\bar{x}_2=\bar{x}_4$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_3=\bar{x}_4$*	
Parameter	***2***	***4***	***Calc***	***Theo***	***Acc***	***Rej***	***3***	***4***	***Calc***	***Theo***	***Acc***	***Rej***
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	54.82	75.98	5.99	1.98		X	145.27	75.98	4.85	1.99		X
Susp. solids	61.00	89 *36*	4.74	1.98		X	176.23	89.36	4.36	1.99		X
pH(lab)	8.26	8.26	0.04	1.98	X		8.03	8.26	13.94	1.99		X
Alkalinity	177.00	200.64	19.37	1.98		X	149.97	200.64	20.89	1.99		X
Hardness	239.70	262.38	11.25	1.98		X	199.17	262.38	21.39	1.99		X
Ortho-P	0.17	0.17	0.40	1.98	X		0.16	0.17	1.51	1.99	X	
NH_3-N	0.18	0.06	10.64	1.98		X	0.07	0.06	0.87	1.99	X	
NO_2-N	0.14	0.10	5.74	1.98		X	0.14	0.10	7.67	1.99		X
NO_3-N	1.85	2.65	8.01	1.98		X	2.33	2.65	3.81	1.99		X
pH (field)	7.98	8.04	1.97	1.98	X		7.62	8.04	14.42	1.97		X
Secchi disk	9.60	20.75	1.27	1.97	X		7.83	9.18	323	1.97		X
Temp: 0'	29.04	20.75	24.16	1.96		X	23.93	20.75	11.44	1.96		X
3'	28.86	20.69	38.47	1.96		X	23.91	20.69	11.67	1.96		X
Mid	28.82	20.68	38.44	1.96		X	23.91	20.68	11.70	1.96		X
Btm	28.79	20.66	38.89	1.96		X	23.89	20.66	11.74	1.96		X
DO: 0'	5.53	7.20	15.86	1.96		X	5.53	7.20	16.35	1.96		X
3'	5.18	7.13	18.62	1.96		X	5.51	7.13	15.69	1.96		X
Mid	5.09	7.11	19.18	1.96		X	5.55	7.11	15.23	1.96		X
Btm	5.15	7.11	18.47	1.96		X	5.56	7.11	14.92	1.96		X

Note: For parameter units and number of samples, see notes in tables 9 and 10.

Table 15. Water Quality *t* test Results, LaGrange, 1988

Parameter	Mean ($\bar{x}$) for periods		t-value		Hypothesis: $\bar{x}_1=\bar{x}_2$		Mean ($\bar{x}$) for periods		t-value		Hypothesis: $\bar{x}_1=\bar{x}_3$	
	1	2	Calc	Theo	Acc	Rej	1	3	Calc	Theo	Acc	Rej
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Turbidity	53.13	45.36	1.86	1.98	X		53.13	54.17	1.60	1.99	X	
Susp. solids	49.73	50.32	0.13	1.98	X		49.73	52.97	0.69	1.99	X	
pH(lab)	8.40	8.21	5.35	1.98		X	8.40	8.16	6.32	1.99		X
Alkalinity	182.13	171.20	5.18	1.98		X	182.13	146.03	57.16	1.99		X
Hardness	279.28	257.02	4.98	1.98		X	279.28	220.30	26.47	1.99		X
Ortho-P	0.13	0.21	7.32	1.98		X	0.13	0.21	9.24	1.99		X
NH_3-N	0.17	0.24	3.09	1.98		X	0.17	0.23	2.51	1.99		X
NO_2-N	0.08	0.13	6.31	1.98		X	0.08	0.20	5.82	1.99		X
NO_3-N	1.62	1.28	5.54	1.98		X	1.62	1.82	2.68	1.99		X
pH (field)	8.19	8.02	5.30	1.97		X	8.19	7.98	5.72	1.97		X
Secchi disk	11.12	11.63	1.92	1.97	X		11.12	10.46	1.93	1.97	X	
Temp: 0'	25.05	2932	39.36	1.96		X	25.05	27.04	7.86	1.96		X
3'	24.62	29.06	44.27	1.96		X	24.62	26.83	8.92	1.96		X
Mid	24.51	29.00	45.80	1.96		X	24.51	26.75	9.07	1.96		X
Btm	24.46	28.97	45.66	1.96		X	24.46	26.72	9.11	1.96		X
DO: 0'	7.09	5.23	13.96	1.96		X	7.09	5.71	9.44	1.96		X
3'	6.28	4.60	15.57	1.96		X	6.28	5.21	8.03	1.96		X
Mid	5.94	4.42	16.36	1.96		X	5.94	5.05	7.20	1.96		X
Btm	5.88	4.38	16.26	1.96		X	5.88	5.01	7.09	1.96		X
	c. Periods land 4						**d. Periods 2 and 3**					
	1	4			$\bar{x}_1=\bar{x}_4$		2	3			$\bar{x}_2=\bar{x}_3$	
Turbidity	53.13	66.90	6.72	1.98		X	45.36	54.17	2.89	1.99		X
Susp. solids	49.73	65.92	4.25	1.98		X	50.32	52.97	0.47	1.99	X	
pH(lab)	8.40	8.26	3.99	1.98		X	8.21	8.16	1.40	1.99	X	
Alkalinity	182.13	148.68	28.76	1.98		X	171.20	146.03	12.57	1.99		X
Hardness	279.28	228.78	16.28	1.98		X	257.02	220.30	8.91	1.99		X
Ortho-P	0.13	0.18	7.84	1.98		X	0.21	0.21	0.05	1.99	X	
NH_3-N	0.17	0.14	1.39	1.98	X		0.24	0.23	0.48	1.99	X	
NO_9-N	0.08	0.09	1.96	1.98	X		0.13	0.20	3.46	1.99		X
NO_3-N	1.62	2.24	7.51	1.98		X	1.28	1.82	8.28	1.99		X
pH (field)	8.19	8.02	5.65	1.97		X	8.02	7.98	0.98	1.97	X	
Secchi disk	11.12	7.75	12.24	1.97		X	11.63	10.46	333	1.97		X
Temp: 0'	25.05	22.29	26.02	1.96		X	29.32	27.04	9.19	1.96		X
3'	24.62	22.16	24.56	1.96		X	29.06	26.83	9.20	1.96		X
Mid	24.51	22.12	24.10	1.96		X	29.00	26.75	9.31	1.96		X
Btm	24.46	22.10	23.89	1.96		X	28.97	26.72	9.28	1.96		X
DO: 0'	7.09	6.55	4.22	1.96		X	5.23	5.71	3.98	1.96		X
3'	6.28	631	0.23	1.96	X		4.60	5.21	5.34	1.96		X
Mid	5.94	6.25	3.17	1.96		X	4.42	5.05	5.62	1.96		X
Btm	5.88	6.22	3.48	1.96		X	4.38	5.01	5.62	1.96		X

Note: For parameter units and number of samples, see notes in tables 9 and 10.

Table 15. Water Quality *t* test Results, LaGrange, 1988 (Continued)

	Mean ($\bar{x}$) for periods		*t-value*		*Hypothesis: $\bar{x}_2=\bar{x}_4$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_3=\bar{x}_4$*	
Parameter	***2***	***4***	***Calc***	***Theo***	***Acc***	***Rej***	***3***	***4***	***Calc***	***Theo***	***Acc***	***Rej***
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	45.36	66.90	7.96	1.98		X	54.17	66.90	3.79	1.99		X
Susp. solids	50.32	65.92	3.15	1.98		X	52.97	65.92	2.40	1.99		X
pH(lab)	8.21	8.26	1.61	1.98		X	8.16	8.26	2.92	1.99		X
Alkalinity	171.20	148.68	11.88	1.98		X	146.03	148.68	2.78	1.99		X
Hardness	257.02	228.78	6.07	1.98		X	22030	228.78	3.28	1.99		X
Ortho-P	0.21	0.18	2.81	1.98		X	0.21	0.18	4.07	1.99		X
NH_3-N	0.24	0.14	4.42	1.98		X	0.23	0.14	3.78	1.99		X
NO_9-N	0.13	0.09	4.17	1.98		X	0.20	0.09	5.16	1.99		X
NO_3-N	1.28	2.24	12.90	1.98		X	1.82	2.24	4.94	1.99		X
pH (field)	8.02	8.02	0.17	1.97	X		7.98	8.02	1.20	1.97	X	
Secchi disk	11.63	7.75	13.55	1.97		X	10.46	7.75	7.52	1.97		X
Temp: 0'	29.32	22.29	75.91	1.96		X	27.04	22.29	19.22	1.96		X
3'	29.06	22.16	79.22	1.96		X	26.83	22.16	19.23	1.96		X
Mid	29.00	22.12	79.95	1.96		X	26.75	22.12	19.07	1.96		X
Btm	28.97	22.10	79.20	1.96		X	26.72	22.10	19.04	1.96		X
DO: 0'	5.23	6.55	13.37	1.96		X	5.71	6.55	7.27	1.96		X
3'	4.60	6.31	19.51	1.96		X	5.21	6.31	9.35	1.96		X
Mid	4.42	6.25	21.53	1.96		X	5.05	6.25	10.22	1.96		X
Btm	4.38	6.22	21.63	1.96		X	5.01	6.22	10.33	1.96		X

Note: For parameter units and number of samples, see notes in tables 9 and 10.

Table 16. Water Qualify *t* test Comparison Results, LaGrange Pool, 1987 and 1988

Parameter		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$*	
		1987	*1988*	*Calc*	*Theo*	*Acc*	*Rej*	*1987*	*1988*	*Calc*	*Theo*	*Acc*	*Rej*
		a. Period 1						**b. Period 2**					
Turbidity		88.47	53.13	10.33	1.98		X	54.82	45.36	4.09	1.99		X
Susp. solids		105.87	49.73	9.91	1.98		X	61.00	50.32	2.12	1.99		X
pH(lab)		8.18	8.40	8.10	1.98		X	8.26	8.21	1.59	1.99	X	
Alkalinity		188.00	182.13	3.86	1.98		X	177.00	171.20	2.94	1.99		X
Hardness		264.98	275.28	5.77	1.98		X	239.70	257.02	4.01	1.99		X
Ortho-P		0.12	0.13	0.51	1.98	X		0.17	0.21	4.19	1.99		X
NH_3-N		0.05	0.17	7.24	1.98		X	0.18	0.24	2.60	1.99		X
NO_2-N		0.24	0.08	15.62	1.98		X	0.14	0.13	1.46	1.99	X	
NO_3-N		4.07	1.62	16.63	1.98		X	1.85	1.28	6.24	1.99		X
pH (field)		8.13	8.19	2.12	1.99		X	7.98	8.02	1.04	1.99	X	
Secchi disk		7.40	11.12	13.42	1.99		X	9.60	11.63	7.04	1.99		X
Temp:	0'	26.56	25.05	11.65	1.98		X	29.04	29.32	2.61	1.98		X
	3'	26.51	24.46	15.33	1.98		X	28.86	29.06	2.03	1.98		X
	Mid	26.48	24.51	16.09	1.98		X	28.82	29.00	1.81	1.98	X	
	Btm	26.51	24.46	16.96	1.98		X	28.79	28.97	1.78	1.98	X	
DO:	0'	6.16	7.09	7.59	1.98		X	5.53	5.23	2.76	1.98		X
	3'	6.01	6.28	2.66	1.98		X	5.18	4.60	5.89	1.98		X
	Mid	6.00	5.94	0.66	1.98	X		5.09	4.42	7.02	1.98		X
	Btm	6.01	5.88	1.47	1.98	X		5.15	4.38	7.97	1.98		X
		c. Period 3						**d. Period 4**					
Turbidity		145.27	54.17	6.42	2.00		X	75.98	66.90	2.39	1.99		X
Susp. solids		176.23	52.97	6.23	2.00		X	89.36	65.92	3.97	1.99		X
pH(lab)		8.03	8.16	4.70	2.00		X	8.26	8.27	0.32	1.99		X
Alkalinity		149.97	146.03	1.66	2.00	X		200.64	148.68	47.66	1.99		X
Hardness		199.17	220.30	7.30	2.00		X	262.38	228.78	12.66	1.99		X
Ortho-P		0.16	0.21	7.03	2.00		X	0.17	0.18	2.85	1.99		X
NH_3-N		0.07	0.23	7.60	2.00		X	0.06	0.14	6.31	1.99		X
NO_2-N		0.14	0.20	19.33	2.00		X	0.10	0.09	0.27	1.99	X	
NO_3-N		2.33	1.82	5.97	2.00		X	2.65	2.25	4.88	1.99		X
pH (field)		7.62	7.98	9.53	2.00		X	8.04	8.02	0.68	1.99		X
Secchi disk		7.83	10.46	5.92	2.00		X	9.18	7.75	4.35	1.99		X
Temp:	0'	23.93	27.04	10.10	1.99		X	20.75	22.29	7.43	1.98		X
	3'	23.91	26.82	9.57	1.99		X	20.69	22.16	7.15	1.98		X
	Mid	23.91	26.75	9.32	1.99		X	20.68	2112	7.03	1.98		X
	Btm	23.89	26.72	9.28	1.99		X	20.66	22.10	7.01	1.98		X
DO:	0'	5.53	5.71	1.45	1.99	X		7.20	6.55	6.98	1.98		X
	3'	5.51	5.21	2.41	1.99		X	7.13	6.31	8.77	1.98		X
	Mid	5.55	5.05	4.06	1.99		X	7.11	6.25	9.08	1.98		X
	Btm	5.56	5.01	4.42	1.99		X	7.11	6.23	9.30	1.98		X

Note: For parameter units and number of samples, see notes in tables 9 and 10.

Table 17. Field-Measured Water Quality Results, Analysis of Variance (ANOVA) Statistical Tests, Peoria Pool, Mile 179.0

Parameter	*Mean ($\bar{x}$) for periods*				*Standard deviation (s) for periods*				*F-value*		*Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$*	
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
17a. 1987 Results												
pH	7.99	7.98	7.48	8.03	0.189	0.313	0.259	0.122	9.60	3.47		X
Secchi disk	7.50	10.75	7.28	11.20	1.871	1.422	3.500	1.230	11.33	3.47		X
Temp: 0'	26.53	28.83	23.87	20.88	1.746	1.456	3.346	3.021	23.28	3.47		X
3'	24.46	28.65	23.80	20.79	1.720	1.357	3.342	3.046	23.16	3.47		X
Mid	26.43	28.52	23.70	20.75	1.703	1.378	3.259	3.017	23.39	3.47		X
Btm	26.43	28.47	23.64	20.73	1.680	1.367	3.221	3.018	23.62	3.47		X
DO: 0'	5.66	6.29	5.94	7.67	0.778	1.379	1.334	1.090	6.55	3.47		X
3'	5.59	5.91	5.87	7.58	0.792	1.442	1.289	1.066	6.57	3.47		X
Mid	5.51	5.46	5.81	7.52	0.792	1.269	1.245	1.023	8.75	3.47		X
Btm	5.50	5.49	5.80	7.51	0.782	1.138	1.270	1.014	9.35	3.47		X
17b. 1988 Results												
pH	8.36	8.14	8.19	8.26	0.199	0.261	0.160	0.381	1.60	3.47	X	
Secchi disk	11.50	12.00	11.57	10.70	1.225	1.758	1.512	2.983	0.83	3.47	X	
Temp: 0'	24.63	28.87	27.20	21.84	1.526	1.089	3.547	1.423	29.37	3.47		X
3'	24.34	28.73	27.04	21.61	1.351	1.034	3.377	1.326	33.81	3.47		X
Mid	23.96	28.49	26.83	21.43	1.209	1.020	3.225	1.229	38.05	3.47		X
Btm	23.89	28.38	26.74	21.33	1.248	1.075	3.232	1.253	36.76	3.47		X
DO: 0'	7.32	5.55	7.02	7.96	2.013	1.425	1.747	0.983	4.52	3.47		X
3'	6.75	5.20	6.59	7.55	1.648	1.401	1.591	0.758	5.40	3.47		X
Mid	5.72	4.66	5.73	7.25	1.451	1.176	0.977	0.513	9.42	3.47		X
Btm	5.56	4.47	5.51	7.24	1.428	1.122	0.695	0.614	11.76	3.47		X

Note: DO is expressed in mg/L, temperature in degrees Celsius, and pH in pH units. Number of samples for all parameters for periods 1, 2, 3, and 4 are 14, 12, 7, and 10, respectively.

Table 18. Laboratory-Measured Water Quality Results, Analysis of Variance (ANOVA) Statistical Tests, Peoria Pool, Mile 179.0

	Mean ($\bar{x}$) for periods				*Standard deviation (s) for periods*				*F-value*		*Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$*	
Parameter	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
18a. 1987 Results												
Turbidity	74.33	39.40	77.00	55.20	18.294	3.361	9.000	12.194	8.75	4.15		X
Susp. solids	80.00	35.20	81.33	60.80	22.662	17.810	5.033	13.682	7.15	4.15		X
pH	8.14	8.27	7.93	8.22	0.091	0.107	0.721	0.040	11.52	4.15		X
Alkalinity	184.67	170.20	158.00	199.20	10.386	4.712	9.165	9.365	17.01	4.15		X
Hardness	262.17	232.80	205.00	260.60	16.726	11.344	17.521	13.240	13.21	4.15		X
Ortho-P	0.15	0.18	0.18	0.22	0.025	0.019	0.001	0.055	3.76	4.15	X	
NH3-N	0.12	0.10	0.08	0.07	0.103	0.054	0.042	0.054	0.36	4.15		X
NO2-N	0.37	0.24	0.26	0.16	0.070	0.039	0.161	0.048	8.59	4.15		X
NO3-N	4.41	2.23	2.61	2.87	1.210	0.458	0.384	0.283	6.81	4.15		X
18b. 1988 Results												
Turbidity	47.33	41.20	43.33	40.60	10.386	4.147	11.060	7.925	0.71	4.15	X	
Susp. solids	42.17	36.80	39.33	37.60	11.583	7.190	12.662	13.297	0.25	4.15	X	
pH	8.48	8.24	8.24	8.31	0.142	0.189	0.198	0.175	2.33	4.15	X	
Alkalinity	180.33	147.40	136.67	139.20	8.571	12.502	5.507	3.033	29.24	4.15		X
Hardness	279.00	226.20	214.67	216.00	17.481	17.398	9.074	6.000	24.34	4.15		X
Ortho-P	0.19	0.20	0.22	0.23	0.036	0.019	0.015	0.026	2.31	4.15	X	
NH_3-N	0.09	0.16	0.13	0.10	0.069	0.113	0.112	0.057	0.76	4.15	X	
NO_2-N	0.12	0.10	0.11	0.07	0.052	0.017	0.026	0.030	1.93	4.15	X	
NO_3-N	2.49	2.08	2.41	2.81	0.674	0.321	0.150	0.449	1.62	4.15	X	

Note: Turbidity is expressed in NTUs, pH in pH units, and all others in mg/L. Number of samples for all parameters for periods 1, 2, 3, and 4 are 14, 12, 7, and 10, respectively.

Table 19. Field-Measured Water Quality Results, Analysis of Variance (ANOVA) Statistical Tests, LaGrange Pool, Mile 1133

Parameter	*Mean ($\bar{x}$) for periods*				*Standard deviation (s) for periods*				*F-value*		*Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$*	
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
19a. 1987 Results												
pH	8.15	7.90	7.59	8.04	0.188	0.245	0.164	0.34	13.75	3.46		X
Secchi disk	7.57	8.92	6.86	9.10	2.377	1.706	3.078	1.792	2.27	3.46	X	
Temp: 0'	26.66	29.05	23.90	20.78	2.100	1.476	2.998	3.604	22.19	3.46		X
3'	26.61	29.01	23.87	20.73	2.042	1.478	3.026	3.623	22.26	3.46		X
Mid	26.57	29.00	23.87	20.73	2.063	1.484	3.026	3.623	22.05	3.46		X
Btm	26.62	28.95	23.86	20.71	2.030	1.476	3.021	3.613	22.28	3.46		X
DO: 0'	5.88	4.76	5.10	6.84	0.795	1.604	1.188	0.957	6.50	3.46		X
3'	5.70	4.58	5.10	6.88	0.697	1.573	1.183	1.203	7.35	3.46		X
Mid	5.69	4.57	5.13	6.78	0.697	1.614	1.191	0.971	7.13	3.46		X
Btm	5.71	4.64	5.16	6.78	0.701	1.605	1.179	0.999	6.66	3.46		X
19b. 1988 Results												
pH	8.11	7.93	7.95	7.96	0.321	0.277	0.139	0.156	1.51	3.46	X	
Secchi disk	10.36	12.00	10.71	7.60	2.925	1.915	1.380	2.458	6.74	3.46		X
Temp: 0'	24.81	2938	27.08	22.17	1.806	1.246	3.562	0.921	29.72	3.46		X
3'	24.35	29.00	26.76	22.04	1.387	1.089	3.482	0.890	34.51	3,46		X
Mid	24.30	28.96	26.73	22.02	1.369	1.066	3.474	0.903	34.82	3.46		X
Btm	24.30	28.93	26.71	22.01	1.381	1.102	3.469	0.916	34.17	3.46		X
DO: 0'	6.77	4.52	5.05	5.80	1.594	1.389	0.994	0.994	6.90	3.46		X
3'	5.93	3.74	4.42	5.62	1.556	0.962	0.862	0.934	9.44	3.46		X
Mid	5.80	3.64	4.31	5.56	1.484	0.932	0.895	0.901	10.05	3.46		X
Btm	5.78	3.60	4.24	5.54	1.522	0.912	0.889	0.903	10.03	3.46		X

Note: DO is expressed in mg/L, temperature in degrees Celsius, and pH in pH units. Number of samples for all parameters for periods 1, 2, 3, and 4 are 14, 13, 7, and 10, respectively.

Table 20. Laboratory-Measured Water Quality Results, Analysis of Variance (ANOVA) Statistical Tests, LaGrange Pool, Mile 1133

Parameter	*Mean ($\bar{x}$) for periods*				*Standard deviation (s) for periods*				*F-value*		*Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$*	
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
20a. 1987 Results												
Turbidity	87.33	58.60	184.67	78.40	16.476	7.765	86.327	15.076	9.30	4.15		X
Susp. solids	107.67	70.00	240.00	90.40	28.296	20.832	98.305	20.562	11.27	4.15		X
pH	8.17	8.24	7.99	8.20	0.069	0.103	0.017	0.102	5.88	4.15		X
Alkalinity	191.17	177.80	150.00	201.00	6.735	3.194	18.681	4.848	25.54	4.15		X
Hardness	267.67	243.40	198.00	263.60	7.865	16.134	21.071	8.677	21.88	4.15		X
Ortho-P	0.12	0.16	0.16	0.16	0.017	0.029	0.017	0.024	4.81	4.15		X
NH_3-N	0.07	0.21	0.07	0.07	0.034	0.079	0.055	0.040	7.78	4.15		X
NO_2-N	0.21	0.14	0.15	0.07	0.078	0.040	0.025	0.048	6.44	4.15		X
NO_3-N	4.01	1.91	2.31	2.73	1.233	0.600	0.511	0.456	5.84	4.15		X
20b. 1988 Results												
Turbidity	57.83	43.40	52.67	111.00	35.482	8.111	0.577	95.433	1.58	4.15	X	
Susp. solids	75.00	48.00	53.33	132.00	52.429	14.265	4.163	145.031	1.06	4.15	X	
pH	8.44	8.12	8.05	8.23	0.146	0.151	0.260	0.096	5.84	4.15		X
Alkalinity	184.33	167.40	146.67	150.20	5.279	9.529	3.512	3.899	37.20	4.15		X
Hardness	317.50	251.20	220.00	216.00	81.171	15.707	5.568	27.559	4.68	4.15		X
Ortho-P	0.12	0.21	0.21	0.17	0.058	0.042	0.023	0.010	4.40	4.15		X
NH_3-N	0.13	0.23	0.26	0.17	0.089	0.135	0.062	0.083	1.53	4.15	X	
NO_2-N	0.08	0.15	0.22	0.10	0.033	0.033	0.061	0.018	3.06	4.15		X
NO3-N	1.64	1.27	2.73	2.25	0.506	0.242	1.699	0.490	11.67	4.15		X

Note: Turbidity is expressed in NTUs, pH in pH units, and all others in mg/L. Number of samples for all parameters for periods 1, 2, 3, and 4 are 14, 13, 7, and 10, respectively.

Table 21. Water Quality *t* test Results, Peoria Pool, Mile 179.0, 1987

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_1=\bar{x}_2$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_1=\bar{x}_3$*	
	1	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods land 2						**b. Periods l and 3**					
Turbidity	74.33	39.40	4.18	2.26		X	7433	77.00	2.23	2.37	X	
Susp. solids	80.00	35.20	3.59	2.63		X	80.00	8133	0.10	2.37	X	
pH(lab)	8.14	8.27	2.24	2.63	X		8.14	7.93	3.40	2.37		X
Alkalinity	184.67	170.20	2.86	2.63		X	184.67	158.00	3.75	2.37		X
Hardness	262.17	232.80	3.33	2.26		X	262.17	205.00	4.77	2.37		X
Ortho-P	0.15	0.18	2.34	2.26		X	0.15	0.18	2.13	2.37	X	
NH_3-N	0.12	0.10	0.34	2.26	X		0.12	0.08	0.58	2.37	X	
NO_2-N	0.37	0.24	3.60	2.26		X	0.37	0.26	1.36	2.37	X	
NO_3-N	4.41	2.23	3.79	2.26		X	4.41	2.61	2.44	2.37		X
pH (field)	7.99	7.98	0.02	2.06	X		7.99	7.48	5.04	2.09		X
Secchidisk	7.50	10.75	4.92	2.06		X	7.50	7.28	0.19	2.09	X	
Temp: 0'	26.53	28.83	3.61	2.06		X	26.53	23.87	2.43	2.09		X
3'	26.46	28.65	3.55	2.06		X	26.46	23.80	2.44	2.09		X
Mid	26.43	28.52	3.41	2.06		X	26.43	23.70	2.55	2.09		X
Btm	26.43	28.47	2.34	2.06		X	26.43	23.64	2.64	2.09		X
DO: 0'	5.66	6.29	1.46	2.06	X		5.66	5.94	0.62	2.09	X	
3'	5.59	5.91	0.72	2.06	X		5.59	5.87	0.63	2.09	X	
Mid	5.51	5.46	0.12	2.06	X		5.51	5.81	0.68	2.09	X	
Btm	5.50	5.49	0.01	2.06	X		5.50	5.80	0.68	2.09	X	
	c. Periods 1 and 4						**d. Periods 2 and 3**					
	1	*4*			*$\bar{x}_1=\bar{x}_4$*		2	*3*			*$\bar{x}_2=\bar{x}_3$*	
Turbidity	74.33	55.20	1.99	2.26	X		39.40	77.00	8.76	2,45		X
Susp. solids	80.00	60.80	1.65	2.26	X		35.20	81.33	4.26	2.45		X
pH(lab)	8.14	8.22	1.85	2.26	X		8.27	7.93	4.81	2.45		X
Alkalinity	184.67	199.20	2.41	2.26		X	170.20	158.00	2.55	2.45		X
Hardness	262.17	260.60	0.17	2.26	X		232.80	205.00	2.78	2.45		X
Ortho-P	0.15	0.22	2.72	2.26		X	0.18	0.18	0.00	2.45	X	
NH_3-N	0.12	0.07	0.92	2.26	X		0.10	0.08	0.34	2.45	X	
NO_2-N	0.37	0.16	5.71	2.26		X	0.24	0.26	0.37	2,45	X	
NO3-N	4.41	2.87	2.77	2.26		X	2.23	2.61	1.21	2.45	X	
pH (field)	7.99	8.03	0.59	2.07	X		7.98	7.48	3.54	2.11		X
Secchi disk	7.50	11.20	5.45	2.07		X	10.75	7.28	3.07	2.11		X
Temp: 0'	26.53	20.88	5.81	2.07		X	28.83	23.87	4.52	2.11		X
3'	26.46	20.79	5.82	2.07		X	28.65	23.80	4.50	2.11		X
Mid	26.43	20.75	5.88	2.07		X	28.52	23.70	4.55	2.11		X
Btm	26.43	20.73	5.93	2.07		X	28.47	23.64	4.59	2.11		X
DO: 0'	5.66	7.67	5.28	2.07		X	6.29	5.94	0.53	2.11	X	
3'	5.59	7.58	5.25	2.07		X	5.91	5.87	0.06	2.11	X	
Mid	5.51	7.52	5.41	2.07		X	5.46	5.81	0.58	2.11	X	
Btm	5.50	7.51	5.49	2.07		X	5.49	5.80	0.55	2.11	X	

Note: For parameter units and number of samples, see notes in tables 17 and 18.

Table 21. Water Quality *t* test Results, Peoria Pool, Mile 179.0, 1987 (Continued)

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_2=\bar{x}_4$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_3=\bar{x}_4$*	
	2	*4*	*Calc*	*Theo*	*Acc*	*Rej*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	39.40	55.20	2.79	2.31		X	77.00	55.20	2.66	2.45		X
Susp. solids	35.20	60.80	2.55	2.31		X	81.33	60.80	2.44	2.45	X	
pH(lab)	8.27	8.22	1.02	2.31	X		7.93	8.22	7.48	2.45		X
Alkalinity	170.20	199.20	6.19	2.31		X	158.00	*19920*	6.07	2.45		X
Hardness	232.80	260.60	3.57	2.31		X	205.00	260.60	5.14	2.45		X
Ortho-P	0.18	0.22	1.39	2.31	X		0.18	0.22	1.10	2.45	X	
NH_3-N	0.10	0.07	0.64	2.31	X		0.08	0.07	0.29	2.45	X	
NO_2-N	0.24	0.16	3.02	2.31		X	0.26	0.16	1.50	2.45	X	
NO_3-N	2.23	2.87	2.64	2.31		X	2.61	2.87	1.09	2.45	X	
pH (field)	7.98	8.03	0.40	2.11	X		7.48	8.03	5.78	2.13		X
Secchi disk	10.75	11.20	0.79	2.09	X		7.28	11.20	3.30	2.13		X
Temp: 0'	28.83	20.88	8.09	2.09		X	23.87	20.88	1.92	2.13	X	
3'	28.65	20.79	8.06	2.09		X	23.80	20.79	1.93	2.13	X	
Mid	28.52	20.75	8.01	2.09		X	23.70	20.75	1.92	2.13	X	
Btm	28.47	20.73	7.98	2.09		X	23.64	20.73	1.91	2.13	X	
DO: 0'	6.29	7.67	2.57	2.90		X	5.94	7.67	2.93	2.13		X
3'	5.91	7.58	3.02	2.09		X	5.87	7.58	2.98	2.13		X
Mid	5.46	7.52	4.11	2.09		X	5.81	7.52	3.09	2.13		X
Btm	5.49	7.51	4.34	2.09		X	5.80	7.51	3.08	2.13		X

Note: For parameter units and number of samples, see notes in tables 17 and 18.

Table 22. Water Quality *t* test Results, Peoria Pool, Mile 179.0, 1988

Parameter	Mean ($\bar{x}$) for periods 1	2	*t*-value Calc	Theo	Hypothesis: $\bar{x}_1=\bar{x}_2$ Acc	Rej	Mean ($\bar{x}$) for periods 1	3	*t*-value Calc	Theo	Hypothesis: $\bar{x}_1=\bar{x}_3$ Acc	Rej
	a. Periods 1 and 2						**b. Periods land 3**					
Turbidity	47.33	41.20	1.23	2.26	X		47.33	43.33	0.53	2.37	X	
Susp. solids	42.17	36.80	0.90	2.26	X		42.17	39.33	034	2.37	X	
pH(lab)	8.48	8.24	2.44	2.26		X	8.48	8.24	2.18	2.37		X
Alkalinity	180.33	147.40	5.18	2.26		X	180.33	136.67	7.90	2.37		X
Hardness	279.00	226.20	5.00	2.26		X	279.00	214.67	5.85	2.37		X
Ortho-P	0.19	0.20	0.66	2.26	X		0.19	0.22	1.48	2.37	X	
NH_3-N	0.09	0.16	1.34	2.26	X		0.09	0.13	0.73	2.37	X	
NO_2-N	0.12	0.10	0.80	2.26	X		0.12	0.11	0.36	2.37	X	
NO_3-N	2.49	2.08	1.24	2.26	X		2.49	2.41	0.20	2.37	X	
pH (field)	8.36	8.14	2.43	2.06		X	8.36	8.19	1.89	2.09	X	
Secchi disk	11.50	12.00	0.85	2.06	X		11.50	11.57	0.12	2.09	X	
Temp: 0'	24.63	28.87	8.02	2.06		X	24.63	27.20	2.39	2.09		X
3'	24.34	28.73	9.18	2.06		X	24.34	27.04	2.65	2.09		X
Mid	23.96	28.49	10.22	2.06		X	23.96	26.83	2.99	2.09		X
Btm	23.89	28.38	9.74	2.06		X	23.89	26.74	2.95	2.09		X
DO: 0'	7.32	5.55	2.54	2.06		X	7.32	7.02	0.34	2.09	X	
3'	6.75	5.20	2.56	2.06		X	6.75	6.59	0.22	2.09	X	
Mid	5.72	4.66	2.03	2.06	X		5.72	5.73	0.01	2.09	X	
Btm	5.56	4.47	2.13	2.06		X	5.56	5.51	0.10	2.09	X	
	c. Periods land 4						**d. Periods 2 and 3**					
	1	4			$\bar{x}_1=\bar{x}_4$		2	3			$\bar{x}_2=\bar{x}_3$	
Turbidity	47.33	40.60	1.18	2.26	X		41.20	43.33	0.40	2.45	X	
Susp. solids	42.17	37.60	0.61	2.26	X		36.80	39.33	0.37	2.45	X	
pH(lab)	8.48	8.31	1.73	2.26	X		8.24	8.24	0.02	2.45	X	
Alkalinity	180.33	139.20	10.14	2.26		X	147.40	136.67	1.38	2.45	X	
Hardness	279.00	216.00	7.63	2.26		X	226.20	214.67	1.04	2.45	X	
Ortho-P	0.19	0.23	104	2.26	X		0.20	0.22	1.62	2.45	X	
NH_3-N	0.09	0.10	0.31	2.26	X		0.16	0.13	0.37	2.45	X	
NO_2-N	0.12	0.07	1.80	2.26	X		0.10	0.11	0.52	2.45	X	
NO3-N	2.49	2.81	0.92	2.26	X		2.08	141	1.64	2.45	X	
pH (field)	8.36	8.26	0.83	2.07	X		8.14	8.19	0.51	2.11	X	
Secchi disk	11.50	10.70	0.91	2.07	X		12.00	11.57	0.54	2.11	X	
Temp: 0'	24.63	21.84	4.55	2.07		X	28.87	27.20	1.58	2.11	X	
3'	24.34	21.61	4.92	2.07		X	28.73	27.04	1.64	2.11	X	
Mid	23.96	21.43	5.03	2.07		X	28.49	26.83	1.68	2.11	X	
Btm	23.89	2133	4.95	2.07		X	28.38	26.74	1.64	2.11	X	
DO: 0'	7.32	7.96	0.92	2.07	X		5.55	7.02	1.99	2.11	X	
3'	6.75	7.55	1.42	2.07	X		5.20	6.59	1.98	2.11	X	
Mid	5.72	7.25	3.17	2.07		X	4.66	5.73	1.02	2.11	X	
Btm	5.56	7.24	3.48	2.07		X	4.47	5.51	2.19	2.11		X

Note: For parameter units and number of samples, see notes in tables 17 and 18.

Table 22. Water Quality *t* test Results, Peoria Pool, Mile 179.0, 1988 (Continued)

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_2=\bar{x}_4$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_3=\bar{x}_4$*	
	2	*4*	*Calc*	*Theo*	*Acc*	*Rej*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	41.20	40.60	0.15	2.31	X		43.33	40.60	0.42	2.45	X	
Susp. solids	36.80	37.60	0.12	231	X		39.33	37.60	0.18	2.45	X	
pH(lab)	8.24	8.31	0.68	2.31	X		8.24	831	0.61	2.45	X	
Alkalinity	147.40	139.20	1.43	2.31	X		136.67	139.20	0.86	2.45	X	
Hardness	226.20	216.00	1.24	231	X		214.67	216.00	0.25	2.45	X	
Ortho-P	0.20	0.23	1.91	2.31	X		0.22	0.23	0.39	2.45	X	
NH_3-N	0.16	0.10	1.10	231	X		0.13	0.10	0.53	2.45	X	
NO_2-N	0.10	0.07	1.81	2.31	X		0.11	0.07	1.72	2.45	X	
NO_3-N	2.08	2.81	2.98	231		X	2.41	2.81	1.47	2.45	X	
pH (field)	8.14	8.26	0.88	2.09	X		8.19	8.26	0.43	2.13	X	
Secchi disk	12.00	10.70	1.27	2.09	X		11.57	10.70	0.71	2.13	X	
Temp: 0'	28.87	21.84	13.14	2.09		X	27.20	21.84	4.44	2.13		X
3'	28.73	21.61	14.16	2.09		X	27.04	21.61	4.65	2.13		X
Mid	28.49	21.43	14.74	2.09		X	26.83	21.43	4.87	2.13		X
Btm	28.38	21.33	14.22	2.09		X	26.74	21.33	4.85	2.13		X
DO: 0'	5.55	7.96	4.51	2.09		X	7.02	7.96	1.42	2.13	X	
3'	5.20	7.55	4.73	2.09		X	6.59	7.55	1.67	2.13	X	
Mid	4.66	7.25	6.45	2.09		X	5.73	7.25	4.22	2.13		X
Btm	4.47	7.24	6.97	2.09		X	5.51	7.24	5.44	2.13		X

Note: For parameter units and number of samples, see notes in tables 17 and 18.

Table 23. Water Qualify *t* test Comparison Results, Peoria Pool, Mile 179.0, 1987 and 1988

a. Period 1

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$*	
	1987	*1988*	*Calc*	*Theo*	*Acc*	*Rej*
Turbidity	7433	47.33	3.14	2.23		X
Susp. solids	80.00	42.17	3.64	2.23		X
pH(lab)	8.14	8.48	5.03	2.23		X
Alkalinity	184.67	180.33	0.79	2.23	X	
Hardness	262.17	279.00	1.70	2.23	X	
Ortho-P	0.15	0.19	2.32	2.33		X
NH_3-N	0.12	0.09	0.66	2.23	X	
NO_2-N	0.37	0.12	6.90	2.23		X
NO_3-N	4.41	2.49	3.41	2.23		X
pH (field)	7.99	8.36	5.08	2.18		X
Secchi disk	7.50	11.50	6.69	2.18		X
Temp: 0'	26.53	24.63	3.07	2.18		X
3'	26.46	24.34	3.63	2.18		X
Mid	26.43	23.96	4.42	2.18		X
Btm	26.43	23.89	4.55	2.18		X
DO: 0'	5.66	732	2.89	2.18		X
3'	5.59	6.75	2.38	2.18		X
Mid	5.51	5.72	0.49	2.18	X	
Btm	5.50	5.56	0.15	2.18	X	

b. Period 2

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$*	
	1987	*1988*	*Calc*	*Theo*	*Acc*	*Rej*
Turbidity	39.40	41.20	0.75	2.31	X	
Susp. solids	35.20	36.80	0.19	2.31	X	
pH(lab)	8.27	8.24	0.31	2.31	X	
Alkalinity	170.20	147.40	3.82	2.31		X
Hardness	232.80	226.20	0.71	2.31	X	
Ortho-P	0.18	0.20	1.83	2.31	X	
NH_3-N	0.10	0.16	0.97	2.31	X	
NO_2-N	0.24	0.10	7.12	2.31		X
NO_3-N	2.23	2.08	0.62	2.31	X	
pH (field)	7.98	8.14	1.32	2.23	X	
Secchi disk	10.75	12.00	1.92	2.23	X	
Temp: 0'	28.83	28.87	0.08	2.23	X	
3'	28.65	28.73	0.17	2.23	X	
Mid	28.52	28.49	0.07	2.23	X	
Btm	28.47	28.38	0.17	2.23	X	
DO: 0'	6.29	5.55	1.28	2.23	X	
3'	5.91	5.20	1.22	2.23	X	
Mid	5.46	4.66	1.61	2.23	X	
Btm	5.49	4.47	2.21	2.23	X	

c. Period 3

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$*	
	1987	*1988*	*Calc*	*Theo*	*Acc*	*Rej*
Turbidity	77.00	43.33	4.09	2.78		X
Susp. solids	81.33	39.33	5.34	2.78		X
pH(lab)	7.93	8.24	2.51	2.78	X	
Alkalinity	158.00	136.67	3.46	2.78		X
Hardness	205.00	214.67	0.85	2.78	X	
Ortho-P	0.18	0.22	1.90	2.78	X	
NH_3-N	0.08	0.13	0.67	2.78	X	
NO_2-N	0.26	0.11	1.67	2.78	X	
NO_3-N	2.61	2.41	0.87	2.78	X	
pH (field)	7.48	8.19	6.15	2.57		X
Secchi disk	7.28	11.57	2.98	2.57		X
Temp: 0'	23.87	27.80	1.83	2.57	X	
3'	23.80	27.04	1.81	2.57	X	
Mid	23.70	26.83	1.81	2.57	X	
Btm	23.64	26.74	1.80	2.57	X	
DO: 0'	5.94	7.02	1.30	2.57	X	
3'	5.87	6.59	0.92	2.57	X	
Mid	5.81	5.73	0.54	2.57	X	
Btm	5.80	5.51	0.14	2.57	X	

d. Period 4

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$*	
	1987	*1988*	*Calc*	*Theo*	*Acc*	*Rej*
Turbidity	55.20	40.60	2.25	2.31	X	
Susp. solids	60.80	37.60	2.72	2.31		X
pH(lab)	8.22	8.31	1.25	2.31	X	
Alkalinity	199.20	139.20	13.63	2.31		X
Hardness	260.60	216.00	6.86	2.31		X
Ortho-P	0.22	0.23	0.51	2.31	X	
NH_3-N	0.07	0.10	0.74	2.31	X	
NO_2-N	0.16	0.07	3.24	2.31		X
NO_3-N	2.87	2.81	0.24	2.31	X	
pH (field)	8.03	8.26	1.86	2.31	X	
Secchi disk	11.20	10.70	0.49	2.31	X	
Temp: 0'	20.88	21.84	0.91	2.31	X	
3'	20.79	21.61	0.78	2.31	X	
Mid	20.75	21.43	0.66	2.31	X	
Btm	20.73	21.33	0.58	2.31	X	
DO: 0'	7.67	7.96	0.63	2.31	X	
3'	7.58	7.55	0.07	2.31	X	
Mid	7.52	7.25	0.70	2.31	X	
Btm	7.51	7.24	0.73	2.31	X	

Note: For parameter units and number of samples, see notes in tables 17 and 18.

Table 24. Water Quality *t* test Results, LaGrange Pool, Mile 1133, 1987

Parameter	Mean ($\bar{x}$) for periods		t-value		Hypothesis: $\bar{x}_1=\bar{x}_2$		Mean ($\bar{x}$) for periods		t-value		Hypothesis: $\bar{x}_1=\bar{x}_3$	
	1	2	Calc	Theo	Acc	Rej	1	3	Calc	Theo	Acc	Rej
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Turbidity	87.33	58.60	3.56	2.26		X	87.33	184.67	2.86	2.37		X
Susp. solids	107.67	70.00	2.46	2.26		X	107.67	240.00	3.24	2.37		X
pH(lab)	8.17	8.24	1.35	2.26	X		8.17	7.99	4.33	2.37		X
Alkalinity	191.17	177.80	4.05	2.26		X	191.17	150.00	5.07	2.37		X
Hardness	267.67	243.40	3.27	2.26		X	267.67	198.00	7.53	2.37		X
Ortho-P	0.12	0.16	3.10	2.26		X	0.12	0.16	4.00	2.37		X
NH_3-N	0.07	0.21	3.75	2.26		X	0.07	0.07	0.06	2.37	X	
NO_2-N	0.21	0.14	1.85	2.26	X		0.21	0.15	1.41	2.37	X	
NO_3-N	4.01	1.91	3.46	2.26		X	4.01	2.31	2.23	2.37	X	
pH (field)	8.15	7.90	6.67	2.06		X	8.15	7.59	1.59	2.09	X	
Secchi disk	7.57	8.92	1.69	2.06	X		7.57	6.86	2.38	2.09		X
Temp: 0'	26.66	29.05	3.41	2.06		X	26.66	23.90	2.46	2.09		X
3'	26.61	29.01	3.46	2.06		X	26.61	23.87	2.47	2.09		X
Mid	26.57	29.00	3.49	2.06		X	26.57	23.87	2.42	2.09		X
Btm	26.62	28.95	3.39	2.06		X	26.62	23.86	2.50	2.09		X
DO: 0'	5.88	4.76	2.31	2.06		X	5.88	5.10	2.31	2.09		X
3'	5.70	4.58	2.41	2.06		X	5.70	5.10	1.46	2.09	X	
Mid	5.69	4.57	2.38	2.06		X	5.69	5.13	1.36	2.09	X	
Btm	5.71	4.64	2.27	2.06		X	5.71	5.16	1.33	2.09	X	
	c. Periods 1 and 4						**d. Periods 2 and 3**					
	1	4			$\bar{x}_1=\bar{x}_4$		2	3			$\bar{x}_2=\bar{x}_3$	
Turbidity	87.33	78.40	0.93	2.26	X		58.60	184.67	3.44	2.45		X
Susp. solids	107.67	90.40	1.33	2.26	X		70.00	240.00	3.93	2.45		X
pH(lab)	8.17	8.20	0.62	2.26	X		8.24	7.99	4.05	2.45		X
Alkalinity	191.17	201.00	2.72	2.26		X	177.80	150.00	3.43	2.45		X
Hardness	267.67	263.60	0.82	2.26	X		243.40	198.00	3.47	2.45		X
Ortho-P	0.12	0.16	3.83	2.26		X	0.16	0.16	0.11	2.45	X	
NH_3-N	0.07	0.07	0.14	2.26	X		0.21	0.07	2.56	2.45		X
NO_2-N	0.21	0.07	3.54	2.26		X	0.14	0.15	0.18	2.45	X	
NO_3-N	4.01	2.73	2.17	2.26	X		1.91	2.31	0.96	2.45	X	
pH (field)	8.15	8.04	3.04	2.07		X	7.90	7.59	1.53	2.10	X	
Secchi disk	7.57	9.10	1.71	2.07	X		8.92	6.86	1.95	2.10	X	
Temp: 0'	26.66	20.78	5.04	2.07		X	29.05	23.90	5.21	2.10		X
3'	26.61	20.73	5.08	2.07		X	29.01	23.87	5.16	2.10		X
Mid	26.57	20.73	5.02	2.07		X	29.00	23.87	5.15	2.10		X
Btm	26.62	20.71	5.12	2.07		X	28.95	23.86	5.13	2.10		X
DO: 0'	5.88	6.84	2.70	2.07		X	4.76	5.10	0.49	2.10	X	
3'	5.70	6.88	3.06	2.07		X	4.58	5.10	0.76	2.10	X	
Mid	5.69	6.78	3.22	2.07		X	4.57	5.13	0.82	2.10	X	
Btm	5.71	6.78	3.09	2.07		X	4.64	5.16	0.76	2.10	X	

Note: For parameter units and number of samples, see notes in tables 19 and 20.

Table 24. Water Qualify *t* test Results, LaGrange Pool, Mile 1133, 1987 (Continued)

Parameter	Mean ($\bar{x}$) for periods 2	Mean ($\bar{x}$) for periods 4	t-value Calc	t-value Theo	Hypothesis: $\bar{x}_2=\bar{x}_4$ Acc	Hypothesis: $\bar{x}_2=\bar{x}_4$ Rej	Mean ($\bar{x}$) for periods 3	Mean ($\bar{x}$) for periods 4	t-value Calc	t-value Theo	Hypothesis: $\bar{x}_3=\bar{x}_4$ Acc	Hypothesis: $\bar{x}_3=\bar{x}_4$ Rej
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	58.60	78.40	2.61	231		X	184.67	78.40	2.83	2.45		X
Susp. solids	70.00	90.40	1.56	2.31	X		240.00	90.40	3.46	2.45		X
pH(lab)	8.24	8.20	0.59	2.31	X		7.99	8.20	3.47	2.45		X
Alkalinity	177.80	201.00	8.94	2.31		X	150.00	201.00	6.08	2.45		X
Hardness	243.40	263.60	2.47	2.31		X	198.00	263.60	6.38	2.45		X
Ortho-P	0.16	0.16	0.12	2.31	X		0.16	0.16	0.25	2.45	X	
NH_3-N	0.21	0.07	3.46	2.31		X	0.07	0.07	0.04	2.45	X	
NO_2-N	0.14	0.07	2.53	2.31		X	0.15	0.07	2.46	2.45		X
NO_3-N	1.91	2.73	2.45	2.31		X	2.31	2.73	1.22	2.45	X	
pH (field)	7.90	8.04	6.17	2.08		X	7.59	8.04	1.69	2.13	X	
Secchi disk	8.92	9.10	0.24	2.08	X		6.86	9.10	1.90	2.13	X	
Temp: 0'	29.05	20.78	7.54	2.08		X	23.90	20.78	1.88	2.13	X	
3'	29.01	20.73	7.51	2.08		X	23.87	20.73	1.88	2.13	X	
Mid	29.00	20.73	7.49	2.08		X	23.87	20.73	1.88	2.13	X	
Btm	28.95	20.71	7.49	2.08		X	23.86	20.71	1.88	2.13	X	
DO: 0'	4.76	6.84	3.62	2.08		X	5.10	6.84	3.34	2.13		X
3'	4.58	6.88	3.83	2.08		X	5.10	6.88	3.03	2.13		X
Mid	4.57	6.78	3.83	2.08		X	5.13	6.78	3.14	2.13		X
Btm	4.64	6.78	3.69	2.08		X	5.16	6.78	3.05	2.13		X

Note: For parameter units and number of samples, see notes in tables 19 and 20.

Table 25. Water Quality *t* test Results, LaGrange Pool, Mile 1133, 1988

Parameter	Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_1=\bar{x}_2$		Mean ($\bar{x}$) for periods		*t*-value		Hypothesis: $\bar{x}_1=\bar{x}_3$	
	1	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Turbidity	57.83	43.40	0.88	2.26	X		57.83	52.67	0.24	2.37	X	
Susp. solids	75.00	48.00	1.11	2.26	X		75.00	5333	0.69	237	X	
pH(lab)	8.44	8.12	3.61	2.26		X	8.44	8.05	3.00	2.37		X
Alkalinity	184.33	167.40	3.74	2.26		X	184.33	146.67	11.01	237		X
Hardness	317.50	251.20	1.78	2.26	X		317.50	220.00	2.01	2.37	X	
Ortho-P	0.12	0.21	2.58	2.26		X	0.12	0.21	2.26	2.37	X	
NH_3-N	0.13	0.23	1.49	2.26	X		0.13	0.26	2.18	2.37	X	
NO_2-N	0.08	0.15	3.33	2.26	X		0.08	0.22	4.56	2.37		X
NO_3-N	1.64	1.27	1.46	2.26		X	1.64	2.73	1.54	2.37	X	
pH (field)	8.11	7.93	1.64	2.06	X		8.11	7.95	1.28	2.09	X	
Secchidisk	10.36	12.00	1.71	2.06	X		10.36	10.71	0.30	2.09	X	
Temp: 0'	24.81	29.38	7.59	2.06		X	24.81	27.08	1.97	2.09	X	
3'	24.35	29.00	9.63	2.06		X	24.35	26.73	2.29	2.09		X
Mid	24.30	28.96	9.82	2.06		X	24.30	26.73	2.33	2.09		X
Btm	24.30	28.93	9.58	2.06		X	24.30	26.71	2.31	2.09		X
DO: 0'	6.77	4.52	3.89	2.06		X	6.77	5.05	2.60	2.09		X
3'	5.93	3.74	4.36	2.06		X	5.93	4.42	237	2.09		X
Mid	5.80	3.64	4.48	2.06		X	5.80	4.31	2.41	2.09		X
Btm	5.78	3.60	4.42	2.06		X	5.78	4.24	2.42	2.09		X
	c. Periods 1 and 4						**d. Periods 2 and 3**					
	1	*4*			$\bar{x}_1=\bar{x}_4$		2	*3*			$\bar{x}_2=\bar{x}_3$	
Turbidity	57.83	111.00	1.27	2.26	X		43.40	52.67	1.91	2.45	X	
Susp. solids	75.00	132.00	0.90	2.26	X		48.00	53.33	0.61	2.45	X	
pH(lab)	8.44	8.23	2.85	2.26		X	8.12	8.05	0.49	2.45	X	
Alkalinity	184.33	150.20	11.95	2.26		X	167.40	146.67	3.53	2.45		X
Hardness	317.50	216.00	2.65	2.26		X	251.20	220.00	3.23	2.45		X
Ortho-P	0.12	0.17	1.68	2.26	X		0.21	0.21	0.03	2.45	X	
NH_3-N	0.13	0.17	0.74	2.26	X		0.23	0.26	0.31	2.45	X	
NO_2-N	0.08	0.10	1.34	2.26	X		0.15	0.22	2.23	2.45	X	
NO_3-N	1.64	2.25	2.04	2.26	X		1.27	2.73	1.99	2.45	X	
pH (field)	8.11	7.96	1.44	2.07	X		7.93	7.95	0.23	2.10	X	
Secchi disk	10.36	7.60	2.43	2.07		X	12.00	10.71	1.56	2.10	X	
Temp: 0'	24.81	22.17	4.22	2.07		X	29.38	27.08	2.13	2.10		X
3'	24.35	22.04	4.62	2.07		X	29.00	26.76	2.18	2.10		X
Mid	2430	22.02	4.59	2.07		X	28.96	26.73	2.18	2.10		X
Btm	24.30	22.01	4.56	2.07		X	28.93	26.71	2.15	2.10		X
DO: 0'	6.77	5.80	1.70	2.07	X		4.52	5.05	0.88	2.10	X	
y	5.93	5.62	0.57	2.07	X		3.74	4.42	1.56	2.10	X	
Mid	5.80	5.56	0.46	2.07	X		3.64	4.31	1.57	2.10	X	
Btm	5.78	5.54	0.40	2.07	X		3.60	4.24	1.51	2.10	X	

Note: For parameter units and number of samples, see notes in tables 19 and 20.

Table 25. Water Quality *t* test Results, LaGrange Pool, Mile 1133,1988 (Continued)

Parameter	*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_2=\bar{x}_4$*		*Mean ($\bar{x}$) for periods*		*t-value*		*Hypothesis: $\bar{x}_3=\bar{x}_4$*	
	2	*4*	*Calc*	*Theo*	*Acc*	*Rej*	*3*	*4*	*Calc*	*Theo*	*Acc*	*Rej*
	e. Periods 2 and 4						**f. Periods 3 and 4**					
Turbidity	43.40	111.00	1.58	2.31	X		52.67	111.00	1.03	2.45	X	
Susp. solids	48.00	132.00	1.29	2.31	X		53.33	132.00	0.91	2.45	X	
pH(lab)	8.12	8.23	1.32	2.31	X		8.05	8.23	1.42	2.45	X	
Alkalinity	167.40	150.20	3.74	2.31		X	146.67	150.20	1.28	2.45	X	
Hardness	251.20	216.00	2.48	2.31		X	220.00	216.00	0.24	2.45	X	
Ortho-P	0.21	0.17	1.86	231	X		0.21	0.17	3.21	2.45		X
NH_3-N	0.23	0.17	0.87	2.31	X		0.26	0.17	1.56	2.45	X	
NO_2-N	0.15	0.10	2.63	2.31	X		0.22	0.10	4.17	2.45		X
NO_3-N	1.27	2.25	4.00	2.31		X	2.73	2.25	0.62	2.45	X	
pH (field)	7.93	7.96	032	2.08	X		7.95	7.96	0.08	2.13	X	
Secchi disk	12.00	7.60	4.83	2.08		X	10.71	7.60	3.02	2.13		X
Temp: 0'	29.38	22.17	15.32	2.08		X	27.08	22.17	4.22	2.13		X
3'	29.00	22.04	16.41	2.08		X	26.76	2104	4.15	2.13		X
Mid	28.96	22.02	16.52	2.08		X	26.73	22.02	4.14	2.13		X
Btm	28.93	22.01	16.03	2.08		X	26.71	22.01	4.14	2.13		X
DO: 0'	4.52	5.80	2.45	2.08		X	5.05	5.80	1.52	2.13	X	
3'	3.74	5.62	4.69	2.08		X	4.42	5.62	2.68	2.13		X
Mid	3.64	5.56	4.96	2.08		X	431	5.56	2.80	2.13		X
Btm	3.60	5.54	5.09	2.08		X	4.24	5.54	2.95	2.13		X

Note: For parameter units and number of samples, see notes in tables 19 and 20.

Table 26. Water Quality *t* test Results Comparison Results, LaGrange Pool, Mile 1133, 1987 and 1988

Parameter	Mean ($\bar{x}$) for periods 1987	1988	*t*-value Calc	Theo	Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$ Acc	Rej	Mean ($\bar{x}$) for periods 1987	1988	*t*-value Calc	Theo	Hypothesis: $\bar{x}_{87}=\bar{x}_{88}$ Acc	Rej
		a. Period 1						**b. Period 2**				
Turbidity	87.33	57.83	1.85	2.23	X		58.60	43.40	3.03	2.31		X
Susp. solids	107.67	75.00	1.34	2.23	X		70.00	48.00	1.95	2.31	X	
pH(lab)	8.17	8.44	4.16	2.23		X	8.24	8.12	1.47	2.31	X	
Alkalinity	191.17	184.33	1.96	2.23	X		177.80	167.40	2.31	2.31	X	
Hardness	267.67	317.50	1.50	2.23	X		243.40	251.20	0.77	2.31	X	
Ortho-P	0.12	0.12	0.14	2.23	X		0.16	0.21	1.91	2.31	X	
NH_3-N	0.07	0.13	1.51	2.23	X		0.21	0.23	0.37	2.31	X	
NO_2-N	0.21	0.08	4.36	2.23		X	0.14	0.15	2.20	2.31	X	
NO_3-N	4.01	1.64	3.82	2.23		X	1.91	1.27	0.26	2.31	X	
pH (field)	8.15	8.11	0.30	2.18	X		7.90	7.93	0.23	2.20	X	
Secchi disk	7.57	10.36	2.77	2.18		X	8.92	12.00	4.33	2.20		X
Temp: 0'	26.66	24.81	2.50	2.18		X	29.05	29.38	0.60	2.20	X	
3'	26.61	24.35	3.43	2.18		X	29.01	29.00	0.02	2.20	X	
Mid	26.57	24.30	3.43	2.18		X	29.00	28.96	0.08	2.20	X	
Btm	26.22	24.30	3.54	2.18		X	28.95	28.93	0.05	2.20	X	
DO: 0'	5.88	6.77	1.88	2.18	X		4.76	4.52	0.41	2.20	X	
3'	5.70	5.93	0.51	2.18	X		4.58	3.74	1.65	2.20	X	
Mid	5.69	5.80	0.24	2.18	X		4.57	3.64	1.79	2.20	X	
Btm	5.71	5.78	0.11	2.18	X		4.64	3.60	2.03	2.20	X	
		c.		**Period**			**3**	**d. Period 4**				
Turbidity	184.67	52.67	2.65	2.78	X		78.40	111.00	0.75	2.31	X	
Susp. solids	240.00	53.33	3.29	2.78		X	90.40	132.00	0.64	2.31	X	
pH(lab)	7.99	8.05	0.40	2.78	X		8.20	8.23	0.38	2.31	X	
Alkalinity	150.00	146.67	0.30	2.78	X		201.00	150.20	18.26	2.31		X
Hardness	198.00	220.00	1.75	2.78	X		263.60	216.00	3.68	2.31		X
Ortho-P	0.16	0.21	2.80	2.78		X	0.16	0.17	0.51	2.31	X	
NH_3-N	0.07	0.26	3.88	2.78		X	0.07	0.17	2.43	2.31		X
NO_2-N	0.15	0.22	0.41	2.78	X		0.07	0.10	1.61	2.31	X	
NO_3-N	2.31	2.73	1.93	2.78	X		2.73	2.25	1.40	2.31	X	
pH (field)	7.59	7.95	4.47	2.57		X	8.04	7.96	1.19	2.31	X	
Secchi disk	6.86	10.71	3.03	2.57		X	9.10	7.60	1.56	2.31	X	
Temp: 0'	23.90	27.08	1.81	2.57	X		20.78	22.17	1.18	2.31	X	
3'	23.87	26.76	1.66	2.57	X		20.73	22.04	1.11	2.31	X	
Mid	23.87	26.73	1.64	2.57	X		20.73	22.04	1.09	2.31	X	
Btm	23.86	26.71	1.64	2.57	X		20.71	22.01	1.10	2.31	X	
DO: 0'	5.10	5.05	0.09	2.57	X		6.84	5.80	2.39	2.31		X
3'	5.10	4.42	1.23	2.57	X		6.88	5.62	2.63	2.31		X
Mid	5.13	4.31	1.46	2.57	X		6.78	5.56	2.93	2.31		X
Btm	5.16	4.24	1.66	2.57	X		6.78	5.54	2.90	2.31		X

Note: For parameter units and number of samples, see notes in tables 19 and 20.

Table 27. Algae Results, Analysis of Variance (ANOVA) Statistical Tests, Peoria Pool

Parameter	*Mean* ($\bar{x}$) *(algae logjg transform) for periods*				*Standard deviation (s) (algae log10 transform) for periods*				*F-value*		**Hypothesis:** $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$	
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	**Acc**	**Rej**
a. 1987 Results												
Blue-green	1.657	2.112	2.013	2.137	0.726	0.360	0.416	0.336	1.75	3.50	X	
Green	2.160	2.696	1.927	2.231	0.341	0.370	0.548	0.266	6.44	3.50		X
Diatom	2.570	2.987	2.818	2.720	0.270	0.196	0.449	0.367	3.34	3.50	X	
Flagellate	1.783	1.888	0.820	1.324	0.417	0.516	0351	0307	10.75	3.50		X
Total	2.835	3.249	2.942	2.955	0.292	0.228	0.441	0.271	4.14	3.50		X
No. taxa	30.420	30.500	31.500	31.670	3.848	3.440	10.010	5.523	0.13	3.50	X	
Diver, index	3.494	2.907	3.375	2.745	0.568	0.490	0.191	0.372	9.30	3.50		X
b. 1988 Results												
Blue-green	1.488	1.437	2.206	1.681	0.280	0.512	0.312	0.180	7.47	3.51		X
Green	2.502	2.365	2.595	2.317	0.245	0.138	0.122	0.119	4.02	3.51		X
Diatom	3.037	2.746	2.887	2.580	0.207	0.216	0.255	0.206	8.18	3.51		X
Flagellate	1.835	1.116	1.340	1.050	0.521	0.258	0.174	0.231	10.62	3.51		X
Total	3.191	2.930	3.152	2.824	0.221	0.204	0.187	0.141	7.73	3.51		X
No. taxa	30.58	28.89	33.67	32.89	4.926	2.571	3.445	4.729	2.19	3.51	X	
Diver, index	2.88	3.04	3.36	3.58	0.270	0.326	0.293	0.306	11.07	3.51		X

Note: Algae counts are expressed in numbers/mL. Number of statistical samples for algae counts for periods 1, 2, 3, and 4 are 12, 10, 6, and 9, respectively, during 1987; and 12, 9, 6, and 9, respectively, during 1988. Each statistical sample represents the average of 10 analytical samples.

Table 28. Algae Results, Analysis of Variance (ANOVA) Statistical Tests, LaGrange Pool

Parameter	*Mean ($\bar{x}$) (algae log10 transform) for periods*				*Standard deviation (s) (algae log10 transform) for periods*				*F-value*		***Hypothesis: $\bar{x}_1=\bar{x}_2=\bar{x}_3=\bar{x}_4$***	
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*Calc*	*Theo*	***Acc***	***Rej***
a. 1987 Results												
Blue-green	1.436	1.260	1.714	1.364	0.526	0.460	0.183	0301	1.56	3.50	X	
Green	2.117	2.355	1.939	2.041	0.277	0.150	0.232	0.121	6.10	3.50		X
Diatom	2.574	2.652	2.426	2.492	0.464	0352	0.089	0308	0.60	3.50	X	
Flagellate	1.716	1.470	0.887	1.257	0383	0341	0375	0.180	8.89	3.50		X
Total	2.818	2.889	2.629	2.693	0.406	0.263	0.096	0.206	132	3.50	X	
No. taxa	25.333	27.200	26.830	28.444	4.185	3.765	4.167	4300	1.02	3.50	X	
Diver. index	3.203	2.838	2.714	2.678	0.765	0.543	0.246	0.682	1.43	3.50	X	
b. 1988 Results												
Blue-green	1.512	0.963	1.592	1.064	0.341	0.403	0.089	0.313	7.65	3.51		X
Green	2.346	2.310	2.402	2.244	0.192	0.088	0.199	0.106	1.45	3.51	X	
Diatom	2.779	2.685	2.682	2.442	0.277	0.188	0317	0.152	3.64	3.51		X
Flagellate	1.545	1.128	1.175	1.037	0.486	0.189	0.277	0.200	4.85	3.51		X
Total	2.966	2.845	2.915	2.689	0.247	0.173	0.231	0.085	3.61	3.51		X
No. taxa	29.545	28.545	27.800	29.220	3.532	4.866	4.147	4.842	0.22	3.51	X	
Diver, index	3.532	4.866	4.147	4.842	0.301	0.301	0.456	0.310	2.16	3.51	X	

Note: Algae counts are expressed in numbers/mL. Number of statistical samples for algae counts for periods 1, 2, 3, and 4 are 12, 10, 6, and 9, respectively, during 1987; and 11, 11, 5, and 9, respectively, during 1988. Each statistical sample represents the average of 10 analytical samples.

Table 29. Algae *t* test Results, Peoria Pool, 1987

	Mean (M_g, $\bar{x}$) for periods		*t-value*		*Hypothesis: $M_g1=M_g2$*		*Mean (M_g, $\bar{x}$) for periods*		*t-value*		*Hypothesis: $M_g1=M_g3$*	
Parameter	*1*	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Blue-green	45.39	129.42	1.80	2.09	X		4539	103.04	1.10	2.12	X	
Green	144.54	496.59	3.53	2.09		X	144.54	84.53	1.12	2.12	X	
Diatom	37.54	970.51	4.06	2.09		X	37.54	657.66	1.47	2.12	X	
Flagellate	60.67	77.27	0.53	2.09	X		60.67	6.61	4.85	2.12		X
Total	683.91	1774.19	3.65	2.09		X	683.91	874.98	0.62	2.12	X	
No.taxa	30.42	30.50	0.05	2.09	X		30.42	31.50	0.34	2.12	X	
Diversity index	3.49	2.91	2.57	2.09		X	3.49	2.37	4.64	2.12		X
	c Periods 1 and 4						**d. Periods 2 and 3**					
	1	*4*			*Mg1=Mg4*		*2*	*3*			*Mg2=Mg3*	
Blue-green	45.39	137.09	1.84	2.09	X		129.42	103.04	0.50	2.15	X	
Green	144.54	170.22	0.52	2.09	X		496.59	84.53	337	2.15		X
Diatom	37.54	524.81	1.09	2.09	X		970.51	657.66	1.06	2.15	X	
Flagellate	60.67	21.09	2.78	2.09		X	77.21	6.61	4.46	2.15		X
Total	683.91	901.57	0.96	2.09	X		1774.19	874.98	1.86	2.15	X	
No.taxa	30.42	31.67	0.61	2.09	X		30.50	31.50	0.29	2.15	X	
Diversity index	3.49	2.75	3.43	2.09		X	2.91	2.37	2.52	2.15		X
	e. Periods 2 and 4						**f. Periods 3 and 4**					
	2	4			*Mg2=Mg4*		*3*	*4*			*Mg3=Mg4*	
Blue-green	129.42	137.09	0.16	2.11	X		103.04	137.09	0.64	2.16	X	
Green	496.59	170.22	3.11	2.11		X	84.53	170.22	1.45	2.16	X	
Diatom	970.51	524.81	2.00	2.11	X		657.66	524.81	0.46	2.16	X	
Flagellate	77.27	21.09	2.86	2.11		X	6.61	21.09	2.94	2.16		X
Total	1774.19	901.57	2.56	2.11		X	874.98	901.57	2.56	2.16		X
No.taxa	30.50	31.67	0.56	2.11	X		31.50	31.67	0.04	2.16	X	
Diversity index	2.91	2.75	0.81	2.11	X		237	2.75	2.23	2.16		X

Note: Algae counts are expressed in number/mL; see note in table 27 for number of samples.
Mg = geometric mean for algae; *x* - arithmetic mean for number of taxa and diversity index.

Table 30. Algae *t* test Results, Peoria Pool, 1988

Parameter	Mean (M_g, $\bar{x}$) for periods		*t*-value		Hypothesis: $M_{g1}=M_{g2}$		Mean (M_g, $\bar{x}$) for periods		*t*-value		Hypothesis: $M_{g1}=M_{g3}$	
	1	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Blue-green	30.76	2735	0.29	2.09	X		30.76	160.69	4.94	2.12		X
Green	317.69	231.74	1.51	2.09	X		317.69	393.55	0.87	2.12	X	
Diatom	1088.93	557.19	3.13	2.09		X	1088.93	770.90	134	2.12	X	
Flagellate	6839	13.06	3.79	2.09		X	6839	21.88	2.24	2.12		X
Total	155239	851.14	2.77	2.09		X	1552.39	1419.06	037	2.12	X	
No. taxa	30.58	28.89	0.94	2.09	X		30.58	33.67	1.37	2.12	X	
Diversity index	2.88	3.04	1.22	2.09	X		2.88	336	3.46	2.12		X
	c. Periods 1 and 4						**d. Periods 2 and 3**					
	1	*4*			*Mg1=Mg4*		*2*	*3*			*Mg2=Mg3*	
Blue-green	30.76	47.97	1.80	2.09	X		27.35	160.69	3.27	2.16		X
Green	317.69	207.49	2.07	2.09	X		231.74	393.55	332	2.16		X
Diatom	1088.93	380.19	5.01	2.09		X	557.19	770.90	1.16	2.16	X	
Flagellate	6839	11.22	4.20	2.09		X	13.06	21.88	1.85	2.16	X	
Total	1552.39	666.81	4.34	2.09		X	851.14	1419.06	2.14	2.16	X	
No. taxa	30.58	32.89	1.08	2.09	X		28.89	33.67	3.09	2.16		X
Diversity index	2.88	3.58	5.61	2.09		X	3.04	336	1.94	2.16	X	
	e. Periods 2 and 4						**f. Periods 3 and 4**					
	2	*4*			*Mg2=Mg4*		*3*	*4*			*Mg3=Mg4*	
Blue-green	27.35	47.97	1.35	2.12	X		160.69	47.97	4.16	2.16		X
Green	231.74	207.49	0.77	2.12	X		393.55	207.49	4.40	2.16		X
Diatom	557.19	380.19	1.66	2.12	X		770.90	380.19	2.58	2.16		X
Flagellate	13.06	11.22	0.57	2.12	X		21.88	11.22	2.60	2.16		X
Total	851.14	666.81	1.28	2.12	X		1419.06	666.81	3.89	2.16		X
No. taxa	28.89	32.89	2.23	2.12		X	33.67	32.89	0.35	2.16	X	
Diversity index	3.04	3.58	3.67	2.12		X	3.36	3.58	1.43	2.16	X	

Note: Algae counts are expressed in number/mL; see note in table 27 for number of samples. *Mg* = geometric mean for algae; *x*= arithmetic mean for number of taxa and diversity index.

Table 31. Algae *t* test Comparison Results, Peoria Pool, 1987 and 1988

Parameter	*Mean (M_g, $\bar{x}$) for periods*		*t-value*		*Hypothesis: $M_g87=M_g88$*		*Mean (M_g, $\bar{x}$) for periods*		*t-value*		*Hypothesis: $M_g87=M_g88$*	
	1987	*1988*	*Calc*	*Theo*	*Acc*	*Rej*	*1987*	*1988*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Period 1						**b. Period 2**					
Blue-green	4539	30.76	0.75	2.07	X		129.42	2735	3.35	2.11		X
Green	144.54	317.69	2.82	2.07		X	49.59	231.74	2.53	2.11		X
Diatom	37.54	1088.93	4.75	2.07		X	970.51	557.19	2.55	2.11		X
Flagellate	60.67	68.39	0.27	2.07	X		77.27	13.06	4.04	2.11		X
Total	683.91	1552.39	3.37	2.07	X		1774.9	851.14	3.20	2.11		X
No. taxa	30.42	30.58	0.01	2.07	X		30.50	28.89	1.16	2.11	X	
Diversity index	3.49	2.88	3.39	2.07		X	2.91	3.04	0.68	2.11	X	
	c Period 3						**d. Period 4**					
Blue-green	103.04	160.69	0.91	2.23	X		137.09	47.97	3.59	2.12		X
Green	84.53	393.55	2.92	2.23		X	170.22	207.49	0.89	2.12	X	
Diatom	657.66	770.90	0.33	2.23	X		524.81	380.19	1.00	2.12		X
Flagellate	6.61	21.88	3.25	2.23		X	21.09	11.22	2.14	2.12		X
Total	874.98	1419.06	1.08	2.23	X		901.57	666.81	1.29	2.12	X	
No. taxa	31.50	33.67	0.50	2.23	X		31.67	32.89	0.50	2.12	X	
Diversity index	2.37	3.36	6.88	2.23		X	2.75	3.58	5.29	2.12		X

Note: Algae counts are expressed in numbers/mL; see note in table 27 for number of samples. *Mg* = geometric mean for algae; *x* = arithmetic mean for number of taxa and diversity index.

Table 32. Algae *t* test Results, LaGrange Pool, 1987

Parameter	Mean (M_g, $\bar{x}$) for periods		*t*-value		Hypothesis: $M_{g1}=M_{g2}$		Mean (M_g, $\bar{x}$) for periods		*t*-value		Hypothesis: $M_{g1}=M_{g3}$	
	1	2	Calc	Theo	Acc	Rej	1	3	Calc	Theo	Acc	Rej
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Blue-green	27.29	18.20	0.83	2.09	X		27.29	51.76	1.24	2.15	X	
Green	130.92	226.46	2.43	2.09		X	130.92	86.90	1.35	2.15	X	
Diatom	374.97	448.75	0.44	2.09	X		374.97	266.69	0.76	2.15	X	
Flagellate	52.00	29.51	1.57	2.09	X		52.00	7.71	4.36	2.15		X
Total	657.66	774.46	0.47	2.09	X		657.66	425.60	1.11	2.15	X	
No. taxa	2533	27.20	1.09	2.09	X		2533	26.83	0.12	2.15	X	
Diversity index	3.20	2.84	1.26	2.09	X		3.20	2.71	1.43	2.15	X	
	c. Periods 1 and 4						**d. Periods 2 and 3**					
	1	*4*			*Mg1=Mg4*		*2*	*3*			*Mg2=Mg3*	
Blue-green	27.29	23.12	0.37	2.11	X		18.20	51.76	2.28	2.15		X
Green	130.92	109.90	0.77	2.11	X		226.46	86.90	4.98	2.15		X
Diatom	374.97	310.46	0.46	2.11	X		448.75	266.69	1.52	2.15	X	
Flagellate	52.00	18.07	331	2.11		X	29.51	7.71	3.31	2.15		X
Total	657.66	493.17	0.84	2.11	X		774.46	425.60	2.30	2.15		X
No. taxa	25.33	28.44	1.67	2.11	X		27.20	26.83	0.18	2.15	X	
Diversity index	3.20	2.68	1.63	2.11	X		2.84	2.71	0.47	2.15	X	
	e. Periods 2 and 4						**f. Periods 3 and 4**					
	2	*4*			*Mg2=Mg4*		*3*	*4*			*Mg3=Mg4*	
Blue-green	18.20	23.12	0.57	2.11	X		51.76	23.12	2.54	2.20		X
Green	226.46	109.90	4.98	2.11		X	86.90	109.90	1.12	2.20	X	
Diatom	448.75	310.46	1.05	2.11	X		266.69	310.46	0.50	2.20	X	
Flagellate	29.51	18.07	1.67	2.11	X		7.71	18.07	2.58	2.20		X
Total	774.46	493.17	1.79	2.11	X		425.60	493.17	1.79	2.20	X	
No. taxa	27.20	28.44	0.67	2.11	X		26.83	28.44	0.72	2.20	X	
Diversity index	2.84	2.68	0.57	2.11	X		2.71	2.68	0.11	2.20	X	

Note: Algae counts are expressed in number/mL; see note in table 28 for number of samples. *Mg* = geometric mean for algae; *x* = arithmetic mean for number of taxa and diversity index.

Table 33. Algae *t* test Results, LaGrange Pool, 1988

Parameter	*Mean (M_g, $\bar{x}$) for periods*		*t-value*		*Hypothesis: $M_{g1}=M_{g2}$*		*Mean (M_g, $\bar{x}$) for periods*		*t-value*		*Hypothesis: $M_{g1}=M_{g3}$*	
	1	*2*	*Calc*	*Theo*	*Acc*	*Rej*	*1*	*3*	*Calc*	*Theo*	*Acc*	*Rej*
	a. Periods 1 and 2						**b. Periods 1 and 3**					
Blue-green	32.51	9.18	3.44	2.09		X	32.51	39.08	0.51	2.15	X	
Green	221.82	204.17	0.57	2.09	X		221.82	252.35	0.54	2.15	X	
Diatom	601.17	484.17	0.93	2,09	X		601.17	480.84	0.62	2.15	X	
Flagellate	30.08	13.43	2.65	2.09		X	30.08	14.96	1.57	2.15	X	
Total	924.70	699.84	1.33	2.09	X		924.70	822.24	039	2.15	X	
No. taxa	29.54	28.55	0.55	2.09	X		29.54	27.80	0.87	2.15	X	
Diversity index	3.04	3.16	0.92	2.09	X		3.04	3.33	1.52	2.15	X	
	c. Periods 1 and 4						**d. Periods 2 and 3**					
	1	*4*			*Mg1-Mg4*		*2*	*3*			*Mg2=Mg3*	
Blue-green	32.51	11.59	2.92	2.10		X	9.18	39.08	3.39	2.15		X
Green	221.82	175.39	1.42	2.10	X		204.17	252.35	1.32	2.15	X	
Diatom	601.17	276.70	3.25	2.10		X	484.17	480.84	0.02	2.15	X	
Flagellate	30.08	10.89	2.93	2.10		X	13.43	14.96	0.40	2.15	X	
Total	924.70	488.65	3.19	2.10		X	699.84	822.24	0.68	2.15	X	
No. taxa	29.54	2922	0.17	2.10	X		28.55	27.80	0.30	2.15	X	
Diversity index	3.04	3.38	2.51	2.10		X	3.16	3.33	0.90	2.15	X	
	e. Periods 2 and 4						**f. Periods 3 and 4**					
	2	*4*			*Mg2=Mg4*		*3*	*4*			*Mg3=Mg4*	
Blue-green	9.18	11.59	0.59	2.11	X		39.08	11.59	3.62	2.18		X
Green	204.17	175.39	1.50	2.11	X		252.35	175.39	1.97	2.18	X	
Diatom	484.17	276.70	3.11	2.11		X	480.84	276.70	1.94	2.18	X	
Flagellate	13.43	10.89	1.04	2.11	X		14.96	10.89	1.08	2.18	X	
Total	699.84	488.65	2.46	2.11		X	82224	488.65	2.69	2.18		X
No. taxa	28.55	29.22	0.31	2.11	X		27.80	2922	0.55	2.18	X	
Diversity index	3.16	3.38	1.65	2.11	X		3.33	3.38	027	2.18	X	

Note: Algae counts are expressed in number/mL; see note in table 28 for number of samples. *Mg* = geometric mean for algae; *x* = arithmetic mean for number of taxa and diversity index.

Table 34. Algae *t* test Comparison Results, LaGrange Pool, 1987 and 1988

Parameter	Mean (M_g, $\bar{x}$) for periods		*t*-value		Hypothesis: $M_g87=M_g88$		Mean (M_g, $\bar{x}$) for periods		*t*-value		Hypothesis: $M_g87=M_g88$	
	1987	1988	Calc	Theo	Acc	Rej	1987	1988	Calc	Theo	Acc	Rej
	a. Period 1						**b. Period 2**					
Blue-green	27.29	32.51	0.40	2.08	X		18.20	9.18	1.58	2.09	X	
Green	130.92	221.82	2.29	2.08		X	226.46	204.17	0.85	2.09	X	
Diatom	374.97	601.17	1.27	2.08	X		448.75	484.17	0.27	2.09	X	
Flagellate	52.00	35.08	0.94	2.08	X		29.51	13.43	2.88	2.09		X
Total	657.66	924.70	1.04	2.08	X		774.46	699.84	0.45	2.09	X	
No. taxa	25.33	29.54	2.62	2.08		X	27.20	28.55	0.71	2.09	X	
Diversity index	3.20	3.04	0.69	2.08	X		2.84	3.16	1.64	2.09	X	
	c. Period 3						**d. Period 4**					
Blue-green	51.76	39.08	1.36	2.26	X		23.12	11.59	2.01	2.13	X	
Green	86.90	252.35	3.51	2.26		X	109.90	175.39	3.78	2.12		X
Diatom	266.69	480.84	1.90	2.26	X		310.46	276.69	0.43	2.12	X	
Flagellate	7.71	14.96	1.43	2.26	X		18.07	10.89	2.45	2.12		X
Total	425.60	822.24	2.77	2.26		X	493.17	488.65	0.05	2.12	X	
No. taxa	26.83	27.80	0.38	2.26	X		28.44	29.22	0.36	2.12	X	
Diversity index	2.71	3.33	2.25	2.26	X		2.68	3.38	2.83	2.12		X

Note: Algae counts are expressed in number/mL; see note in table 28 for number of samples. *Mg* = geometric mean for algae; *x* = arithmetic mean for number of taxa and diversity index.

Table 35. Benthic Macroinvertebrate Densities Sampled in the Presence and Absence of Commercial Navigation, Peoria Pool, July and September 1987

Organism	IEPA pollution tolerance value	Station location bv river mile																			
		226.9		219.8		209.4		196.9		193.5		183.2		179.0		174.9		164.4		158.0	
		7/87	9/87	7/87	9/87	7/87	9/87	7/87	9187	7/87	9/87	7/87	9/87	7/87	9/87	7/87	9/87	1/87	9/87	7/88	9/87
Psychomyia sp.	2												19							13	19
Unionidae	2								6												
Corbicula manilensis	4	38	19	6	6	6	6		6												
Hexagenia limbata	5																		6		
Sphaerium sp.	5																			6	
Caenis sp.	6												6								6
Cheumatopsyche sp.	6						6		38				26							13	13
Chironomidae	6	281	179	210	159	19	64		96	83	45	96	83	13	6	32	45	38	26	77	64
Ceratopogonidae	7	13	6	6																	
Gomphus sp.	7													6							
Stenelmis sp.	7						6														
Chaoborus sp.	8															6					
Hirundinea	9											6									
Tubificidae	10	6	6	13	6	32	45		6	274	38	77		153	13	121	6	115	51		121
Total number of organisms		338	210	235	171	57	127	-	152	357	83	179	134	172	19	159	51	153	83	109	223
Total number of taxa		4	4	4	3	3	5	-	5	2	2	3	4	3	2	3	2	2	3	4	5
Shannon Weiner Diversity Index		0.86	0.80	0.65	0.44	1.34	1.65	-	1.47	0.78	1.00	1.17	1.49	0.60	0.90	0.94	0.52	0.81	1.23	1.32	1.68
IEP A MBI		5.9	6.0	6.2	6.1	8.0	7.4	-	5.9	9.1	7.8	7.8	5.4	9.6	8.7	9.1	6.5	9.0	8.4	5.5	7.8

Notes: Benthic macroinvertebrate densities are expressed as organisms per square meter
MBI = Macroinvertebrate Biotic Index.
No commercial navigation occurred during the July 1987 sampling, while commercial navigation had resumed before the September 1987 sampling.

Table 36. Benthic Macroinvertebrate Densities Sampled in the Presence and Absence of Commercial Navigation, LaGrange Pool, July and September 1987

Organism	IEPA pollution tolerance value	Station location by river mile																			
		155.0		*150.2*		*147.3*		*139.0*		*132.0*		*110.2*		*97.0*		*9.7*		*89.2*		*80.2*	
		7/87	*9/87*	*7/87*	*9/87*	*7/87*	*9/87*	*7/87*	*9/87*	*7/87*	*9/87*	*7/87*	*9/87*	*7/87*	*9/87*	*7/87*	*9/87*	*7/87*	*9/87*	*7/88*	*9/87*
Psychomyia sp.	2					6			26												
Unionidae	2											6									
Corbicula manilensis	4											6	6	19		45	6	6	6	38	
Sienonema sp.	4					6															
Hexagenia limbata	5																			6	
Caenis sp.	6																				
Cheumatopsyche sp.	6				57	217	6		19							83	51				
Chironomidae	6	70	108	51	179	6	45	51	32	6	77	13	57	274	191	644	32	242	57	51	51
Ceratopogonidae	7				13			45	51						6						
Stenelmis sp.	7			102	26					13	6										
Chaoborus sp.	8											6									
Tubificidae	10	32	32									166	51	32	13			6		268	57
Total number of organisms		102	140	153	275	235	51	96	128	19	83	197	114	325	210	791	89	254	63	363	108
Total number of taxa		2	2	2	4	4	2	2	4	2	2	5	3	3	3	5	3	3	2	4	2
Shannon-Weiner Diversity Index		0.90	0.78	0.92	1.40	0.51	0.52	1.00	1.90	0.90	0.37	0.93	1.24	0.78	0.52	0.97	1.25	0.32	0.45	1.16	1.00
IEPAMBI		7.2	6.9	6.7	6.1	5.8	6.0	6.5	5.6	6.7	6.1	9.2	7.7	6.3	6.3	5.9	5.9	6.0	5.8	8.7	8.1

Notes: Benthic macroinvertebrate densities are expressed as organisms per square meter.
MBI = Macroinvertebrate Biotic Index.
No commercial navigation occurred during the July 1987 sampling, while commercial navigation had resumed before the September 1987 sampling.

Table 37. Benthic Macroinvertebrate Densities Sampled in the Peoria Pool, July and September 1988

Organism	IEPA pollution tolerance value	Station location bv river mile																			
		226.9		219.8		209.4		196.9		193.5		183.2		179.0		174.9		164.4		158.0	
		7/88	9/88	7/88	9/88	7/88	9/88	7/88	9/88	7/88	9/88	7/88	9/88	7/88	9/88	7/88	9/88	7/88	9/88	7/88	9/88
Chaoborus punctipennis														6							
Chironomus sp.	11*																				
Chironomus tentans	11					6														6	
Cryptochimomus fulvus	8					13		89		89				13				204	19	26	
Gtyptotendipes barbipes	10	45		38		64		19	6	6	13	19	13	13				13		38	6
Gtyptotendipes lobiferus	10																				
Gtyptotendipes panpes	10					13			6				6								6
Mtcrochironomus sp.						26															
Palpomyip tibialis	6																				
Paratendipes duplicatus	3																			6	
Pentaneura flavifrons	3			6				160	13	38	26	6	19	440	179	664	115	721	115	415	57
Pentaneura melanops	3																				
Polypedilum flavus	6										19						45				
Potamyia flava	4	51	26	51	64	249	166		38		38	19	13							6	13
Hexagenia atrocaudata	6																				
Gomphus notatus	7													6	19			13			6
Berosus sp.									6												
Zaitzevia sp.			6															6			
Helobdella elongata	8																				
Helobdella stagnalis	8											45								19	
Uniomerus telralasmus	1																	19			
Tubificidae	10	19	57		217	179	89	198	172	287	223	179	70	160	147	1448	1168	772	798	332	753
Total number of organisms		115	89	95	281	550	255	466	241	420	319	268	121	638	345	2112	1328	1748	932	848	841
Total number of taxa		3	3	3	2	7	2	4	6	4	5	5	5	6	3	2	3	7	3	8	6
Shannon-Weiner Diversity Index		1.48	1.19	1.26	0.77	1.94	0.93	1.70	1.39	1.25	1.45	1.49	1.78	1.23	1.25	0.90	0.63	1.61	0.68	1.66	0.65
1EPAMBI		7.4	8.2	6.6	9.1	7.5	7.4	7.7	8.9	9.6	8.5	9.1	8.3	5.0	6.1	7.8	9.2	7.1	9.2	6.4	9.4

Motes: Benthic macroinvertebrate densities are expressed as organisms per square meter.
MBI = Macroinvertebrate Biotic Index.

Table 38. Benthic Macroinvertebrate Densities Sampled in the LaGrange Pool, July and September 1988

Organism	1EPA pollution tolerance value	Station location by river mile 155.0		150.0		147.3		139.0		132.0		119.7		110.2		97.0		89.2		80.0	
		7/88	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*	*7/88*	*9/88*
Chaoborus punctipennis																					
Chironomus sp.	11			70																	6
Chironomus tentans	11																				
Crytochironomusfulvus	8											6						19		644	
Ghptotendipes barbipes	10	13		13								147	6	13				45		6	
Glyptotendipes lobiferus	10		6								6		19								
Ghptotendipes panpes	10					6										13		38			
Microchironomus sp.																		77			
Palpomyia tibialis	6											6						6			
Pamtendipes duplicautus	3	191		351		83		306		338											
Pentaneura flavifrons	3																				
Pentaneura melanops	3	6	13	13				6					6					19		453	51
Polypedilum flavus	6		191		147		13		26		13		32	13			19		77		
Potamyia flava	4																				
Hexagenia atrocaudata	6									6											
Gomphus notatus	7																				
Berosus sp.																					
Zaitzevia sp.																		6			
Helobdella elongata	8																				
Helobdella stagnalis	8																				
Unionmerus tetralasmus	1				6																
Tubificidae	10	102	134	294	115	19	115	166	140	32	26	96	45	13	13	83	115	38	166	6	77
Total number of organisms		312	344	741	268	108	128	478	166	376	45	255	108	39	13	96	134	248	243	1115	134
Total number of taxa		4	4	5	3	3	2	3	2	3	3	4	5	3	1	2	2	8	2	4	3
Shannon-Weiner Diversity Index		1.26	1.28	1.57	1.12	.97	0.47	1.02	0.63	0.54	1.36	1.24	1.95	1.59	0.0	0.57	0.59	2.63	0.90	1.12	1.19
IEPA MBI		5.5	7.5	6.6	7.6	4.6	9.6	5.4	9.4	3.6	8.8	8.8	8.3	8.0	10.0	10.0	9.4	8.8	8.7	7.7	7.4

Notes: Benthic macroinvertebrate densities are expressed as organisms per square meter.
MBI = Macroinvertebrate Biotic Index.

Table 39. Benthos and Benthic Sediment *t* test Results, July and September 1987 and 1988

	1987						1988					
	Mean ($\bar{x}$) for date		*t-value*		*Hypothesis: $\bar{x}_7=\bar{x}_9$*		*Mean ($\bar{x}$) for date*		*t-value*		*Hypothesis: $\bar{x}_7=\bar{x}_9$*	
Parameter	*7/87*	*9/87*	*Calc*	*Theo*	*Acc*	*Rej*	*7/88*	*9/88*	*Calc*	*Theo*	*Acc*	*Rej*
a. Peoria Pool-One Year												
Total number	201.00	125.30	1.92	2.10	X		724.00	475.50	0.99	2.10	X	
Log total no.	175.79	103.27	1.71	2.10	X		476.43	341.19	0.79	2.10	X	
Number taxa	3.11	3.50	0.79	2.10	X		4.90	3.80	1.36	2.10	X	
IEPAMBI	7.80	7.00	1.28	2.10	X		7.42	8.41	1.88	2.10	X	
Diversity index	0.94	1.09	0.87	2.10	X		1.45	1.07	2.40	2.10		X
% moisture	35.33	39.12	0.54	2.10	X		39.84	41.69	0.20	2.10	X	
% vol. solids	4.21	4.40	0.18	2.10	X		5.11	5.29	0.15	2.10	X	
b. LaGrange Pool - One Year												
Total number	253.50	126.10	1.77	2.10	X		376.80	158.30	1.99	2.10	X	
Log total no.	177.42	116.69	1.30	2.10	X		255.27	118.30	1.75	2.10	X	
Number taxa	3.20	2.70	1.07	2.10	X		3.90	2.70	1.87	2.10	X	
IEPA MBI	7.47	6.62	1.75	2.10	X		6.90	8.67	2.45	2.10		X
Diversity index	0.84	0.95	0.61	2.10	X		1.25	0.95	1.17	2.10	X	
% moisture	22.73	20.13	0.87	2.10	X		25.00	22.18	0.81	2.10	X	
% vol. solids	1.55	1.31	0.58	2.10	X		2.81	2.09	1.04	2.10	X	
c. Peoria Pool-Two Years												
	7/87	*7/88*			$\bar{x}_{87}=\bar{x}_{88}$		*9/87*	*9/88*			$\bar{x}_{87}=\bar{x}_{88}$	
Total number	201.00	724.00	0.99	2.10	X		125.30	475.50	0.83	2.10	X	
Log total no.	175.79	476.43	2.58	2.10		X	103.27	341.19	3.29	2.10		X
Number taxa	3.11	4.90	1.07	2.10	X		3.50	3.80	0.10	2.10	X	
IEPAMBI	7.80	7.42	0.73	2.10	X		7.00	8.41	0.54	2.10	X	
Diversity index	0.94	1.45	2.01	2.10	X		1.09	1.07	0.02	2.10	X	
% Moisture	35.33	39.84	0.64	2.10	X		39.12	41.69	0.72	2.10	X	
% Vol. solids	4.21	5.11	1.94	2.10	X		4.40	5.29	1.63	2.10	X	
d. LaGrange Pool-Two Years												
Total number	253.50	376.80	0.99	2.10	X		126.10	158.30	0.83	2.10	X	
Log total no.	177.42	255.27	0.81	2.10	X		116.69	118.30	0.17	2.10	X	
Number taxa	3.20	3.90	1.07	2.10	X		2.70	2.70	0.00	2.10	X	
IEPAMBI	7.47	6.90	0.73	2.10	X		6.62	8.67	5.34	2.10		X
Diversity index	0.84	1.25	2.01	2.10	X		0.95	0.95	0.02	2.10	X	
% Moisture	22.73	25.00	0.64	2.10	X		20.13	22.18	0.72	2.10	X	
% Vol. solids	1.55	2.81	1.94	2.10	X		1.31	2.09	1.63	2.10	X	

Note: n = 10 samples per period.

Table 40. Regression Equation Coefficients, Correlation Coefficients, and Coefficients of Determination for Data Plots in Figures 11-22

Independent variable (x):	*Barges*	*(no.ldav)*			*Flow (cfs % 1000)*			
Dependent variable (y)	*a*	*b*	*r*	r^2	*a*	*b*	*r*	r^2
a. Peoria Pool								
Turbidity	59.0	-1.64	-0.2256	0.0509	18.0	3.187	0.9609	0.9234
Suspended solids	61.2	-1.90	-0.2167	0.0470	11.9	3.844	0.9650	0.9312
Secchi disk	10.7	0.18	0.2195	0.0482	15.1	-0.338	-0.8964	0.8035
Surface DO	7.4	0.08	0.1865	0.0348	9.2	-0.129	-0.6740	0.4543
Bottom DO	6.7	0.04	0.1058	0.0112	7.1	-0.017	-0.0975	0.0095
Total algae count	1422.3	-73.22	-0.3990	0.1592	1430.6	-32.200	-0.3843	0.1477
b. LaGrange Pool								
Turbidity	86.5	-3.18	-0.2832	0.0802	7.4	6.175	0.9601	0.9207
Suspended solids	99.7	-4.18	-0.2817	0.0794	-6.1	8.302	0.9772	0.9550
Secchi disk	9.5	-0.04	-0.0648	0.0042	11.7	-0.222	-0.6971	0.4859
Surface DO	5.7	0.10	0.3770	0.1421	6.5	-0.034	-0.2267	0.0514
Bottom DO	5.4	0.07	0.2274	0.0517	5.3	0.034	0.2069	0.0428
Total algae count	644.5	3.83	0.0624	0.0039	904.6	-23.100	-0.6578	0.4327

Table 41. Time Required for the Return of Ambient Water Quality Conditions After Tow Passage

				Return to ambient (minutes)						
				Suspend. solids			*Turbidity*			*DO*
River	*Mile*	*Event*	*No. tows*	*L*	*C*	*R*	*L*	*C*	*R*	*C*
Mississippi	744.6	1	2	120	45	125	60	130	65	-
		2	3	50	50	50	-	30	40	30
		3	1	90	120	180+	90	80	0	0
	472.0	4	3	0	0	180+	0	0	0	56
		5	1	0	40	180+	0	0	0	0
		6	3	0	129	0	0	0	40	40
	258.0	7	1	0	0	0	0	0	0	0
		8	1	15	0	0	0	0	0	0
		9	3	0	0	0	?	0	?	0
Illinois	215.8	1	3	58	58	180+	140	198	73	0
		2	5	60	100	180+	182	182	180+	30
	113.5	3	2	110	50	0	120	110	0	0
		4	4	284	284	125	254	129	254	0
	31.0	5	3	25	143	0	60	65	0	0
		6	4	180+	128	180+	180+	71	180+	0

Notes: R = right and L = left bank looking downstream; C = main channel; 180+ denotes ambient conditions did not return within the alloted sampling time.

Source: Johnson, 1976.

Table 42. Field-Measured Water Quality Data for Days of High- and Low-Density Barge Traffic

Parameter	*No. samples*	*Mean* ($\bar{x}$) *Low* *9/21/88*	*High* *9/23/88*	*Standard deviation (s)* *Low* *9/21/88*	*High* *9/23/88*	*t-value* *Calc*	*Theo*	**Hypothesis:** $\bar{x}_L = \bar{x}_M$ **Acc**	**Rej**
a. LaGrange Pool									
	10	8.08	7.94	0.17	0.09	2.26	2.10		X
Secchi disk	10	10.60	5.50	2.99	1.65	4.72	2.10		X
Temp: 0'	29	22.11	22.09	0.61	0.54	0.14	2.01	X	
3'	29	21.97	22.08	0.48	0.52	0.84	2.01	X	
Mid	29	21.93	22.05	0.44	0.51	0.92	2.01	X	
Btm	29	21.93	22.05	0.45	0.51	0.94	2,01	X	
DO: 0'	29	6.77	6.08	0.95	0.76	3.11	2.01		X
3'	29	6.52	6.02	0.95	0.79	2.17	2.01		X
Mid	29	6.45	6.00	0.97	0.81	1.93	2.01	X	
Btm	29	6.39	6.01	1.01	0.81	1.57	2.01	X	
b. Peoria Pool									
		6/28/88	*6/24/88*	*6/28/88*	*6/24/88*				
pH	10	8.66	8.21	0.14	0.13	7.54	2.10		X
Secchi disk	10	13.80	12.00	4.69	1.76	1.14	2.10	X	
Temp: 0'	28	24.97	24.86	0.77	0.34	0.67	2.01	X	
3' 28	24.36	24.83	0.63	0.37	0.37	2.01	X		
Mid	28	23.65	24.82	0.83	0.36	7.10	2.01		X
Btm	28	23.60	24.74	0.79	0.36	6.93	2.01		X
DO: 0'	28	11.01	5.88	2.81	1.19	8.89	2.01		X
3'	28	9.28	5.78	2.37	1.19	6.99	2.01		X
Mid 28	7.16	5.77	2.04	1.20	3.11	2.01		X	
Btm 28	6.94	5.72	2.00	1.21	2.76	2.01		X	

APPENDIX A:

NEWSPAPER COVERAGE OF THE DAM CLOSING AND THE ILLINOIS STATE WATER SURVEY STUDY

Barges and the Illinois

State to study how barges affect the river's ecology

By TOM EDWARDS
For the Journal Star

The huge barge tow slides powerfully by, pulling the river down into its churning wake, then sending waves crashing into the embankments on its passage. Its great propellers swirl clouds of fine sediment back up from the river bottom, to hang suspended again in the water, block penetration of sunlight, drift into backwater lakes — affecting all the river.

This has been the sentiment of conservationists over the years in their argument against creating bigger locks and deeper channels for still bigger, more powerful tows.

This summer there will be a scientific effort to measure how great — or little — is the effect of barge traffic on the river's ecology.

It will be done in conjunction with the closing of the Peoria and LaGrange locks during July and August for major repairs, during which time there is likely to be little or no barge traffic on the 160-mile stretch of river from LaGrange to Starved Rock (the top of the Peoria Lock and Dam pool).

The Illinois State Water Survey laboratory here, which will conduct the study, learned Wednesday that its application for a $49,371 state grant for it had been approved.

Proposer and leader of the study is Tom Butts, a veteran researcher and associate section head of the ISWS laboratory. And he's excited about it.

"Only every 50 to 100 years is there an opportunity to do this," he said.

"For years a debate has raged among ecologists, environmentalists, and responsible regulatory officials as to the role barge traffic has played in the degradation of the Illinois waterway quality," he wrote in his grant application. "Circumstantial evidence indicates it has contributed significantly to water quality problems. An opportunity now exists for directly examing" this.

"We are going to be collecting physical, chemical and biological data," Butts said.

"It will be a nuts and bolts, grind them out, type of data gathering," he said. "Not an ivory tower type of scientific study."

The study "won't show any long-term environmental effects; but it will show if there are any short-term effects," he continued.

"Speculatively, you can expect an increase in water clarity, and, in turn, a little bit of increase in algae growth" due to greater light penetration into the water.

Blue-green algae is the species that usually increases, which has some unpalatable effects of its own, one being the taste and odor it imparts to water.

"If the dams weren't there, we wouldn't have the blue-green algae blooms," Butts said. "They are a quiet water algae."

The formal title of the study.is, "A Comparison of Illinois River Water Quality During Commercial and Non-Commercial Navigation Periods."

Actual sampling will begin in June, a month before the locks close, and continue through September, a month after they open.

"Before and after the locks are closed, there will be a very high density barge traffic (to get ahead and catch up respectively with deliveries)," Butts said. "We want to measure the effect this high density traffic will have, too."

For comparison, identical sampling will be done during the same four-month period next year when barge traffic should be again normal.

Given comparable river conditions other than the presence or absence of barge tows, Butts expects to produce some telltale evidence of the effects of barge traffic.

The value will be in providing more information for making future decisions in regard to river use, more data against which to weigh evironmental impacts, he said.

Flooding would be the biggest hamper. Besides greatly affecting water quality itself, at high water levels the dam wickets are lowered and barges can negotiate the river without using the locks.

The study will measure the water for oxygen content, temperature, clarity, alkalinity and acidity, numbers of bottom organisms (worms, fingernail clams), hardness, ammonia, algae and ortho-phosphates.

Crews will traverse the 160-mile length of river 2½ times a week during the study period. "We have a lot of good equipment; and we are very well prepared for this," Butts said.

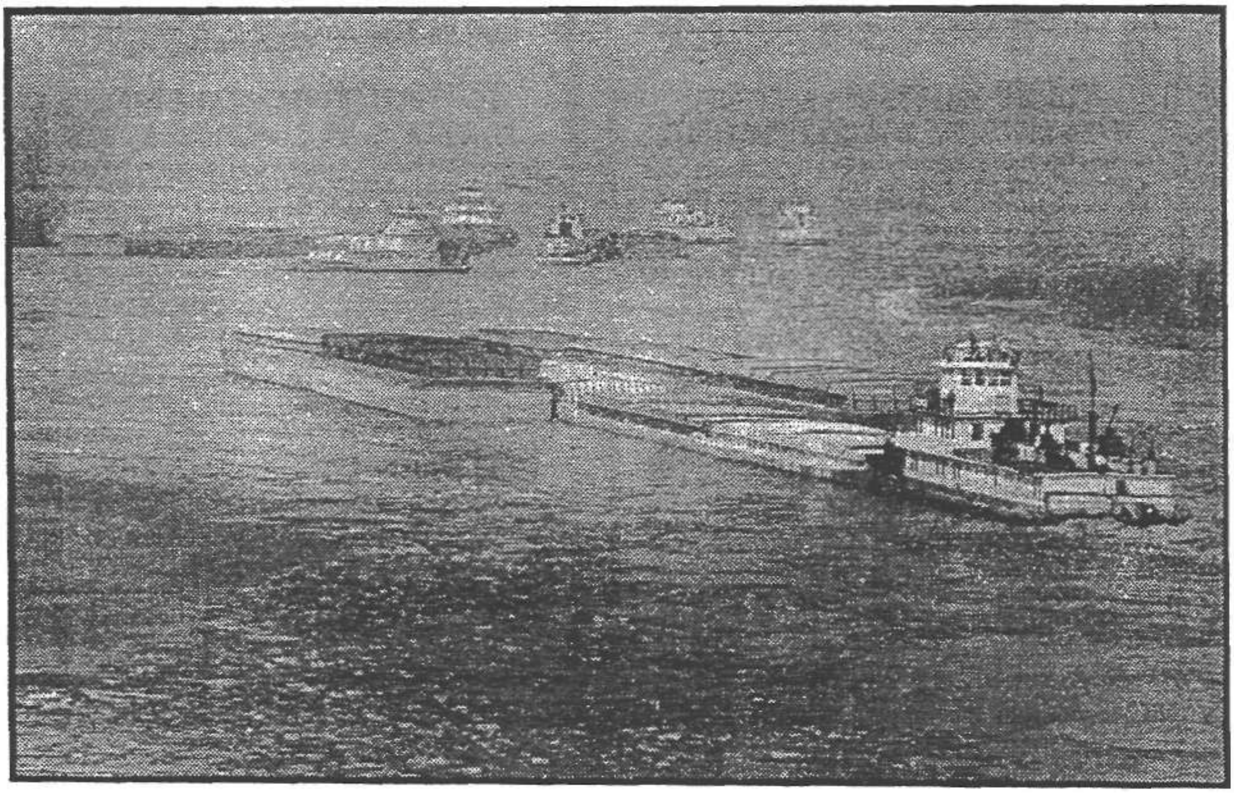
It was decided to take samples up and down the river rather than at one or more cross-sectional points because of the many environmental differences in the river along its way, he said. "We want a profile of the river" and the varying effects of barge traffic on it.

The Illinois Department of Energy and Natural Resources is providing the funds.

In the narrower and faster upstream portion of the river above Starved Rock, about a quarter of the water clarity problem was attributed to barge traffic in a month-long study of that alone by the Illinois Natural History Survey several years ago.

Natural wave action and pleasure: motorboats also affect the suspended sediment load of the river, which largely determines the murkiness (clarity) of the water. -

Tom Edwards is a former Journal Star environmental reporter who occasionally writes free-lance stories.



BARGES MAKE THEIR WAY ALONG THE ILLINOIS RIVER

APPENDIX B:

NEWSPAPER COVERAGE ON INCREASING THE DEPTH OF PEORIA LAKE BY RAISING THE HEIGHT OF THE PEORIA DAM

Peoria Journal Star April 18, 1986

Raising the locks, sediment control key to panel

By THEO JEAN KENYON
of the Journal Star

A Tri-County Regional Planning Commission subcommittee looking into technical aspects of solving Peoria Lake's sedimentation problems agreed Thursday night to pursue recommendations that include raising the Peoria Lock and Dam.

The technical and interagency committee of the Peoria Lake-Illinois River study advisory committee said it "puts the highest priority on control of sedimentation into the river, with the assumption that it will be effective at some point"

Next it voted to move ahead speedily by addressing the issue of raising the dam" and said it will continue to investigate a concept of selective dredging and creation of artificial islands.

Both ideas are among five alternatives presented in a Illinois State Water Survey study, sponsored by the Army Corps of Engineers, Rock Island District.

Committee Chairman Otis Michels described ways in which the islands could be created, and pointed out existing islands that were charted in Upper and Lower Peoria Lakes on navigation maps at the start of the century.

But Richard Grawey, a local Citizens Utility Board representative,expressed concern about risks that could be involved, saying "there are many unknown issues with regard to dredging and island building."

The committee agreed that detailed hydraulic and environmental studies would be required. It will ask for studies made in connection with islands created on the Mississippi River for wildlife refuge.

More urgent is the raising of the Peoria Lock and Dam because the corps has a project in design to rehabilitate the facility, and Michels said the corps will complete the design this year.

Michels said he would be at the corps' Rock Island District office today, and would try to find out "when they have to have final authorization to design a higher gate."

Betty Menold, who chairs the Peoria County Board and is a committee member, moved that Michels begin the process of trying to determine the needed time frame from the corps.

Where the money will come from to pay for the recommended alternatives is unresolved. A finance subcommittee is studying the issue.

However, technical committee members talked about the possibility of creating a port authority or a taking district to generate the needed money, or using an existing legal body.

Port authorities already exist in many Illinois cities: Waukegan, Joliet, Seneca, Shawneetown, Kaskaskia and Havana to name a few.

Richard Bjorklund of the committee also suggested that Build Illinois money would be appropriate since it is the economy of the state that would be affected if Peoria Lake were lost

"The state should care if we lose recreation on the Illinois River, and people go to Missouri instead," Bjorklund.said.

Another possible source of funding is the Upper Mississippi River System Environmental Management Program, of which the Illinois River is a part, but committee members doubted if a project can be put together in time for funding in this fiscal year.

Robert Pinkerton, executive director of the. Tri-County Regional Planning Commission, suggested some money might be sought for a marketing consultant to provide graphics on the proposed solutions.

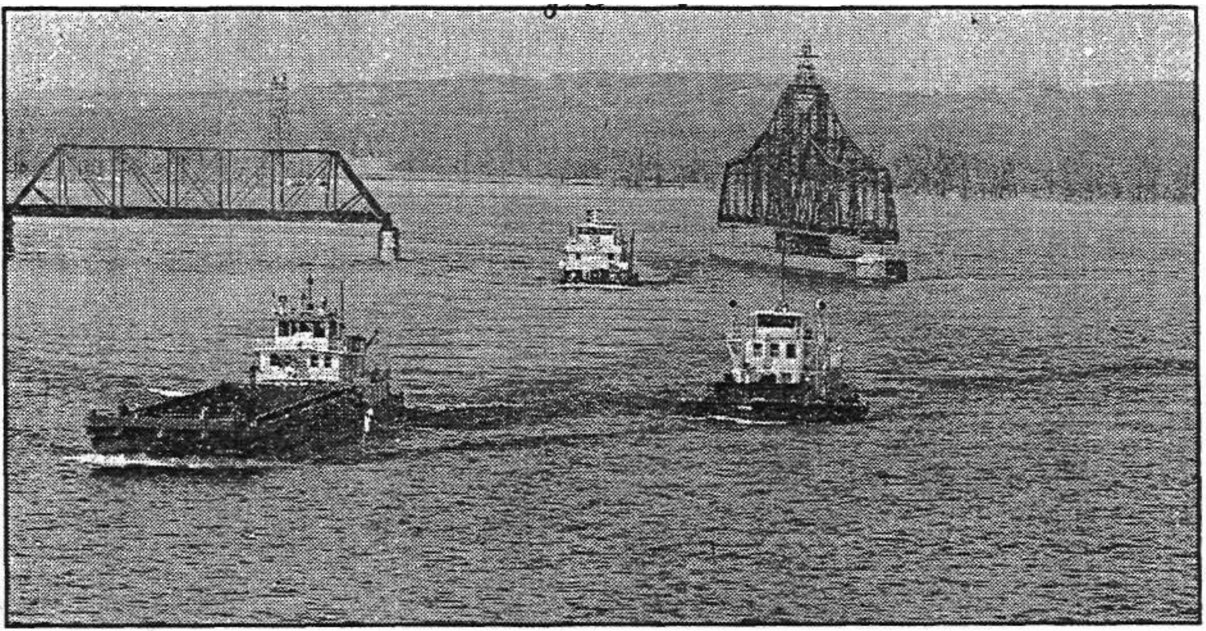
In addition to the technical committee, the Peoria Lake-Illinois River study advisory committee has three other subcommittees: finance committee, Charles Blye, chairman; mitigation committee, William Rutherford, chairman; and planning and design committee, Leland Kew, chairman.

The technical committee will meet at 4 p.m. May 15 at Douglas Hall on the Illinois Central College campus.

APPENDIX C:

NEWSPAPER COVERAGE OF U.S. ARMY CORPS OF ENGINEERS' ANNOUNCEMENT OF NAVIGATION RECONNAISSANCE STUDY ON THE ILLINOIS WATERWAY

Tuesday, August 15, 1989



HEAVY TRAFFIC — Are there too many barges and other boat traffic on the Mississippi River? A two-year study seeks to answer that question'.

River congestion prompts study on possible solutions

By Ed Tlbbetts
QUAD-CITY TIMES

Heavy traffic on the Mississippi and Illinois rivers has prompted the U.S. Army Corps of Engineers to look for ways to clear some of the congestion.

The Corps will begin studying traffic patterns and navigation habits on the Mississippi River in November and on the Illinois in March.

The problem is two-fold — a 50-year-old system and an increase in commercial and recreational traffic. The Corps says the problem is bothersome now, but will only get worse if nothing is done.

In the Quad-Cities, traffic is not considered a problem, but is steady, said Bob Faletti, chief of public relations with the Corps' Rock Island District. The average waiting time for this time of year at Lock and Dam 15 in the Quad-Cities is about 2½ hours.

"The closer to St. Louis you get, the longer the waiting time," Faletti said. At Lock and Dam 22, just south of Hannibal, Mo., the waiting time over the weekend was 40 hours.

The studies will extend from St. Paul, Minn., to St. Louis, Mo., whose districts will" join Rock Island in the work: They should be completed by June 1991 at a cost of $1.5 million.

APPENDIX D:

1986 DISSOLVED OXYGEN/TEMPERATURE DATA

DO/Temperature Statistical Summary For 40 1986 Dates and 2 1985 Dates (n=42)

COE river mile	Depth	*Dissolved Oxygen (mg/L)*					*C.I.*		*Temperature (°C)*		
		Min	*Avg*	*Max*	*S*	$\sigma_{\bar{x}}$	*95%*	*99%*	*Min*	*Avg*	*Max*
231.0	0	6.34	8.93	11.78	1.05	0.16	6.9-10.9	6.2-11.6	21.0	26.17	29.9
	3	6.36	8.91	11.70	1.03	0.16	6.9-10.9	6.3-11.6	21.0	26.16	29.9
	Mid	6.33	8.88	11.61	1.03	0.16	6.9-10.9	6.2-11.5	20.9	26.16	29.9
	Btm	6.33	8.85	11.39	0.99	0.15	6.9-10.8	6.3-11.4	20.8	26.15	29.9
229.6	0	6.28	8.81	11.65	1.06	0.16	6.7-10.9	6.1-11.5	20.8	26.15	29.8
	3	6.22	8.79	11.71	1.09	0.17	6.7-10.9	6.0-11.6	20.7	26.12	29.8
	Mid	6.22	8.76	11.62	1.08	0.17	6.6-10.9	6.0-11.5	20.7	26.12	29.8
	Btm	6.22	8.75	11.45	1.07	0.17	6.6-10.8	6.0-11.5	20.6	26.11	29.7
226.9	0	6.11	8.90	11.66	1.22	0.19	6.5-11.3	5.8-12.0	20.9	26.13	29.7
	3	6.08	8.80	11.42	1.16	0.18	6.5-11.1	5.8-11.8	20.8	26.09	29.6
	Mid	6.08	8.75	1135	1.11	0.17	6.6-10.9	5.9-11.6	20.8	26.07	29.7
	Btm	6.07	8.72	11.23	1.06	0.16	6.6-10.8	6.0-11.5	20.9	26.06	29.6
224.7	0	5.89	8.75	11.50	1.18	0.18	6.4-11.1	5.7-11.8	20.7	26.21	29.7
	3	5.89	8.61	11.59	1.09	0.17	6.5-10.7	5.8-11.4	20.7	26.14	29.5
	Mid	5.89	8.54	11.56	1.06	0.16	6.5-10.6	5.8-11.3	20.7	26.11	29.6
	Btm	5.81	8.49	11.44	1.03	0.16	6.5-10.5	5.8-11.1	20.8	26.09	29.5
222.6	0	5.94	8.46	11.04	1.03	0.16	6.4-10.5	5.8-11.1	20.7	26.21	29.5
	3	5.89	8.22	10.94	0.92	0.14	6.4-10.0	5.8-10.6	20.6	26.12	29.4
	Mid	5.89	8.08	10.87	0.85	0.13	6.4-9.7	5.9-10.3	20.6	26.09	29.4
	Btm	5.87	8.05	10.51	0.82	0.13	6.4-9.6	5.9-10.2	20.0	26.05	29.4
219.8	0	5.96	8.20	11.92	1.08	0.17	6.1-10.3	5.4-11.0	20.9	26.25	29.6
	3	5.95	8.11	11.66	1.01	0.16	6.1-10.1	5.5-10.7	20.8	26.22	29.5
	Mid	5.94	8.06	11.71	1.01	0.16	6.1-10.0	5.4-10.7	20.9	26.21	29.5
	Btm	5.94	8.04	11.56	0.97	0.15	6.1-9.9	5.5-10.5	20.9	26.20	29.5
217.1	0	6.07	8.41	11.82	1.20	0.18	6.0-10.8	5.3-11.5	20.9	26.32	30.0
	3	6.04	8.26	11.75	1.16	0.18	6.0-10.5	5.3-11.2	20.9	26.27	29.9
	Mid	6.00	8.21	11.70	1.15	0.18	5.9-10.5	5.2-11.2	20.9	26.25	29.9
	Btm	6.02	8.18	11.49	1.12	0.17	6.0-10.4	5.3-11.1	21.0	26.23	29.9

S =Standard Deviation and

$\sigma_{\bar{x}}$ = Standard Error of Estimate of the mean = S /(n)½

DO/Temperature Statistical Summary For
40 1986 Dates and 2 1985 Dates (n=42)

COE river mile	Dissolved Oxygen (mg/L)								Temperature (°C)		
							C.I.				
	Depth	*Min*	*Avg*	*Max*	*S*	$\sigma_{\bar{x}}$	*95%*	*99%*	*Min*	*Avg*	*Max*
213.4	0	6.22	8.63	11.41	1.33	0.20	6.0-11.2	5.2-12.0	20.7	2635	30.1
	3	6.20	8.36	10.84	1.14	0.18	6.1-10.6	5.4-113	20.7	26.24	29.9
	Mid	6.18	8.23	10.77	1.07	0.17	6.1-103	53-11.0	20.7	2621	29.9
	Btm	6.15	8.15	10.65	1.03	0.16	6.1-10.2	5.5-10.8	20.8	26.18	29.8
209.4	0	6.20	8.35	11.65	1.33	0.21	5.7-10.9	4.9-11.8	21.1	26.66	29.9
	3	6.18	8.01	11.57	1.14	0.18	5.8-10.2	5.1-10.9	21.1	26.48	29.8
	Mid	6.15	7.77	11.50	1.03	0.16	5.7-9.8	5.1-10.4	21.0	26.40	29.7
	Btm	6.18	7.67	11.32	0.94	0.15	5.8-9.5	5.2-10.1	21.1	2633	29.6
205.4	0	6.01	8.09	11.70	137	0.21	5.4-10.8	4.6-11.6	21.3	26.64	303
	3	5.97	7.84	11.57	1.21	0.19	5.5-10.2	4.7-10.9	21.2	26.47	29.6
	Mid	5.96	7.67	11.44	1.08	0.17	5.5-9.8	4.9-10.4	21.0	26.42	29.6
	Btm	5.96	7.62	11.26	1.05	0.16	5.6-9.7	4.9-103	212	26.39	29.6
200.4	0	5.63	7.87	10.51	1.26	0.19	5.4-103	4.6-11.1	21.2	26.65	30.2
	3	5.62	7.63	10.21	1.12	0.17	5.4-9.8	4.710.5	21.0	26.49	30.1
	Mid	5.60	7.49	10.10	1.04	0.16	5.4-9.5	4.8-10.2	21.0	26.46	30.0
	Btm	5.59	7.44	9.93	0.99	0.15	5.5-9.4	4.9-10.0	21.0	26.43	30.0
196.9	0	5.90	8.00	11.06	1.30	0.20	5.4-10.5	4.6-113	21.2	26.69	31.0
	3	5.75	7.51	10.98	1.10	0.17	5.3-9.7	4.7-103	21.1	2636	30.2
	Mid	5.70	7.17	10.91	1.01	0.16	5.2-9.1	4.6-9.8	21.0	26.16	29.8
	Btm	5.70	7.06	10.96	0.98	0.15	5.1-9.0	4.5-9.6	21.1	26.12	29.8
190.0	0	5.42	7.68	10.72	1.41	0.22	4.9-10.4	4.0-113	20.9	26.57	30.8
	3	5.44	7.17	10.49	1.04	0.16	5.1-9.2	4.5-9.8	20.9	26.35	29.8
	Mid	5.42	6.93	10.17	0.90	0.14	5.2-8.7	4.6-9.2	20.8	26.23	29.6
	Btm	5.20	6.87	9.80	0.91	0.14	5.1-8.6	4.5-9.2	20.7	26.18	29.6
188.0	0	5.50	7.44	10.63	1.34	0.21	4.8-10.1	4.0-10.9	21.2	26.53	30.8
	3	5.47	7.04	10.66	1.05	0.16	5.0-9.1	43-9.7	21.2	26.30	30.0
	Mid	5.41	6.76	10.70	0.97	0.15	4.8-8.7	43-9.2	21.1	26.18	29.7
	Btm	5.35	6.65	10.64	0.93	0.14	4.8-8.5	4.2-9.0	20.9	26.10	29.6

S = Standard Deviation and

$\sigma_{\bar{x}}$ = Standard Error of Estimate of the mean = S /(n)½

DO/Temperature Statistical Summary For 40 1986 Dates and 2 1985 Dates (n=42)

COE river mile		Dissolved Oxygen (mg/L)							Temperature (°C)		
							C.I.				
	Depth	Min	Avg	Max	S	$\sigma_{\bar{x}}$	95%	99%	Min	Avg	Max
183.0	0	5.50	7.29	10.54	1.34	0.21	4.7-9.9	3.8-10.7	21.2	26.53	30.4
	3	5.40	6.76	9.61	0.92	0.14	4.9-8.6	4.4-9.1	21.1	26.28	30.0
	Mid	5.27	6.65	9.57	0.83	0.13	5.0-8.3	4.5-8.8	21.1	26.24	30.0
	Btm	5.07	6.60	9.57	0.86	0.13	4.9-8.3	4.4-8.8	21.1	2621	30.0
179.0	0	5.29	7.04	9.56	1.20	0.18	4.7-9.4	3.9-10.1	21.0	26.43	31.1
	3	5.23	6.82	9.58	1.03	0.16	4.8-8.8	4.2-9.5	21.0	2630	30.3
	Mid	5.21	6.64	9.70	0.94	0.14	4.8-8.5	4.2-9.1	21.0	26.23	30.3
	Btm	5.13	6.62	9.60	0.94	0.15	4.8-8.5	4.2-9.0	21.0	26.21	30.2
177.4	0	5.24	7.02	9.42	1.11	0.17	4.8-9.2	4.2-9.9	20.9	26.43	30.9
	3	5.16	6.82	9.34	1.03	0.16	4.8-8.8	4.2-9.5	20.9	26.31	303
	Mid	5.09	6.59	9.27	0.92	0.14	4.8-8.4	4.2-8.9	20.9	26.22	30.2
	Btm	5.02	6.51	9.12	0.89	0.14	4.8-8.2	4.2-8.8	20.8	26.19	30.1
174.9	0	4.76	7.11	11.68	1.43	0.22	4.3-9.9	3.4-10.8	20.9	26.45	32.7
	3	4.67	6.75	10.18	1.08	0.17	4.6-8.9	4.0-9.5	20.9	26.23	30.2
	Mid	4.64	6.55	10.20	1.01	0.16	4.6-8.5	3.9-9.1	20.9	26.11	30.0
	Btm	4.61	6.48	10.18	1.00	0.16	4.5-8.4	3.9-9.0	20.8	26.05	29.9
170.9	0	5.50	7.73	13.22	1.82	0.28	4.2-11.3	3.0-12.4	19.3	25.97	31.7
	3	5.40	7.33	11.88	1.37	0.21	4.6-10.0	3.8-10.8	19.3	25.76	29.7
	Mid	5.30	7.24	11.84	1.34	0.21	4.6-9.9	3.8-10.7	19.3	25.65	29.7
	Btm	5.40	7.07	10.18	1.13	0.17	4.8-9.3	4.1-10.0	19.2	25.55	29.6
167.0	0	5.70	8.46	14.10	2.09	0.32	4.4-12.5	3.1-13.8	20.3	26.21	30.6
	3	5.60	7.92	11.42	1.60	0.25	4.8-11.0	3.8-12.0	203	25.93	30.0
	Mid	5.66	7.50	10.86	1.32	0.20	4.9-10.1	4.1-10.9	20.2	25.72	29.8
	Btm	5.57	7.24	11.02	1.15	0.18	5.0-9.5	4.3-10.2	20.2	25.53	29.5
166.1	0	5.80	8.35	15.77	2.02	0.31	4.4-12.3	3.1-13.5	20.5	26.05	31.0
	3	5.70	7.92	11.18	1.44	0.22	5.1-10.7	4.2-11.6	20.5	25.86	30.6
	Mid	5.80	7.77	11.05	1.30	0.20	5.2-10.3	4.4-11.1	20.5	25.78	30.6
	Btm	6.00	7.72	10.95	1.27	0.20	5.2-10.2	4.4-11.0	20.3	25.73	30.6

S = Standard Deviation and

$\sigma_{\bar{x}}$ = Standard Error of Estimate of the mean = S /(n)½

DO/Teinperature Statistical Summary For
40 1986 Dates and 2 1985 Dates (n=42)

COE	*Dissolved Oxygen (mg/L)*										
river							*C.I.*		*Temperature (°C)*		
mile	*Depth*	*Min*	*Avg*	*Max*	*S*		*95%*	*99%*	*Min*	*Avg*	*Max*
165.3	0	5.75	8.56	14.18	1.98	0.31	4.7-12.4	3.4-13.7	20.8	26.04	31.0
	3	5.70	8.08	12.34	1.53	0.24	5.1-11.1	4.1-12.0	20.8	25.88	303
	Mid	5.80	7.88	11.90	1.35	0.21	5.2-10.5	4.4-11.3	20.7	25.78	30.2
	Btm	5.96	7.81	11.90	1.34	0.21	5.2-10.4	4.3-11.3	20.7	25.83	30.1
164.4	0	5.90	8.45	12.89	1.81	0.28	4.9-12.0	3.8-13.1	20.9	26.05	303
	3	5.80	8.00	11.80	1.81	0.28	4.4-11.5	3.3-12.7	20.7	25.90	30.2
	Mid	5.80	7.72	11.70	1.38	0.21	5.0-10.4	4.2-11.3	20.4	25.78	30.2
	Btm	5.98	7.65	11.50	1.35	0.21	5.0-10.3	4.2-11.1	20.3	25.70	30.0
162.8	0	6.21	9.23	19.99	2.94	0.45	3.5-15.0	1.6-16.8	20.3	26.35	33.4
	3	5.40	8.41	15.26	2.01	0.31	4.5-12.3	3.2-13.6	20.3	25.98	31.4
	Mid	5.60	7.71	11.91	1.37	0.21	5.0-10.4	4.2-11.2	20.2	25.70	30.1
	Btm	6.00	7.65	11.56	1.30	0.20	5.1-10.2	4.3-11.0	19.8	25.53	30.0
161.6	0	6.07	839	14.80	1.92	0.30	4.6-12.1	3.4-13.2	20.3	25.99	30.8
	3	6.04	8.08	11.69	1.49	0.23	5.1-11.0	4.2-11.9	20.3	25.91	30.1
	Mid	6.00	7.97	11.63	1.43	0.22	5.2-10.8	4.3-11.6	20.3	25.86	30.1
	Btm	6.01	7.88	11.54	1.36	0.21	5.2-10.5	4.4-11.4	20.2	25.78	30.1
160.7	0	5.70	8.18	11.60	1.49	0.23	5.2-11.1	4.3-12.0	20.5	26.07	30.0
	3	5.70	7.98	11.39	1.40	0.22	5.2-10.7	4.4-11.6	20.5	25.94	29.9
	Mid	5.70	7.88	11.45	1.36	0.21	5.2-10.5	4.4-11.4	20.4	26.88	29.9
	Btm	5.85	7.86	11.35	1.33	0.21	5.2-10.5	4.4-113	203	25.84	29.9
159.4	0	5.90	8.03	11.90	1.43	0.22	5.2-10.8	43-11.7	20.6	26.02	29.9
	3	5.75	7.84	11.79	1.33	0.21	5.2-10.4	4.4-113	20.6	25.93	29.9
	Mid	5.92	7.80	11.73	1.32	0.20	5.2-10.4	4.4-11.2	20.6	25.90	29.9
	Btm	6.15	7.76	11.50	1.31	0.20	5.2-10.3	4.4-11.1	20.5	25.78	29.9
158.0	0	6.10	7.98	12.29	1.43	0.22	5.2-10.8	43-11.7	20.4	26.02	30.3
	3	6.00	7.78	11.53	1.32	0.20	5.2-10.4	4.4-11.2	20.4	25.97	29.9
	Mid	5.60	7.73	11.49	1.33	0.21	5.2-10.3	43-11.1	20.4	25.93	29.9
	Btm	5.60	7.70	11.36	1.31	0.20	5.2-10.3	43-11.1	203	25.89	29.8

S = Standard Deviation and

$\sigma_{\bar{x}}$ = Standard Error of Estimate of the mean = S /(n)½

APPENDIX E:

FIELD DATA SHEETS FOR THE LAGRANGE AND PEORIA POOLS

weather

	sun	pc	cloudy	driz	rain	wind
start						
mp 125.6						
stop						

date ______________________

crew 1 ____________ 2 ____________ 3 ____________

					temperature				dissolved oxygen					barge info						
mp	time	no.	pH	diak	0	3	m	b	0	3	m	b	depth	name	↑↓	no.	f	e	mp	remarks
80.2		1																		
82.3																				
85.5																				
89.2																				
93.0		2																		
97.2																				
99.5																				
103.4																				
106.9		3																		
110.2																				
113.3		4																		
116.3																				
119.7																				
121.1		5																		
125.6																				
129.5		6																		
132.0																				
135.7																				
139.0		7																		
143.2																				
145.5		8																		
147.3																				
148.2																				
150.0		9																		
151.0																				
152.0																				
153.0																				
155.0																				
157.6		10																		

		sun	pc	cloudy	driz	rain	wind
weather	start						
	mp 183.0						
	stop						

date ______________________

crew 1 ____________ 2 ____________ 3 ____________

					temperature				dissolved oxygen					barge info						
mp	time	no.	pH	disk	0	3	m	b	0	3	m	b	depth	name	↑↓	no.	f	e	mp	remarks
158.0		11																		
159.4																				
160.7		12																		
161.6																				
162.8		13																		
164.4																				
165.3																				
166.1		14																		
167.0																				
170.9																				
174.9																				
177.4																				
179.0		15																		
183.0																				
188.0																				
190.0																				
196.9		16																		
200.4																				
205.4																				
209.4																				
213.4		17																		
217.1																				
219.8																				
222.6		18																		
224.7																				
226.9		19																		
229.6																				
231.0		20																		

weather

sun	pc	cloudy	driz	rain	wind

time ______________

stage above ______________
stage below ______________

	gate no.											gate no.									
	1		2		3		4		5			6		7		8		9		10	
gate opening→ (feet)																					
	T	DO	T	DO	T	DO	T	DO	T	DO	depth	T	DO	T	DO	T	DO	T	DO	T	DO
											0										
											2										
											4										
											6										
											8										
											10										
											12										
											14										
											16										
											18										
											20										
											22										
											24										
											26										
											28										
											30										

APPENDIX F:

PEORIA POOL SEDIMENT DESCRIPTIONS

1987 Peoria Pool Sediment Descriptions and Characteristics

River	Description of sediments		Percent composition			
			Water		Vol solids	
Mile	End navigation period (July)	End nonnavigation period (Sept)	July	Sept	July	Sept
158.0	Pulverized to large half clam shells on top of a thin layer of gray silt on top of fine to coarse tan sand	Half clam shells, snail shells on top of 2 to 3 inches of gray-black silt-clay on top of medium sand to pea gravel	15.8	63.3	1.3	6.4
164.4	Watery tan to gray-black silt, fine to coarse gray-black sand, many finernail (f.n.) clam shells, snail shells	Somewhat firm tan-gray muck, some fine to medium sand, much pulverized woody detritus, sticks and wood chips, many f.n. clam shells	57.6	57.3	6.3	*6.6*
174.9	Brown-tan to gray muck, some fine to medium sand, woody and leafy detritus	Firm gray-black muck, some fine to medium sand, pulverized woody detritus, small shell fragments	53.9	57.4	7.1	7.2
179.0	Gray-black sandy muck, fine tan-brown sand, coarse gray-black sand, f.n. clam shells	1" gray-tan silt-clay on top of very fine tan-brown sand, medium size wood chips, much pulverized woody detritus, snail shells	33.8	49.5	2.4	5.2
183.2	Large gray-tan gravel, large clam shells, shell fragments	Coarse sand, some large gravel, small to large clam shells, many pulverized shells	43.4	28.7	6.2	3.9
193.5	Firm gray-tan watery silt, black-gray fine pulverized woody detritus, sticks, f.n. clam shells	Firm gray-tan silt clay, very fine sand, wood chips, sticks, much pulverized woody detritus, f.n. clam shells	37.4	36.3	6.0	6.0
196.9	Fine sand mixed with some silt-clay mixed with fine sand on top of hard tan-gray clay	Thin layer of silt and coarse sand on top of tan-gray hard clay, some woody detritus, snail shells	43.6	36.3	5.4	4.2
209.4	Gray-black fine to coarse sand, some pea gravel, pulverized woody detritus, woody detritus, sticks	Tan-brown fine to coarse sand, clean medium to large gravel, coal chips, pulverized shells	28.3	20.4	5.3	1.7
219.8	Tan-brown medium to coarse sand, many coal and shell fragments, small snail shells, some woody detritus	Tan-brown clean fine to coarse sand, coal and shell fragments	20.2	20.3	1.5	1.1
226.8	Tan-brown fine to coarse sand, many small coal fragments, some woody detritus, small snail shells, f.n. clam shells	Tan-brown fine to coarse sand, coal chips, pulverized shells	19.3	21.7	0.6	1.7

1988 Peoria Pool Sediment Descriptions and Characteristics

River	Description of sediments		Percent composition			
			Water		Vol solids	
Mile	End navigation period (July)	End nonnavigation period (Sept)	July	Sept	July	Sept
158.0	Very watery gray-black silt, medium to coarse sand, large clam shells, snail shells, shell fragments, pulverized shells	Gray-black clay-silt, coarse sand to medium gravel, small clam shells, snail shells	55.1	64.0	5.3	7.0
164.4	Firm gray-black silt-clay, some coarse sand, much pulverized woody detritus, shell fragments, snail shells, f.n. clam shells	Firm gray-black pasty silt-clay, coarse sand, some woody detritus, sticks, many f.n. clam shells	53.9	64.5	7.7	7.3
174.9	Somewhat compacted gray-black silt-clay, much woody detritus, small wood chips, some shell fragments	Somewhat compacted gray-black silt-clay loaded with woody detritus	58.4	61.5	8.5	7.8
179.0	Somewhat compacted gray silt-clay, some coarse sand, sticks, very finely pulverized organic and wood detritus	Thin layer of watery gray silt on top of watery silt and very fine sand	57.8	65.1	7.6	6.6
183.2	Some watery tan clay in fine to coarse sand, pea to medium gravel, large clam shells, snail shells, pulverized shells	Coarse sand, pea to medium gravel, clam shells, snail shells, shell fragments	15.5	16.2	2.6	1.0
193.5	Watery black silt, medium to coarse sand, woody detritus, pulverized woody detritus, large sticks, f.n. clam shells	Thin layer watery gray silt and coarse sand on top of much woody detritus mixed with silt and coarse sand, wood chips	47.1	54.6	8.2	6.9
196.9	Thin layer gray-black watery silt on top of gray-black compacted clay, medium to coarse sand, pulverized woody detritus, shell fragments, snail shells, pulverized shells	Thin layer gray silt on top of fine to coarse gray-black sand, pulverized and small woody detritus, shell fragments, snail shells	40.3	42.3	5.6	6.1
209.4	Thin layer of gray-black silt on top gray-tan medium to coarse sand, coal and shell fragments, snail shells, large woody detritus, wood chips	Very thin layer of gray silt on top of very fine to coarse sand, many coal fragments, shell fragments, small snail shells	26.5	20.5	3.2	3.4
219.8	Tan-brown-gray clean fine to coarse sand, many coal flecks, pulverized shells, large wood chips	Gray-tan fine to coarse sand, coal fragments and flecks, woody detritus, shell fragments, snail shells	21.5	23.2	1.4	6.0
226.9	Tan-brown-gray clean fine to coarse sand, many coal flecks, pulverized shells	Tan-brown-gray fine to coarse sand, coal and shell fragments, snail shells	22.3	5.0	1.0	0.8

APPENDIX G:

LAGRANGE POOL SEDIMENT DESCRIPTIONS

1987 LaGrange Pool Sediment Descriptions and Characteristics

River	Description of sediments		Percent composition			
			Water		*Vol solids*	
Mile	*End navigation period (July)*	*End nonnavigation period (Sept)*	*July*	*Sept*	*July*	*Sept*
80.2	Silt and fine sand on top of coarse sand, small shells, woody detritus, shell fragments, pulverized shells	Thick layer black-gray silt on top of fine to coarse brown-tan sand, much woody & leafy detritus, sticks, clam shells	42.0	31.6	3.6	2.9
89.2	Clean tan-brown fine to coarse sand, very small shell fragments, clay lense	Tan-gray medium to coarse sand, small pea gravel, many coal & shell fragments, snail shells	19.4	12.5	0.9	1.0
97.0	Tan medium to fine sand top of sterile gray hard clay	3" medium to coarse sand, very small pea gravel on top of sterile gray hard clay	32.0	18.9	2.8	0.6
110.2	Clean medium tan-gray medium to coarse sand, fine pulverized shells, coal fragments, snail shells	Tan-gray-brown medium to coarse sand, large shell fragments, small shells, snail shells	19.8	21.9	1.3	0.8
119.7	Clean tan-brown fine to coarse sand, pea to medium gravel, some coal and shell fragments, clam shells	Tan-brown medium to coarse sand, small pea gravel, pulverized shells, some woody detritus	18.8	15.6	1.4	2.1
132.0	Tan-brown very fine sand, some shell and coal fragments, some snail shells, some sticks	Tan-brown medium to coarse sand, some shell and coal fragments, some snail shells, some woody detritus, some clam shells	22.0	21.9	0.4	0.6
139.0	Tan-brown medium to coarse sand, some pea gravel, small shell fragments, woody detritus, snail shells	Tan-brown medium to coarse sand, some small shells, shell fragments, pulverized wood detritus, wood chips	18.6	20.3	0.8	0.8
147.3	Tan-brown fine to coarse sand, small pea gravel, woody detritus, sticks, some shell fragments	Tan-brown medium to coarse sand, much woody detritus, sticks, pulverized shells, wood chips	18.6	19.8	1.8	1.2
150.0	Tan-brown coarse sand to pea gravel, large clam shells, shell & coal fragments	Tan-brown coarse sand to medium gravel, many clam shells, pea gravel, snail shells, wood chips	16.5	18.9	1.9	2.4
155.0	Tan-brown fine to coarse sand, some fine shell fragments, snail shells	Tan-brown fine to medium sand, small clam shells, pulverized shells, some black woody detritus, wood chips	19.6	19.9	0.6	0.7

1988 LaGrange Pool Sediment Descriptions and Characteristics

River	*Description of sediments*		*Percent composition*			
			Water		*Vol solids*	
Mile	*End navigation period (July)*	*End nonnavigation period (Sept)*	*July*	*Sept*	*July*	*Sept*
80.2	Watery black-gray silty-sandy muck, some coarse sand, small clam shells, pulverized shells, wood chips, sticks	1" watery gray silt-clay on top of gray fine to coarse sand, small shell fragments, much woody detritus, roots, sticks	35.7	42.4	2.1	4.1
89.2	Thin layer of tan silt on top of fine to coarse sand, clam shells, snail shells, shell and coal fragments	Thin layer of tan-silt on top of gray-tan fine to coarse sand, many snail shells, woody detritus, shell fragments	26.1	23.8	2.8	1.5
97.0	Some clean coarse sand to medium gravel, many large clam shells, snail shells	Clean to medium to coarse tan sand, clam and snail shells, some pea gravel	14.5	15.0	2.7	1.5
110.2	Some clean coarse sand to medium gravel, many large clam shells, snail shells	Very thin layer of watery tan silt on to of gray-tan fine to coarse sand, small pea gravel, shell fragments, snail shells, woody detritus, sticks	20.2	19.3	2.3	1.0
119.7	Layer of tan fine silt-clay on top of tan medium to coarse sand, clam shells, shell fragments, woody detritus, sticks, pulverized shells	Very thin watery tan-silt on top of gray-tan fine to coarse sand, pea to large gravel, rocks, clam and snail shells, woody detritus, shell fragments	39.3	23.0	6.7	4.5
132.0	Brown-tan medium to coarse sand, many shell fragments, snail shells, some woody detritus	Loose tan-brown fine to coarse sand, very small shell fragments	20.0	20.7	0.9	0.6
139.0	Thin layer tan-brown silt on top tan fine to coarse sand, pea and medium gravel, some large gravel, snail shells, woody detritus	Gray fine to coarse sand, shell fragments, pulverized shells, woody detritus	20.6	20.8	5.1	1.5
147.3	Clean tan fine to coarse sand, small pea gravel, coal fragments, some woody detritus, wood chips	Clean tan-brown fine to coarse sand, small to large pea gravel, some snail shells, coal chips	20.3	17.9	1.1	2.0
150.0	Watery gray-black silty sand, medium to coarse sand, small pea gravel, snail shells, some pulverized shells	Tan-brown silty sand, medium to coarse sand, small to large pea gravel, snail shells, small clam shells, woody detritus, wood chips	31.5	21.1	2.6	2.3
155.0	Gray-tan fine to coarse sand, small coal chips, clam shells, pulverized shells, woody detritus, wood chips	Gray-tan fine to coarse sand, some small pea gravel, some woody detritus	22.0	17.8	1.8	1.9

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