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State Water Survey Division

SURFACE WATER SECTION
AT THE
UNIVERSITY OF ILLINOIS

Illinois Institute of Natural Resources

SWS Contract Report 269

RESUSPENSION AND LATERAL MOVEMENT OF SEDIMENT BY TOW TRAFFIC ON THE UPPER MISSISSIPPI AND ILLINOIS RIVERS

Submitted to:
The Environmental Work Team
Master Plan Task Force
Upper Mississippi River Basin Commission

Submitted by:

Nani G. Bhowmik, Principal Investigator

Prepared by:

J. Rodger Adams, Allen P. Bonini,
Chwen-Yuan Guo, David J. Kisser,
and Margaret A. Sexton

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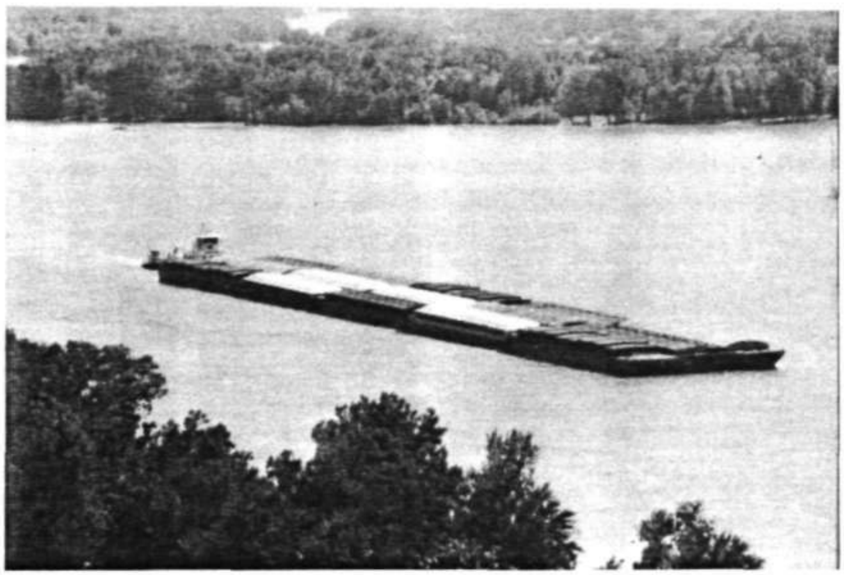

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CONTENTS

CONTENTS (Concluded)

ABSTRACT

This is one of three field studies conducted by the Illinois State Water Survey on the effects of navigation on the Upper Mississippi River System. It is part of the environmental studies for the Comprehensive Master Plan for the Management of the Upper Mississippi River System. The master plan was requested by Congress to assist in determining the ultimate navigation capacity of the system, and specifically to determine the necessity and advisability of a second lock at Locks and Dam 26, Alton, Illinois.

Depth-integrated suspended sediment samples were collected at three locations on a river transect for 90 minutes after a tow passed. The primary study sites were Hadley's Landing, 13.2 miles up the Illinois River from its confluence with the Mississippi River near Grafton, Illinois; Rip Rap Landing, mile 265.1 on the Mississippi River; and Mosier Landing, mile 260.2 on the Mississippi River. The methods we developed worked well and were refined each time we collected field data.

Definite increases in suspended sediment concentrations were observed on both rivers. The increase was greater on the Illinois River than on the Mississippi River. The increases were also greater at the channel border sampling site than in the center of the navigation channel. The greater effect in channel border areas supports the hypothesis that tow traffic moves sediment laterally out of the navigation channel.

Due to the rescoping and truncation of the study from 29 to 16 months, the quantity of data is smaller than originally proposed, and the discussion and analysis of results are preliminary. Theoretical analyses

and mathematical modeling of resuspension and lateral movement of sediment by tow traffic was essentially eliminated in the rescoped project.

INTRODUCTION

As the environmental movement gained power and public attention in the 1960s, the U.S. Army Corps of Engineers began planning to repair, replace, or enlarge the locks at Locks and Dam 26, Alton, Illinois. This locks structure controls access to the Illinois Waterway and the Upper Mississippi River. The following description of the developments following a 1968 recommendation to replace Locks and Dam 26 is based directly on the introduction to the "Preliminary Comprehensive Master Plan for the Management of the Upper Mississippi River System" (Upper Mississippi River Basin Commission, 1981).

Master Plan Studies

In 1968, the District Engineer of the U.S. Army Corps of Engineers, St. Louis District, recommended a replacement project for Locks and Dam 26 providing for the construction of a new dam and two 1200-foot locks two miles downstream of the existing dam at Alton, Illinois. The Secretary of the Array approved the project, and in 1970 Congress appropriated funds for its design. Congress continued to appropriate funds for the project through fiscal year 1975.

On August 6, 1974, the Isaak Walton League, the Sierra Club, and 21 midwestern railroads filed lawsuits in the U.S. District Court to enjoin the U.S. Army Corps of Engineers from beginning construction on the Locks and Dam 26 replacement project at Alton, Illinois. The court ruling of September 5, 1974, stopped further actions toward construction until the U.S. Army Corps of Engineers obtained the consent of Congress and remedied the defects in the Environmental Impact Statement. In response to this ruling, the Corps of Engineers conducted additional studies which were submitted to Congress and ordered to be printed August 26, 1976--House Document No. 94-584 (Board of Engineers for Rivers and Harbors, 1976).

Among other conclusions, the Chief of Engineers recommended that:

> "Congress authorize the replacement of Locks and Dam 26 with a new dam and 110-foot by 1,200-foot main lock at a location two miles downstream from the existing dam, the design and construction of the new dam to provide for the addition of an auxiliary lock at such time as it may be authorized.
>
> and
>
> Congress authorize the Secretary of the Army, acting through the Chief of Engineers, in cooperation with the Departments of Transportation and Interior, the Environmental Protection Agency, and other interested Federal and State agencies, to make an economic evaluation and a comprehensive study of the river environment to determine the impacts of increased navigation which would result from provision of a second lock and submit a report to the Congress on the feasibility and desirability of constructing a second lock."

During 1976 and 1977, the Congress debated several bills to authorize the Corps of Engineers to begin construction of a replacement for Locks and Dam 26. Alternative navigation improvements were also being proposed. Because construction of a second lock would increase the river's capacity for waterway traffic, Congress would have to know the impact that increased traffic would have on the total river system and other modes of transportation. At issue were conflicts that had been brewing for decades: the demand for increased waterway commerce; environmental demands to preserve natural wildlife habitats and prevent damage to the rivers ecology; and the impact that increased waterway commerce would have on other modes of commercial transportation, most notably the railroads and trucking.

On October 21, 1978, President Carter signed into law P.L. 95-502 directing the Upper Mississippi River Basin Commission (UMRBC) to prepare a Comprehensive Master Plan for the Management of the Upper Mississippi

River System in cooperation with appropriate federal, state, and local officials. Under this law, the Master Plan is to be submitted to Congress by January 1, 1982, with a preliminary plan to be completed by January 1, 1981.

The UMRBC established a task force to prepare the first draft of the Master Plan-Plan of Study. They soon realized the time constraints of P.L. 95-502 did not allow sufficient time to properly answer the questions and concerns raised by Congress. On August 15, 1979, the Commission adopted a Plan of Study for the development of a Comprehensive Master Plan for the Management of the Upper Mississippi River System. The Plan of Study outlined a four year study effort, 19 months longer than P.L. 95-502 specified. In September 1980, Congress denied the UMRBC's request for a time extension, so the Commission rescoped all study efforts as necessary to meet the dates specified in the law.

During the development of the Plan of Study and the initial work efforts, appropriations for the Master Plan were made by Congress in three separate appropriation actions. A supplemental Fiscal Year 1979 appropriation of $2,000,000 was approved in July 1979. Fiscal Year 1980 appropriation of $4,000,000 was approved in October 1979, and a $2,400,000 appropriation for Fiscal Year 1981 was approved in September 1980. A budget proposed for Fiscal Year 1982 is currently being considered through the Water Resources Council for $1,000,000.

The Master Plan is intended to identify the economic, environmental, and recreation objectives of the river system. Specifically, the plan will guide and direct any future expansions of navigation capacity, including but not limited to construction of a second lock at Locks and Dam 26. The plan will also address projected effects of natural and manmade activities on the system. Within this overall goal of balancing economic, environmental, and recreational objectives of the river system are two subgoals: 1) to develop technical recommendations, and 2) to develop a management framework for resolving differences between competing interests. Most of the technical questions relate to transportation and environmental issues specifically requested by Congress. These include:

- the navigation carrying capacity of the Mississippi River System;
- the effect of expanded navigation on national transportation policy and the railroads;
- the cost and benefit to the nation of expanded navigation capacity;
- an evaluation of the need for a second lock at Locks and Dam 26;
- the effects of disposing of dredged material in areas outside of the floodplain;
- the development of a study to determine the feasibility of a computerized analytical inventory and analysis system; and
- the effect that increased navigational capacity would have on fish and wildlife, water quality, wilderness, and public recreational opportunities (UMRBC, 1981: 1-4).

Lead members of the Commission were given responsibility for carrying out specific technical studies in these areas. Responsibility for the study of navigation effects was given to the Department of Interior.

Water Survey Involvement

In response to the Plan of Study, a consortium of researchers submitted a combined proposal to accomplish navigation effects studies on Pools 9 and 26 from May 1980 through September 1982. In November 1980, after Congress required the UMRBC to meet the original completion date of January 1, 1982, for the Master Plan, these studies were rescoped. The rescoped studies did not include a comprehensive, consolidated final report, and field studies were curtailed so that the individual principal investigators could submit final reports by September 1, 1981. This reduction in project duration from 29 to 16 months severely limits the amount of analysis and model development by the principal investigators.

The Illinois State Water Survey has conducted studies on several tasks in each phase of the navigation effects program.

Phase I. Literature review and impact analysis based on existing information.

This was a joint effort by the Water Survey and the Illinois Natural Histsory Survey. A literature review was completed in September 1980 and a revised report was submitted in May 1981 (Lubinski et al., 1981). A report which proposed studies to provide data to address information gaps about the effects of navigation on the physical, chemical, and biological regime was submitted in December 1980 (Lubinski et al., 1980).

Phase II. Reconnaissance and selection of sites for site specific studies.

A report on the bed material characteristics and channel geometry of the 80 miles of the Illinois River in Pool 26 was submitted in July 1981 (Schnepper et al., 1981). This task was done by the Water Quality Section of the Water Survey.

Phase III. Impact studies at selected sites.

Three separate but related studies on the physical effects of navigation were performed by the Surface Water Section of the Water Survey.

1. Determination of the Magnitude, Nature, Energy Content, and Patterns of Waves Caused by the Movements of Various Types of Commercial and Recreational Vessels on Pool 26.
2. Determination of the Water and Sediment Inputs to Selected Side Channels and/or Backwater Lakes Associated with the Passage of Large Commercial and Recreational Vessels in Pool 26.
3. Determination of the Extent and Magnitude of Lateral Movements of Sediments Associated with the Movements of Recreational and Commercial Vessels in Pool 26. The results of this task are detailed in this report.

<u>Lateral Movement Study Plan</u>

Given the task of determining the lateral movement of sediment, a hypothesis was set forth in the research proposal: "Movement of Commercial and Recreational Vessels in a Waterway Moves the Suspended and the Bottom Sediments in a Lateral Direction." Our objectives, therefore, were to test the hypothesis in the following manner:

1. To collect a set of data on suspended sediment at a section in a reach of the river to try to answer the following questions: Does the suspended sediment move laterally during the passage of a barge? If so, what are the timelags and the intensity of distribution? What kind of materials are suspended or is it a redistribution of the suspended load? How much time does it take before the increased concentration either settles down in the bed or moves downstream with the water?

2. To determine the effect of this lateral movement of suspended sediment on the sedimentation rates in the backwater lakes.

3. Make an attempt to develop a mathematical model of the lateral movement of sediment due to river traffic.

The remainder of this report will detail the steps taken to accomplish these objectives. After a background review and discussion of site selection, the field and laboratory methods are explained. Presentation of the data follows, along with a discussion and analysis of the results. The rescoping of this study reduced the number of field data collection trips from 12 to 5 and eliminated the time for model development.

Acknowledgements

This project was conducted under the administrative guidance of Stanley A. Changnon, Jr., Chief, Illinois State Water Survey, and Michael L. Terstriep, Head, Surface Water Section.

Allen P. Bonini did an outstanding job organizing and coordinating field trips involving four boats, 10 to 14 people, numerous motor vehicles, and a vast amount of supplies and equipment. He was ably assisted by William C. Bogner. Other section personnel included William Fitzpatrick, D. Kevin Davie, Richard Allgire, and David Jennings. Several regular employees and students joined our group for one field trip. David Kisser supervised the surveying and tow tracking, developed the sampling station location system, and made arrangements for radio communications.

Thomas E. Hill and Thomas E. Walkowiak of the Water Quality Section in Peoria contributed to the success of several field trips. The Water Quality Section also provided two fully equipped boats for each field trip.

Margaret A. Sexton maintained the data files and prepared the data for computer entry by members of the Data and Information Management Unit. Arthur L. Sims of that unit prepared the data tables for this report from our computer data files. C. Y. Guo, Graduate Research Assistant, did the data analysis and developed the programs for computer plotting of the velocity and suspended sediment data.

The suspended sediment samples and bed material samples were analyzed under the direction of Michael V. Miller, Head of the Analytical Chemistry Unit's sediment laboratory.

Illustrations were prepared under direction of John Brother, Jr., and Pamela Lovett typed the camera-ready text.

BACKGROUND REVIEW

Geology of Study Area

Geological History

In the preglacial period, the Iowa River occupied the valley of the present Mississippi River from Muscatine, Iowa, to Grafton, Illinois. The preglacial Mississippi River followed a course from its present location near the Wisconsin-Illinois border to the present-day Illinois Valley near Hennepin, Illinois. There the Teays River, which drained much of Ohio and north-central Indiana and Illinois, joined the Mississippi River Valley from Hennepin to Grafton at the confluence with the Iowa River. The preglacial Missouri River joined the Mississippi near the present confluence. The brief review of glacial history of Illinois and the changes in major streams given here is based on reports by Cote, Reinertsen, and Killey (1969), and Simons et al. (1975).

During the Kansan glaciation, the western drainage system was forced to the east, and the Ohio River to the south, greatly reducing the eastern drainage area of the Teays River. The Iowa River occupied the present Mississippi Valley, and the Mississippi River occupied the present Illinois Valley.

The bedrock of the Illinois Valley was buried during Illinoian glaciation, forcing the Mississippi River westward into a temporary channel. Upon retreat of the glacier, the Mississippi River occupied the Illinois Valley and the Iowa River again occupied the Mississippi Valley. Melt water from the Illinoian glaciation deepened and permanently established the tributary valleys.

The Mississippi River was permanently diverted to its present valley when the Upper Illinois Valley was blocked during Wisconsin glaciation. Upon retreat of this glacier, the Mississippi River remained in it present valley draining the melt water from the north. The melt water from the northeast was drained by the Illinois River which permanently occupied its present valley. The wide river valleys formed by large quantities of melt water from several periods of glaciation are remnants of the ice age.

Physiographic Divisions

Following Leighton, Ekblaw, and Horberg (1948), most of Illinois is in the Central Lowland province. Figure 1 locates the study area and delineates the physiographic sections. The Lincoln Hills section is part of the Ozark Plateau province, and the other three sections are part of the Till Plains section of the Central Lowland province. The Illinois River is the boundary between the Galesburg Plain and the Springfield Plain.

The eastern edge of the Dissected Till Plains section is just north of the study area. This section covers northern Missouri and southern Iowa and extends just a few miles into Illinois between Keokuk and Hannibal. The Dissected Till Plains section is covered by drift from the Kansan glaciation which occurred early in the ice age. The area is in a mature state of erosion, and the drift sheet is thin, so the terrain reflects the ruggedness of the bedrock. Thick loess deposits from later periods of glaciation are present on the adjoining bluffs. The eastern boundary of this section is the western edge of the Illinoian drift sheet.

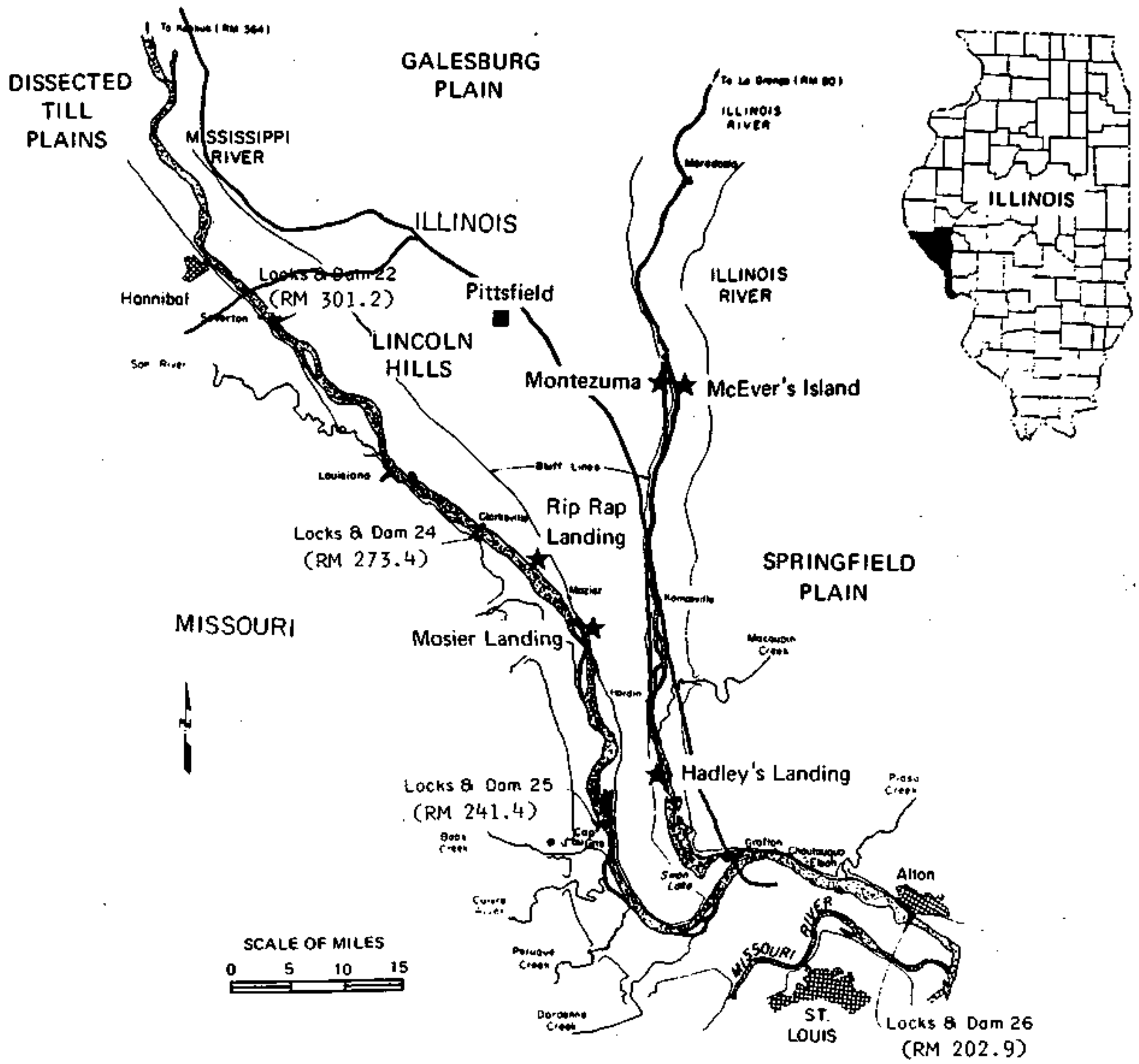


Figure 1. Location of study sites

The two subsections of the Till Plains section present in the study area are the Galesburg Plain on the north and the Springfield Plain on the east. The Galesburg Plain is covered by Illinoian drift. Since the Illinoian glaciation occurred after the Kansan glaciation, the Galesburg Plain is in a youthful stage of erosion, as compared to the Dissected Till Plains section. Since the drift sheet is thick and underlain by Kansan drift, most of the preglacial surface was buried, and only gross features of the bedrock topography are exposed. There are four moraines in this district, two near the drift border, a third parallel to the Illinois Valley, and a fourth in the central part of the region. The numerous minor valleys in the region are deep and youthful while the larger valleys are steep-walled, alluviated and terraced. The Galesburg Plain is defined by its Illinoian drift cover and its large, steep-walled valleys.

The Springfield Plain includes the level portion of the Illinoian drift and is distinguished by its flatness and shallow drainage valleys. There are two low, broad moraines present in the western area. The flat surface of the drift in this region gives rise to shallow valleys and streams with low gradients. Again, the thick Illinoian drift conceals the topography of the bedrock. Along the southeast side of the Illinois Valley there is a belt of thick loess deposits that thins to the southeast. The main difference between the Galesburg and Springfield Plains is the more sharply incised valleys of the Galesburg Plain.

The Lincoln Hills section is driftless with the exception of a few patches of Kansan drift in the north and heavy loess deposits in the south. The area lies above the junction of the Mississippi and Illinois Rivers and is bordered on the west by the Kansan drift and on the east by the Illinoian drift. Since the area is driftless, the features of the bedrock can be seen in the rugged terrain. The central ridge is distinguished by the Lincoln Fold with large peneplains in the uplands. The central ridge is in a mature state of erosion and marked by outcrops of pre-Pennsylvanian limestones. The terrain is rugged and broken by ridges and closely spaced, narrow, steep valleys. The large valleys of the Mississippi and Illinois Rivers are deeply alluviated and terraced.

Characteristics of the Rivers

Early surveys show the Mississippi River channel on the extreme west side of the channel from Hannibal, Missouri, to Clarksville, Missouri, except for a few miles near Louisiana where the entrance of the Salt River had forced the Mississippi into the middle of the river valley. South of Clarksville, as the land separating the Mississippi and Illinois Rivers narrows, the west bank tributaries become increasingly significant. The Mississippi River is shifted toward the eastern bluff, which it follows to Alton, Illinois. The position of the river in its valley was determined during the glacial period and has not changed significantly in the last 150 years.

Though the position of the river within the floodplain has not changed, other characteristics of the Mississippi River have changed progressively with the development of navigation from the beginning of clearing and snagging around 1830 to the present time. The construction of locks and dams in the 1930s to establish the existing 9-foot navigation system began a process of adjustment from a free-flowing, though trained, river to a succession of pools controlled by the operation of the dams to maintain channel depths required for 9-foot draft vessels. In general, the effect of the locks and dams was to increase river widths immediately upstream of a lock and dam and decrease river width immediately downstream. The river bed is degrading as sediment is being trapped in upstream pools. As a result of the higher water levels, creeks and tributaries to the lower reaches of each pool have been aggrading. The higher water levels also resulted in the formation of a number of islands and side channels as the floodplains were submerged.

The locks and dams have had little effect on the flood discharges and stages in the study area. The locks and dams decrease minimum stages directly below locks and dams and increase minimum stages above locks and dams (Simons et al., 1975).

The Illinois River shifts from a raid-valley position at Meredosia, Illinois, as the east bank tributaries become more significant, to the western bluffs. It follows the west bluffs until Hardin, where the influence of the Mississippi River forces the Illinois River to the east bluffs. Like the Mississippi River, the Illinois River has occupied its present channel since glaciation. The construction of Locks and Dam 26 has had little effect on the Illinois River in the study area. The area of the river has not changed significantly. No new islands were formed while major islands remained. The width of the river has not been affected by the higher pool level except near its junction with the Mississippi. The backwater from Locks and Dam 26 has submerged the floodplain for nine miles above the junction, increasing the width from 1000 feet to a maximum of 6000 feet. Further upstream, the width of the Illinois River remains unchanged. The control of the river stage has contributed to the increased rate of sedimentation in the extensive backwater lakes along the Illinois River (Simons et al., 1975).

Previous Navigation Effects Studies

Movement of any vessel involves a complex interaction between the vessel and the water body it traverses. Waves are the most obvious physical result of vessel movement. Propulsion, whether by jet, paddle wheel, or screw propeller, creates a turbulent jet and surge wave pattern which is easily observed and often rather dramatic. Several subtle effects occur, especially in restricted waterways, rivers, or canals. In restricted waterways the relationships between channel geometry and flow and vessel geometry, speed, and track are important factors that affect the magnitude of the effects of vessel traffic.

Plan and longitudinal section drawings in figure 2 indicate the many parameters and effects involved in vessel movement on a confined waterway. For this study, the geometric and propulsion parameters that cause resuspension, mixing, and movement of bed material particles are most important. Velocities below the barge convoy may be high enough to suspend bed material if the depth-to-draft ratio or the blocking factor (channel cross-sectional area divided by vessel submerged cross-sectional area) is small. Propulsion system jet velocities, turbulence, and jet trajectory depend on towboat horsepower, propeller characteristics (number, diameter, pitch, speed, and type) as well as the geometric ratios involving depth and area.

Liou and Herbich (1976) developed a numerical model of the velocity increase caused by a tow using the momentum theory of the propeller. They simulated the velocity distribution downstream of the propeller and obtained a shear velocity and shear stress on the channel bottom. From this, knowing data about a particular ship, the velocity distribution and the grain size of particles which will be moved can be obtained. Thus,

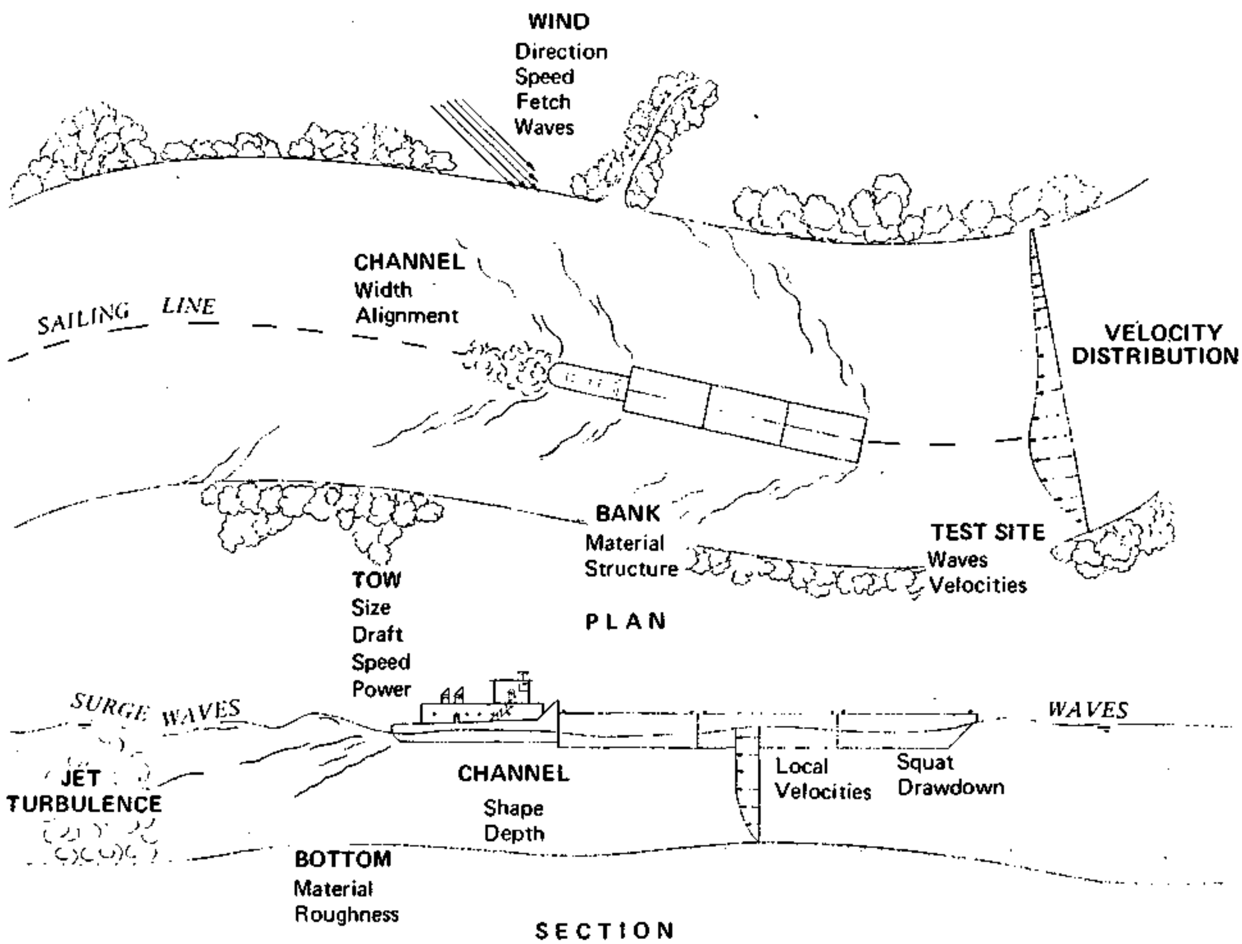


Figure 2. Physical effects of navigation

the resuspension of sediments by a particular barge can be estimated. These resuspended sediments may also be transported to side channels and backwater areas.

Fuehrer and Romisch (1977) presented information on propeller jet expansion behind a tow boat, including equations for calculating the flow velocities at the river bottom due to the propeller jet. Ballin et al. (1977) conducted a moveable bed model study of propeller jet effects on canal beds. They concluded that considerable scour can be caused by propeller jets, particularly by boats which are stationary, starting from rest, or maneuvering in restricted areas. A similar qualitative laboratory investigation was conducted at the Waterways Experiment Station (Maynard, 1977). For the 8-foot draft model tow, a 20-foot water depth was found to be the greatest depth at which significant movement of bed material was observed.

A program of field measurements was conducted on the Ohio River (U.S. Army Corps of Engineers, Huntington District, 1980) which included measurement of the effect of tow traffic on river velocity and sediment resuspension. This field data was analyzed and compared to theoretical calculations by Berger Associates, Ltd. (1980). They found that the propeller jet flow velocity has significant potential to resuspend sediment particles. At a site on the Ohio River,

> "any 3,000 hp (or more) towboat, with a propeller diameter of at least 8 feet puts 100% of the particles into suspension. A small 2,000 hp towboat, with a 5-foot propeller diameter would only disturb 50% of the particles. Therefore, it appears that most of the towboats disturb 100% of the sediments right under the propeller axis.
>
> The lateral distribution of the propeller jet flow velocity is such that the impacted area is 60 feet wide. For example, a 5,600 hp towboat disturbs from 90 to 100% of the sediment along a 40-foot wide strip, and leaves the sediment structure

unchanged outside a 65-foot wide strip." (Berger Associates, Ltd., 1980).

Tow traffic also causes drawdown, displacement currents, and backflow. These effects can also increase sediment resuspension and bank erosion. Gelencser (1977) defines drawdown surge caused by a passing ship in terms of the ship's length, beam, draft, velocity, the channel cross section, and the passing distance. He claims that shoreline damage below the water level is caused principally by drawdown. Fuehrer and Romisch (1977) give detailed equations for drawdown and backflow velocity in European canals due to barge tows. Ballin et al. (1977) also describe drawdown, return velocity, pressures on the channel bed, and squat of the vessels, based on model and prototype studies in West Germany.

Karaki and van Hoften (1974:2-4) describe the flow changes caused by a barge:

> "Beneath the surface, a complex turbulent flow pattern is generated. (There is an increase in velocity of water beneath the boat relative to the mean velocity in the river.) The acceleration of flow depends on the proximity of the bottom of the barge to the river bed and is due to pressure differences created by the water surface profile along the sides of the barges. The interaction of the two flow patterns create a region of marked turbulence and increased velocities along the sides. The propellers of the tug also add turbulence to the already disturbed flow caused by barges. Depending on the proximity of the boat to the streambed and the sizes of bed material, a certain amount of bed sediment is either moved on the bed or suspended in the flow. The material in suspension will remain until the turbulence decays sufficiently for the material to settle out."

> "With either a shallow draft or a deep channel, even though turbulence is generated around the towboats, the effect of disturbances on the riverbed is small. With deeper draft and less clearance between the keel and riverbed, which is the more normal situation with towboats on the river, a flow pattern with a large separation region at the sides and accelerated flow beneath the boat results."

The effects of barge traffic events on main channel and main channel border velocities, pressures and water quality were studied on the

Illinois River reach of Pool 26 and the Mississippi River in Pool 9 between August and October 1980 (Environmental Science and Engineering, 1981):

> "The results of the analysis of the backwater velocity components indicate that near-bottom velocities were substantially affected by tow passage. Upstream tows frequently doubled or tripled the ambient backwater velocities for 2 or 3 minutes. Downstream tows readily reversed the river flow for approximately 2 minutes. The resulting upstream velocities frequently equaled or exceeded ambient downstream river speed. The backwater velocity changes produced by passing tows were generally between 0.5 and 1.0 ft/sec. Offshore components of the induced velocity frequently exceeded 0.2 ft/sec."

Environmental Science and Engineering (1981) compared their field data from Mississippi and Illinois River barge traffic events to calculated results from equations used on the Ohio River (Berger Associates, Ltd., 1980; U.S. Army Corps of Engineers, Huntington District, 1980). They found that these calculated results consistently underestimated the velocity generated by passing tows in the Mississippi and Illinois Rivers.

> "In 82 percent of the cases, the model underestimated the measured velocity. For the data collected near shore (Pool 26, 40 feet from shore), the model underestimated the velocity by a factor of 2. The offshore velocities were underestimated by an average of 30 percent. This amount of error, however, is not unreasonable considering the number of parameters that influence the velocity field. Also, the measured parameters, such as the velocity, tow speed, distance from shore, etc., all have margins of error that could contribute to some of the scattering in the data points. . .
>
> . . .since the model consistently underestimated the velocities, a correction equation was developed so that the model would better fit the data collected on the Upper Mississippi River system. . .The correction equation did not reduce the scatter in the data, but it did eliminate the bias toward predicting values that were too low. The final model results provide realistic estimates of backwater velocities that can be expected from passing tows.
>
> Even though the model provides good estimates for backwater velocities, there are assumptions and simplifications in the

> model development that limit the model's ability to describe the velocity generated by passing tows. The model is one-dimensional, which means it only considers flow parallel to the river channel. The measurements indicated that passing tows frequently produce offshore velocities greater than 0.2 ft/sec. These velocities are not large, but they are approximately equal to the ambient river speed measured on Pool 26. The unnatural offshore component may be important in transporting sediments, eggs, or larvae into or out of the navigation channel. Also, the model uses a depth-integrated velocity technique which does not consider variations of velocity with depth. Since the velocity measurements on Pool 26 indicated the velocity near the surface may be 1.5 to 2.0 times greater than the velocity measured 1 foot from the bottom, the generated velocities from passing tows are undoubtedly greater at distances further from the bottom. Since the final model was calibrated with data collected 1 foot from the bottom of Pool 9 and Pool 26, it will still underestimate velocity changes at mid-depth or near the surface." (Environmental Science and Engineering, 1981)

Direct field measurement of resuspension of sediment due to tow traffic has been done on a limited basis. Aerial photographs of tow-generated turbidity plumes were taken by Karaki and van Hoften (1974) and Link and Williamson (1976).

Environmental Science and Engineering (1981) also measured light transmissivity during tow passage on the Upper Mississippi and Illinois Rivers. They observed a slight reduction in transmissivity in approximately 50 percent of the passages. However, the transmissivity was measured adjacent to the channel and not directly beneath the tow where impacts from the propwash would be the greatest. Based on their observations of tow-induced velocity changes, they conclude that tows do resuspend sediments although the environmental impact may not be great.

> "Although tow traffic significantly changes the river velocity for a short period, the impacts on the sediments and river ecology may not be as great. Tow traffic, however, does contribute to increased resuspension of sediments. Fine sand (0.1 mm) can be resuspended as the velocity exceeds 0.8 ft/sec. Consequently, whenever the tow-induced currents in combination with the ambient river velocity exceed 0.8 ft/sec, unnatural resuspension of sediments will occur. Once the sediments are in suspension, they will remain in suspension because the ambient

river velocity is usually above the settling velocity for this size sediment. This occurrence, however, must be evaluated with knowledge that the natural river velocity frequently exceeds 0.8 ft/sec. Consequently, sediment resuspension and transport are continuous natural processes, and the added sediment resuspension potential created by river traffic may not produce significant impacts on the ecology of the river. The major effects of river traffic on suspended sediments will be to eliminate periods of relatively low turbidity that might occur during low river flow." (Environmental Science and Engineering, 1981)

The U.S. Army Corps of Engineers, Huntington District (1980) also used optical measurements to determine the amount and relative abundance of suspended sediment after tow passage. They measured transmittance across the tow wake once for each event using a towed beam transmissometer.

"Tow traffic effects on water clarity or opacity, as indicated by nephelometry and light transmittance, were significant only in clearer waters. Under more turbid conditions (storm-event runoff), changes in optical properties due to towboat traffic were less evident, if measureable at all. Changes in near-surface lateral distributions of water clarity or opacity, as indicated by decreased light transmittance, were measured in the wakes of passing tows. This effect was usually limited to the overall width of the tow and varied according to ambient river conditions, type of vessel propulsion, and draft of tow. As a rule the more turbid the ambient river conditions, the less significant the change effected by tow passage. The open-wheel propulsion system increased turbidity more than the Kort nozzle system. Deep-draft tows caused more bottom disturbance than shallow-draft tows."

They concluded that the effects of tow traffic on the Ohio River are only significant during low flow.

For a stream with the dimensions of the Ohio River, significant environmental impacts occur only in shallow areas or if tows venture outside the sailing line. Significant impacts occur only under low flow conditions. Effects on the river bottom are considered to be minor and confined to an area 60 feet wide beneath the tow. Only nominal stresses are introduced into the system as a result of displacement or backwater flow effects. Wave effects on shallows are considered to be nominal to minor." (U.S. Army Corps of Engineers, Huntington District, 1980)

Berger Associates, Ltd. (1980) estimated the magnitude and duration of sediment resuspension expected from tow passage.

> "In the worst case, it appears that duration of the disturbance added to the time of settlement after the disturbance averages five to ten minutes and rarely exceeds twenty minutes for typical Ohio River bed material (d_{50}=0.5 mm). The concentration of suspended sediment at the time of disturbance is also very insignifiant since the propeller jet flow velocity , as high as 6.5 ft/sec generates a very localized concentration of suspended sands of only 2.2 kg/m^3, or 2,200 ppm."

Forty tow passages at sites on the Upper Mississippi and Illinois Rivers were monitored by Johnson (1976). He measured turbidity and suspended solids during normal pool conditions. Johnson concluded that "tow traffic on the Upper Mississippi and Illinois Rivers during normal pool conditions contribute to existing levels of suspended sediment measured as both suspended solids (a gravimetric measurement) and as turbidity (an optical measurement). Furthermore, it was found that lateral movement of sediments resuspended by tows and transported from the main channel to shoreward areas, including potentially productive side channel areas, does occur during normal pool conditions."

Many factors can affect the magnitude and duration of sediment resuspension due to tow traffic. Johnson (1976:126) observed the effects of speed and type of traffic:

> "It appeared that faster moving tows had a greater effect on resuspending sediments than did slower moving tows. Also, multiple tow traffic produced additive effects and maintained previously elevated concentrations caused by prior traffic."

Barge effects can vary in different rivers and even in different sections of the same river, as Karaki and van Hoften (1974:26-27) noted.

> "Large towboats caused greater resuspension of sediments in the channel than smaller pleasure crafts due to their size and proximity to the river bed. The Illinois River is more susceptible to these effects than the Upper Mississippi River because of the finer bed material and generally shallower

depths. Increasing river traffic will increase resuspension and thus turbidity at a rate proportional to the frequency of towboat. passage."

Berger Associates, Ltd. (1980) claim "the upstream tows generate a larger disturbance since their speed is decreased by opposite currents, whereas the propeller flow velocity is increased." Johnson (1976:125) observed longer recovery times for the Illinois River than for the Mississippi River.

SITE SELECTION

Selection Process

The original project scope allowed for coordination of site selection by the State Water Survey and Natural History Survey so that physical and biological studies would be conducted at similar, preferably the same, sites which would be typical reaches of the Illinois and Mississippi rivers in Pool 26. This coordination was not possible in the rescoped study plans. Primary and secondary site selection criteria were established as shown in table 1. The primary criteria for site selection were established to describe each potential site in sufficient detail to identify typical and similar sites. The secondary criteria were needed because of the number of personnel and boats and other requirements for conducting field data collection.

The site selection process began with the examination of topographic maps, navigation charts (U.S. Army Corps of Engineers, 1974, 1978), and hydrographic survey charts (U.S. Army Corps of Engineers, 1971, 1977). A number of possible sites were selected on each river. Aerial reconnaissance trips added greatly to our knowledge of river-reach geometry and potential site location and access. Each site considered suitable after the overflight was then visited by land. Two sites were selected on each river. The first site at which we collected data on the Illinois River was intended only as a place to test our methodology, and was not one of the selected sites. Also, the second site where we collected data on the Mississippi River was an alternate site.

Table 1. Site Selection Criteria

Primary Site Characteristics

- Typical 9 foot navigation channel
  - Depth about 15
  - Representative width
  - Natural or dredged channel
  - Representative channel geometry and configuration
  - Alignment
    - Straight
    - Representative radius bend
  - No obstructions
    - Wing dams
    - Bridges
    - Loading docks
    - Fleeting areas
    - Marinas/boat launches
    - Ferry crossing
  - Coincide with side channel site, if possible
  - Possible site for intensive biological study
  - Barges not coasting or maneuvering

Secondary Site Characteristics

- Land access
  - Vehicles
  - Survey stations and related lines-of-sight
- Shore area
  - For installation of wave instrumentation (Pool 26 only)
  - Boat landing
- River access
  - Boat launching site nearby
  - Secure boat harbor for boats.

Description of Sites

The first field data collection trip, conducted to determine the practicality of the proposed field methods, was at mile 121.5 on the Illinois River. This site is in the LaGrange Pool, upstream from Havana, Illinois and is shown in figure 3. The survey stations were on the levee of the Thompson Lake Drainage and Levee District, opposite Quiver Island. Bed material data reported by Bhowmik and Schicht (1980:33) give median diameters of 0.38 mm at mile 118.0 and 0.40 mm at mile 124.0. The bed material at mile 121.5 is probably similar fine to medium sand.

On the second and third field trips, we collected data at Hadley's Landing, mile 13.2 on the Illinois River. Main channel bed material is sand with a median diameter of 0.47 mm. The bed material at one-half depth is sand, median diameter of 0.90 mm, on the outside of the bend and silt, median diameter of 0.038 mm, on the inside of the bend (Schnepper et al., 1981). A site map is shown in figure 4. The survey stations were located on the west bank where the road is close to the river bank. A channel cross section, looking downstream, is shown in figure 5. Figure 6 shows an aerial view of Hadley's Landing.

Since Hadley's Landing is on a bend opposite Twelve Mile Island, we searched for a straight reach on the Illinois River without an island. Two potential sites, McDonald's Daymark, mile 16.5, and north of Woods Branch, mile 35.5, were found to meet these criteria. Due to the limited number of field trips possible and the need to collect some data on the Mississippi River, data were not collected at either of these locations.

A search for sites on the Mississippi River was conducted from its confluence with the Illinois River at mile 218 to mile 296. No sites were found in Pool 26 that met our secondary criteria. Thus, we selected

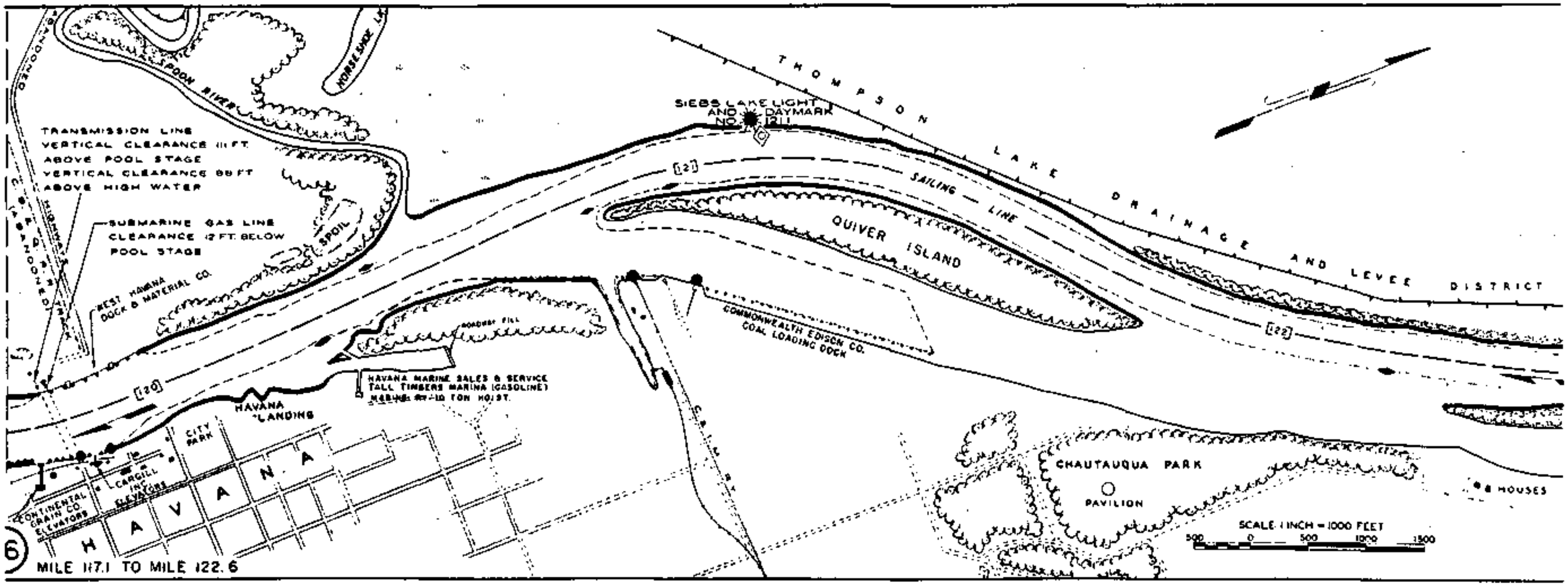


Figure 3. Site map at Illinois River mile 121.5

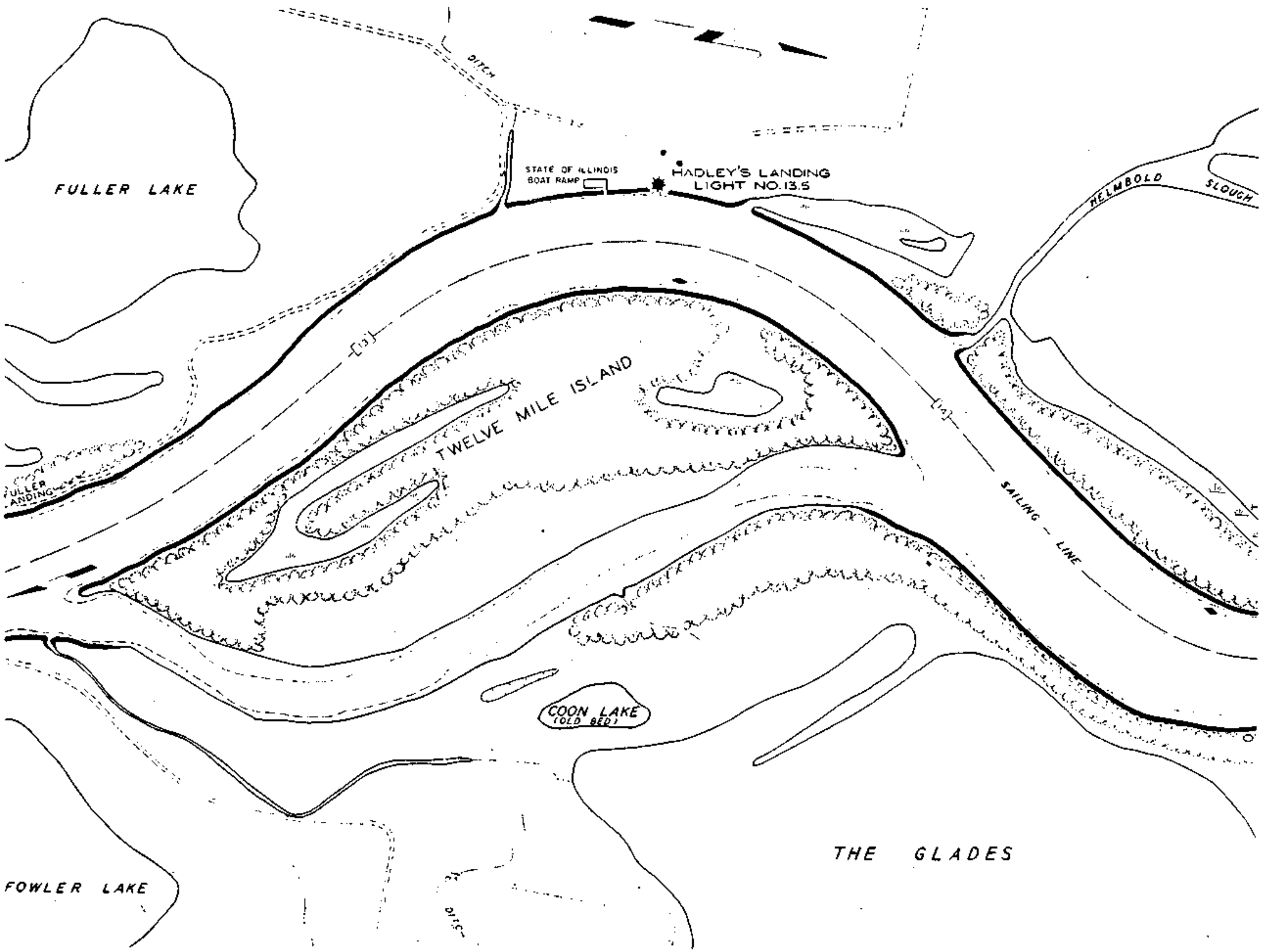


Figure 4. Site map at Illinois River mile 13.2

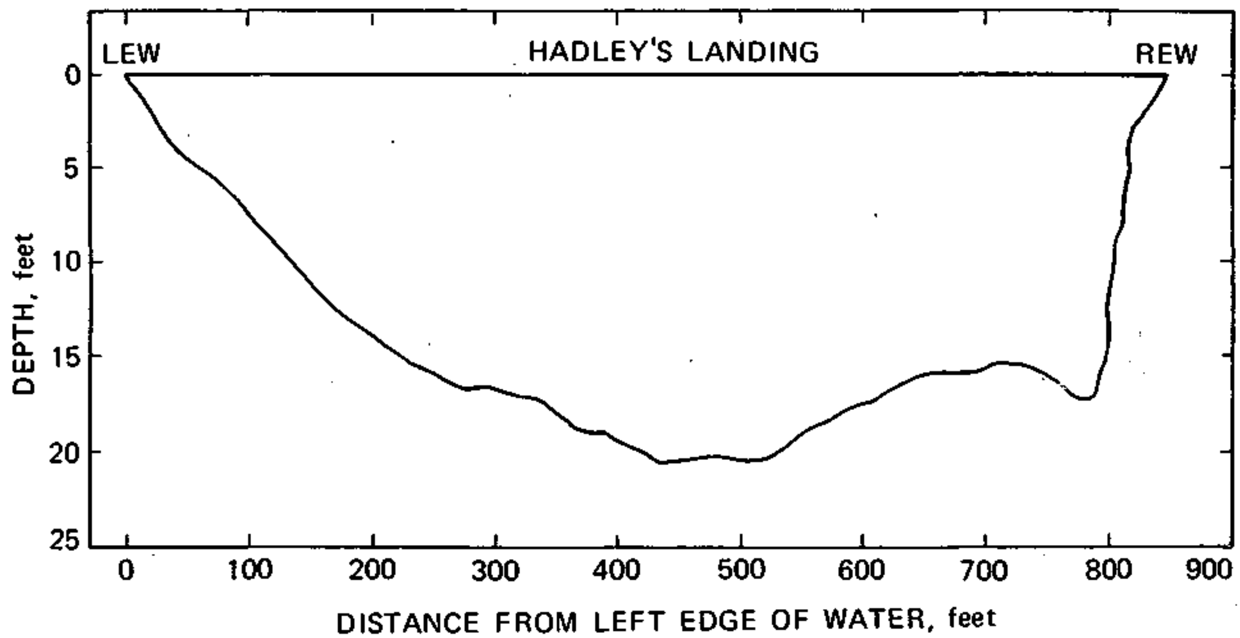


Figure 5. Cross section of channel at Illinois River mile 13.2

Figure 6. Aerial view of site at Illinois River mile 13.2

Figure 7. Aerial view of site at Mississippi River mile 265.1

several possible sites in Pool 25 that met both Che primary and secondary criteria. The channel reaches aC Che Cwo sices described below are typical of channel reaches in both Pool 25 and Pool 26 above the mouth of the Illinois River. There are only a few docks and loading facilities so the traffic density is the same.

Rip Rap Landing Conservation Area, mile 265.1, Mississippi River, between Belleview and Mozier, Illinois, was selected for our site on the Mississippi River. One survey station was at the parking lot in the left center of figure 7 and the other at the edge of the open field in the center of figure 7. A location map of Rip Rap Landing is shown in figure 8. Fourteen bed material samples were collected with a median diameter of 0.42 mm. The particle size values and uniformity coefficients are given in table 2. The river bed profile is shown in figure 9.

Table 2. Bed Material Particle Size, Mississippi River Mile 265.1

Sample #	Distance (feet) from LEW	d_{50}	d_{95}	U
1	1080	0.60	2.50	2.00
2	840	0.38	1.60	3.00
3	760	0.40	1.60	2.60
4	680	0.37	1.30	3.36
5	640	0.35	2.20	3.20
6	520	0.22	0.77	4.50
7	400	0.45	1.70	2.70
8	360	0.43	2.50	1.92
9	320	0.44	1.30	1.88
10	240	0.43	1.80	2.09
11	200	0.49	1.80	1.90
12	160	0.47	3.00	2.08
13	120	0.40	0.80	1.72
14	80	0.40	-	1.65

In May 1981, we intended to return to Rip Rap Landing for a second set of field data. However, high water prevented vehicular access. We

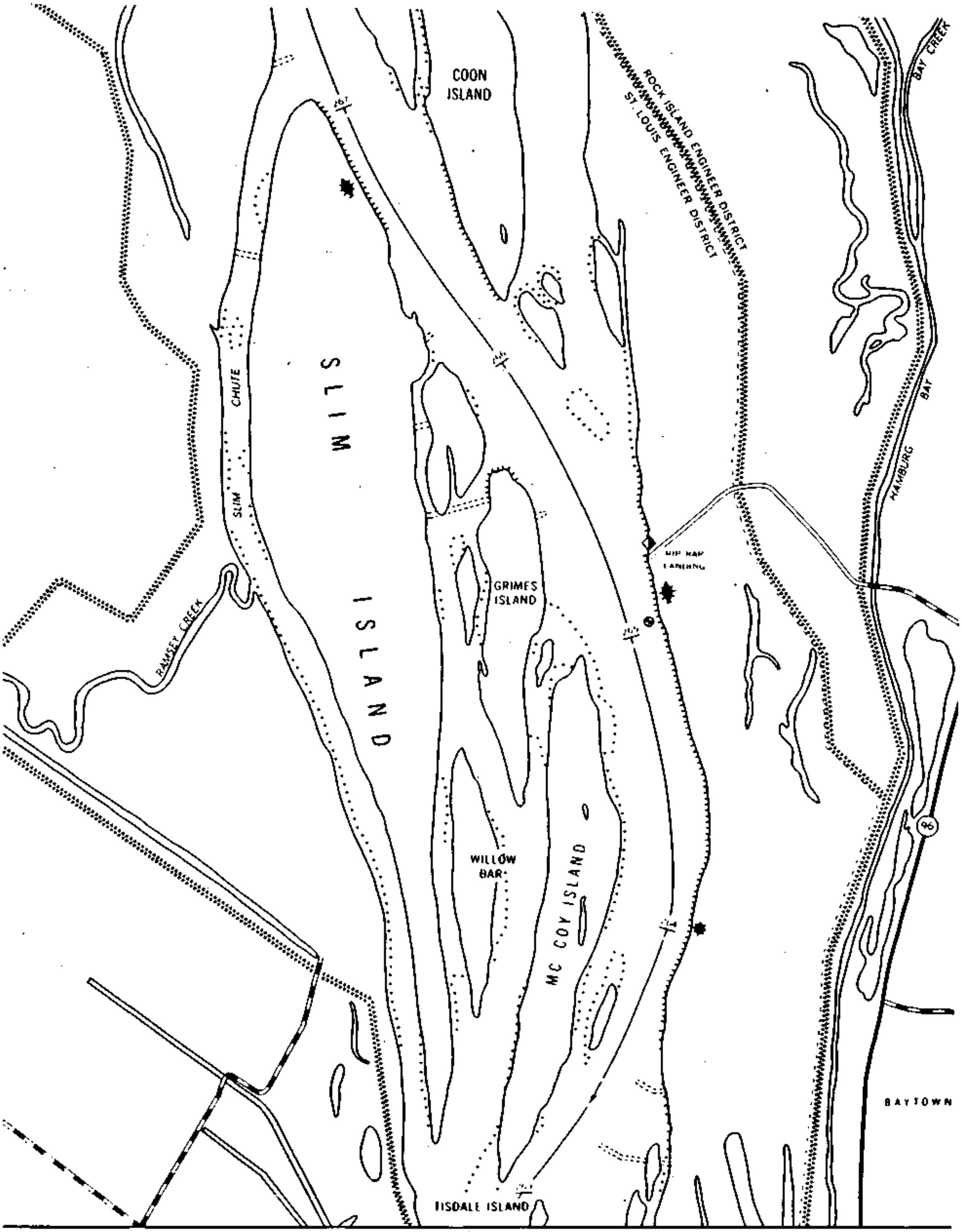


Figure 8. Site map at Mississippi River mile 265.1

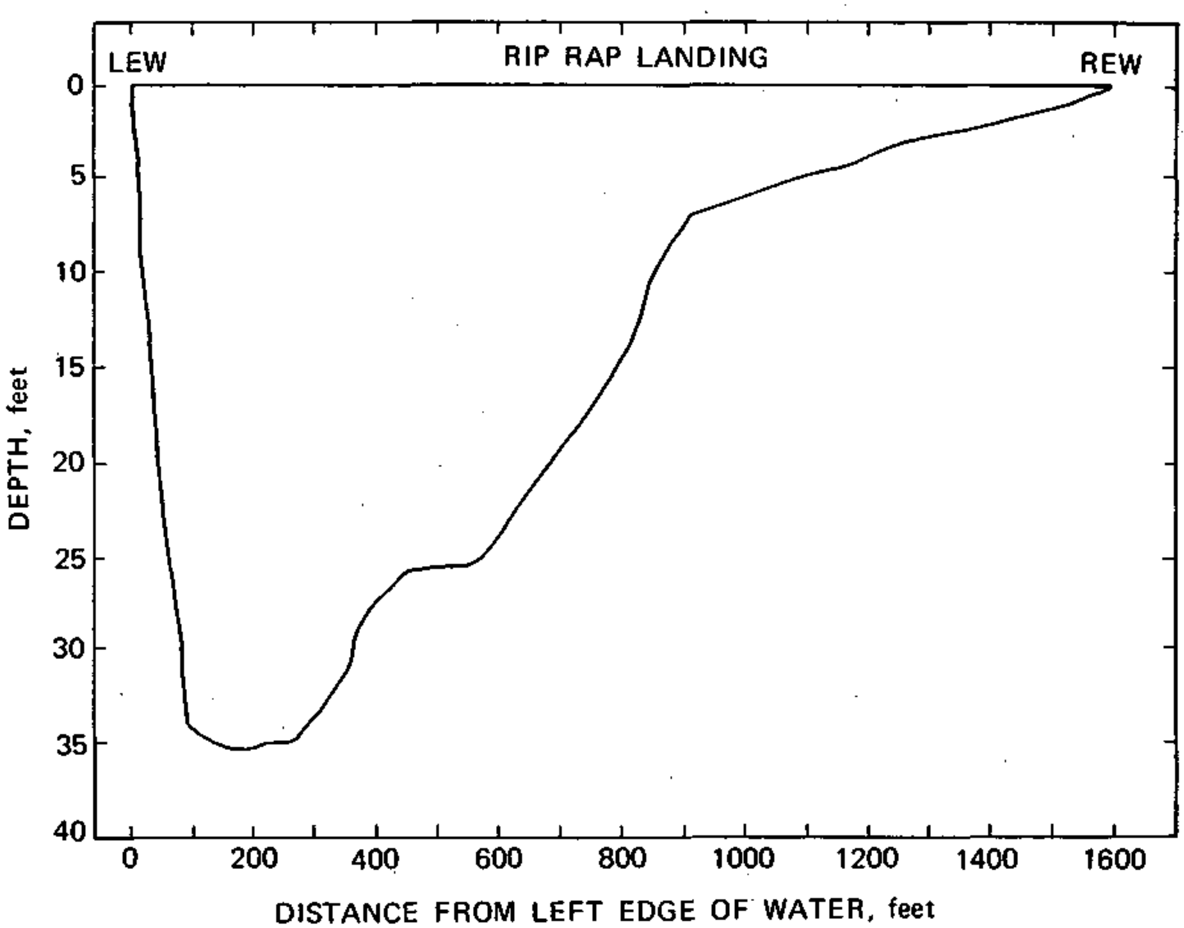


Figure 9. Channel cross section at Mississippi River mile 265.1

found the site at Mosier (Mozier) Landing, Mississippi River, mile 260.2, accessible. The location map of this site is shown in figure 10. The primary survey station and study transect are in the center of the aerial photograph in figure 11. A cross section from the hydrographic charts is shown in figure 12. A cross-sectional survey was not made because the river stage was dropping several feet per day and a water discharge, sediment load, and cross section measurement was not practicable.

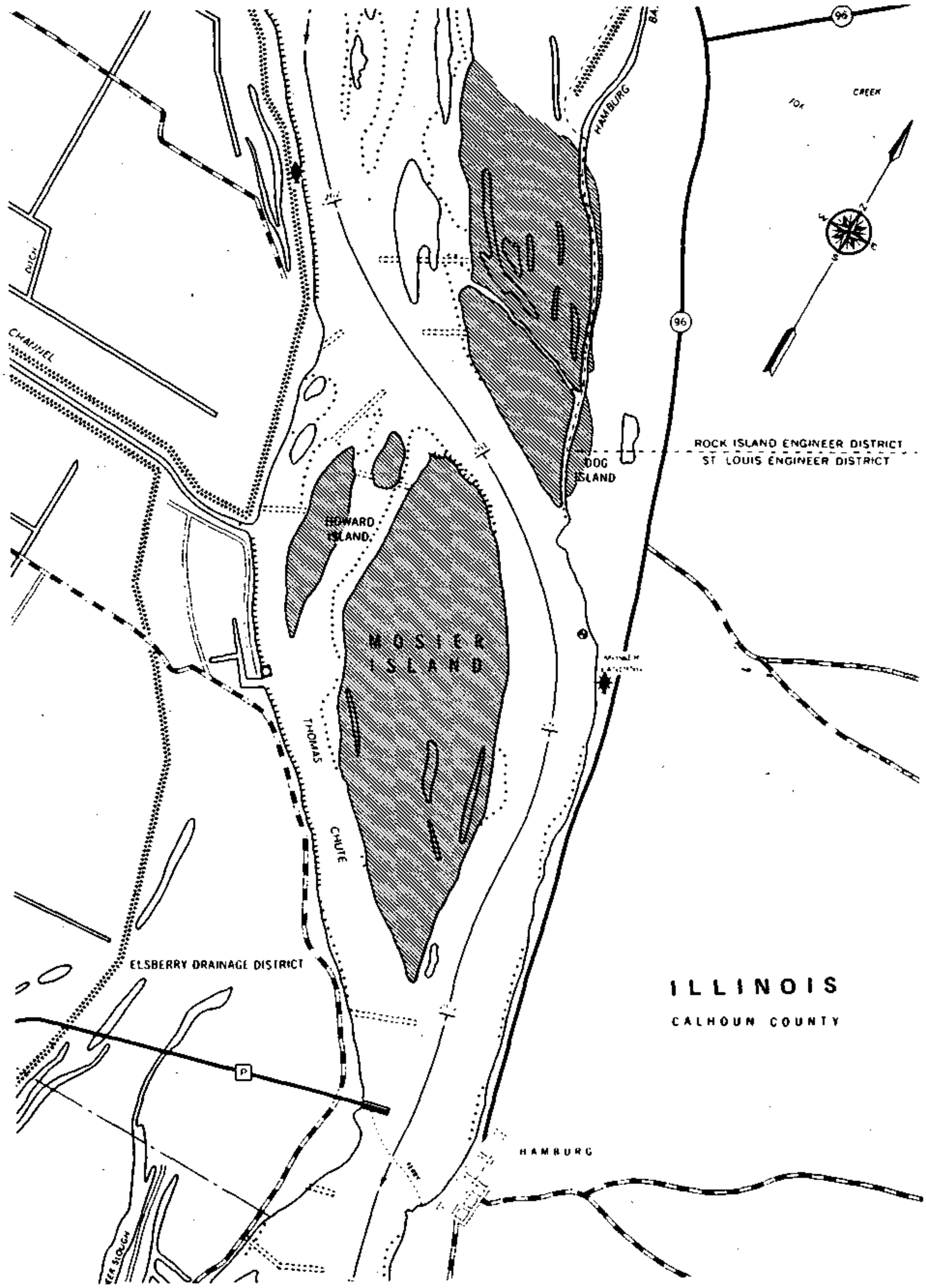


Figure 10. Site map at Mississippi River mile 260.2

Figure 11. Aerial view of site at Mississippi River mile 260.2

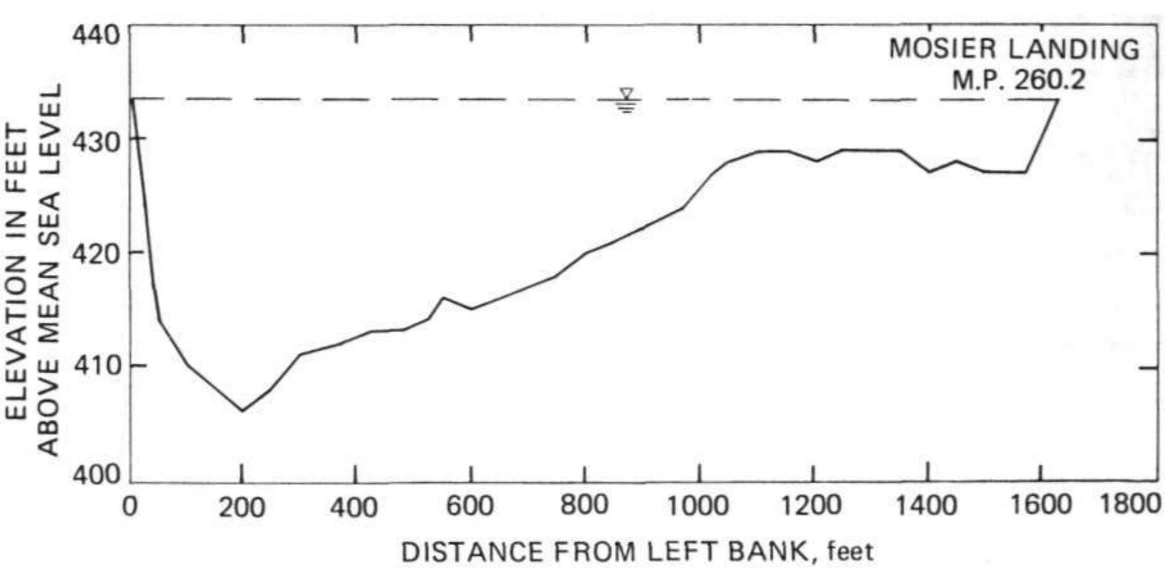


Figure 12. Channel cross section at Mississippi River mile 260.2

FIELD AND LABORATORY METHODS

Surveying

In the field, the survey team was responsible for four tasks. These were:

1. Determine the track of both ends of each tow as it passes through the sampling area.
2. Determine the average velocity of each tow as it passes through the sampling area.
3. Develop a means of repositioning the sampling boats precisely and quickly after a tow passes and for background data collection.
4. Develop appropriate communications methodology and systems.

In developing procedures for these tasks, an effort was made to maintain simplicity and flexibility, while taking into consideration costs in terms of equipment and personnel.

Track Determination

A standard bearing intersection system of survey was used to determine the track of the tow. A baseline of sufficient length, usually eight hundred to fifteen hundred feet, was established on one shore adjacent to the sampling site. A semi-permanent marker was set at each end of this line. One of these was then referred to as the primary survey station, and the other was termed the secondary survey station.

It was desirable but not critical to have the baseline situated to allow a clear line-of-sight from end to end. Locations were selected which provided the greatest unobstructed view of the sampling area and channel approaches. We found that a one-half to one-mile section of the river could be viewed with little difficulty in most cases. This enabled us to measure tow tracks which extended at least one thousand feet above or below the sampling sites.

After establishing the baseline location, the next task was to perform a site survey. This would define the shape and position of the shorelines adjacent to the sampling area and the locations of all data-gathering instruments. The precise distance between the survey stations--the length of the baseline--was measured electronically, and routine land-survey procedures were employed to produce a site configuration base map. This map was reproduced in quantity and subsequently used to plot the track data for each tow, giving us a visual representation of events as they actually occurred in the field.

Given this basic set-up, the determination of track was accomplished relatively easily. For example: A tow was observed approaching one end of the sampling area. Tracking operations began as soon as the entire length of the vessel was observable from both survey stations. The basic device used to make our measurements was a Lietz TM-10C precision theodolite set at each survey station. Figure 13 illustrates the tracking procedure.

Each theodolite was zeroed on the opposite station, and this provided the index for all angular measurements. Horizontal angles were measured simultaneously from each station to a previously agreed-upon point on the tow--usually the centerline foresight mast which was present on the bow of the leading barge of most tows. These angles were measured to the nearest one minute of arc and recorded. The procedure was repeated for the stern of the tug, where the sighting point was usually the radar mast or the jack-staff.

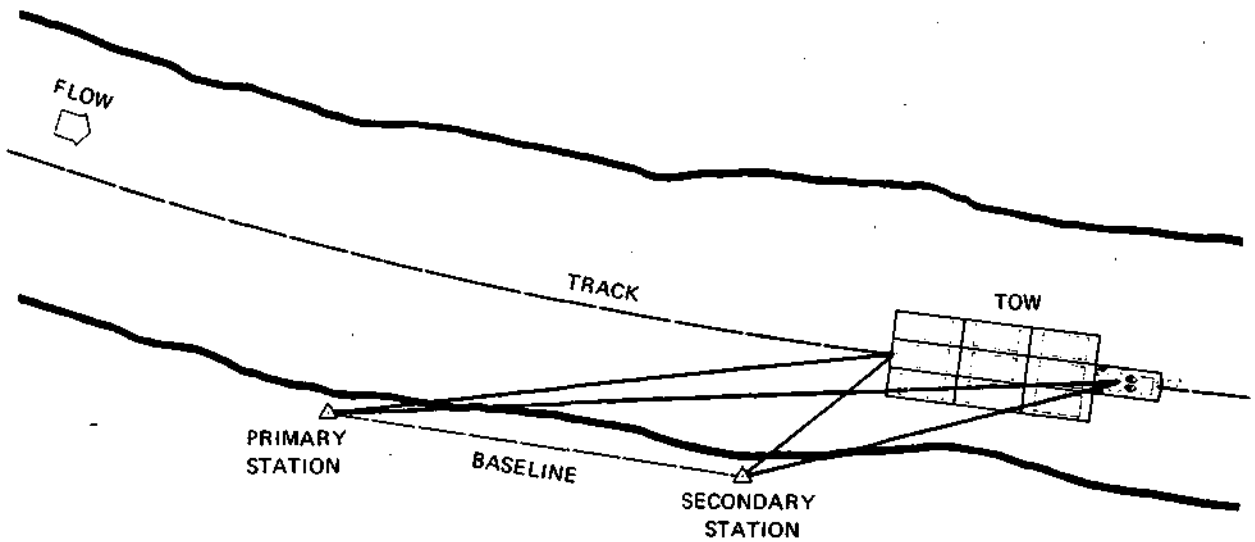


Figure 13. Tow tracking procedure

Figure 14. Tows passing near Hosier Landing

These angular measurements followed each other as rapidly as possible and were always taken in pairs. In other words, an angle to the bow from each station was measured at the same instant, and an angle to the stern from each station was measured at the same instant, forming a set of angles consisting of two pairs.

To make recording the angles easier and faster, a pocket-size, battery-powered tape recorder was utilized at each survey station. A running account of the tracking operation and the angular data was recorded and later transcribed.

This process continued at regular intervals until the tow passed from the observed area. At first glance this procedure seems cumbersome, but in actuality each pair of angles could be measured and recorded in about thirty seconds. Usually an interval of about one minute was left between sets of angles. This method proved effective even during multiple tow passages like the one shown in figure 14. The coordination between survey stations was maintained by continuous radio communication, and all actions were initiated and directed from the primary station.

A graphic depiction of each track was developed by plotting the point of intersection of each pair of angles on the base maps and connecting the resulting points. Having measured angles to both bow and stern, we were able to show differences in the tracks of each end of the tow.

Tow Velocity Determination

The speed of the tows was determined by timing the tracks. At the precise instant of measuring the first angle, bow or stern as convenient, a stop watch was started. The watch was stopped at the instant of the appropriate last angle measurement. The resulting elapsed time was compared with the track length to obtain the average velocity. This calculation was usually performed at the same time that the tracks were plotted. Velocities thus determined were shore-relative. It may be desirable to adjust them for the effects of current. The velocity of the tows was actually a by-product of the bearing intersection procedure--another good reason why that system was adopted.

Sampling Boat Repositioning

For repositioning our three work boats in the proper location on the river, a method was developed which made no direct demands on the survey stations, requiring only the attention of the boat operator while quickly and easily providing for boat repositioning. Dubbed the "delta system," it consisted of a series of shore-based, color-coded visual guides. When aligned from the boat operator's viewpoint, these indicated exactly the correct position. Figures 15 and 16 illustrate the workings of this system.

In practice the delta system was set up in the following manner: The primary survey station was established near a line which constituted a channel transect, to which sampling locations were referenced. Two eight-foot-tall posts were erected on shore about one hundred feet apart and on the sample transect line. The post furthest back from shore was termed the index post, and the other was called the foresight post. These posts were brightly painted and set up to be clearly visible from the water. When the two posts appeared to be aligned, one behind the other, the boats were positioned on the transect line.

The boats were arranged and anchored along this line in the selected positions for sampling. Figure 17 shows the three work boats (A, B, and

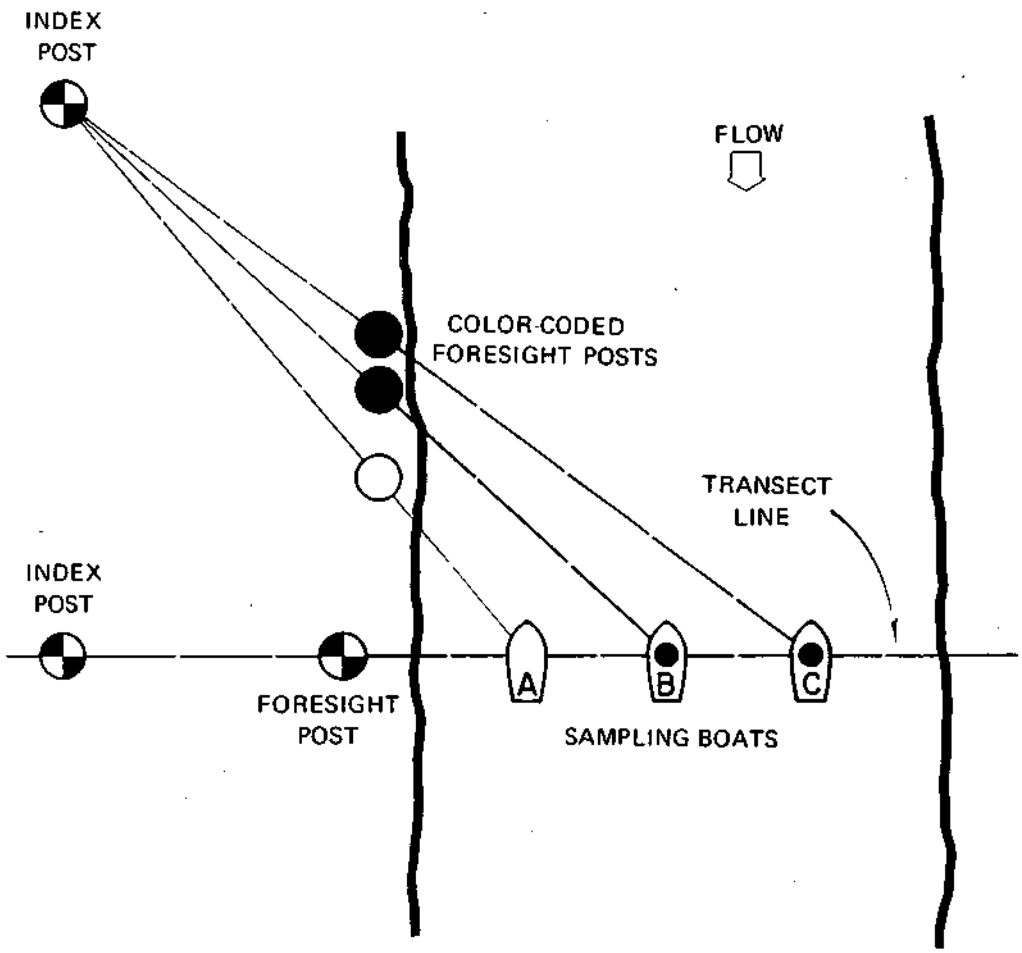


Figure 15. Delta post system

Figure 16. Delta post system viewed from boat

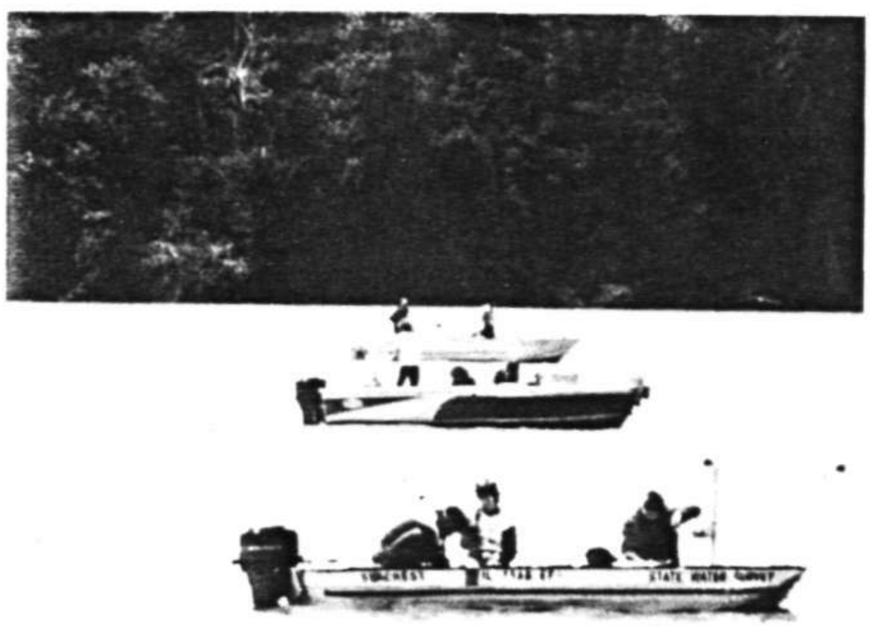


Figure 17. Sampling boats in position

C) in their sampling positions. Boat C was located in the main channel directly in the tow track, boat A was out of the main channel in shallower water (closest to shore), and boat B was located halfway between boats A and C on the transect line. At some convenient distance upstream, usually four or five hundred feet, another index post was erected in a clear area on shore. Between this post and the water, color-coded foresight posts were set. in positions which aligned with each of the sampling boats. This part of the system had a delta shape, which prompted the name. Each boat now had two sets of visual references for its correct position: one alignment defined the transect line, and the color-coded alignment intersected the transect line at the boat's correct position.

Here is an example of how the entire delta system was used. The sampling boats moved out into the channel as a tow passed. The boats moved upstream toward their positions, because steering into the current allowed more precise boat handling. With careful manipulation of heading and throttle, the boats could be maneuvered to the point where the transect line and the color-coded alignment intersected, which defined the appropriate sampling position. The boat was immediately moved directly upstream, taking into account the effects of wind and current, and the anchor was set. The boat was then allowed to drift back downstream and the anchor line was secured when the boat was in the correct sampling position.

Communications

Our communications network consisted of a hand-held citizen band transceiver in each sampling boat and survey station. They all had at least one frequency in common. The primary survey station was also equipped with a vehicle-mounted, mobile transceiver with full forty-channel capability. The secondary survey station's hand-held unit was equipped with crystals for the common frequency and for a second frequency for use during tracking operations. Thus, the common frequency was available for communication between the sampling boats during tow tracking.

On trip five the secondary survey station also had a vehicle-mounted, forty-channel citizen band radio and the primary station had a marine band radio in addition to its citizen band radio. The marine band radio was used for communication with the tow pilots and the Coast Guard.

The primary survey station served as the coordinating facility since it commanded full-site overview and had the most powerful transceiver. Messages concerning operations and safety were relayed through this station.

Sampling Equipment

Suspended Sediment Samplers

Three different suspended sediment samplers were used for our study--the US DH-59, US P-61, and US P-72--which are standard samplers designed for the United States Geological Survey. The DH-59 was used in boat A for all five trips and boats B and C for the first three trips and part of trips four and five. The P-61 and P-72 were used in boats B and C for the last two field trips. The DH-59 was used in boat B for part of trip 4 and in boat C for part of trip 5 due to mechanical problems with the P-61 samplers.

The DH-59 consists of a streamlined bronze casting 15 inches long and weighing 24 pounds (11 kg). This sampler is pictured in figure 18. A

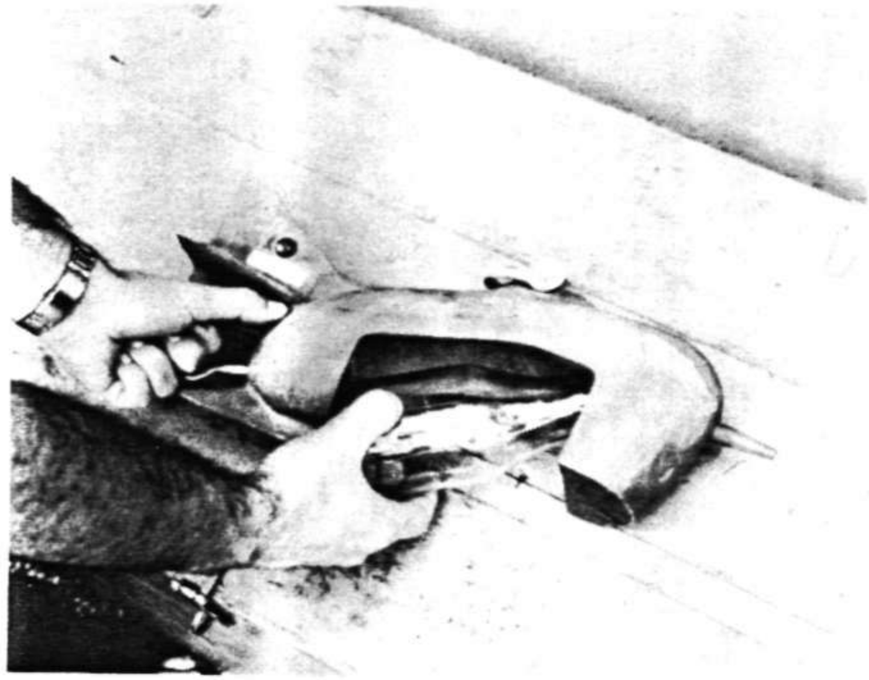


Figure 18. DH-59 sampler

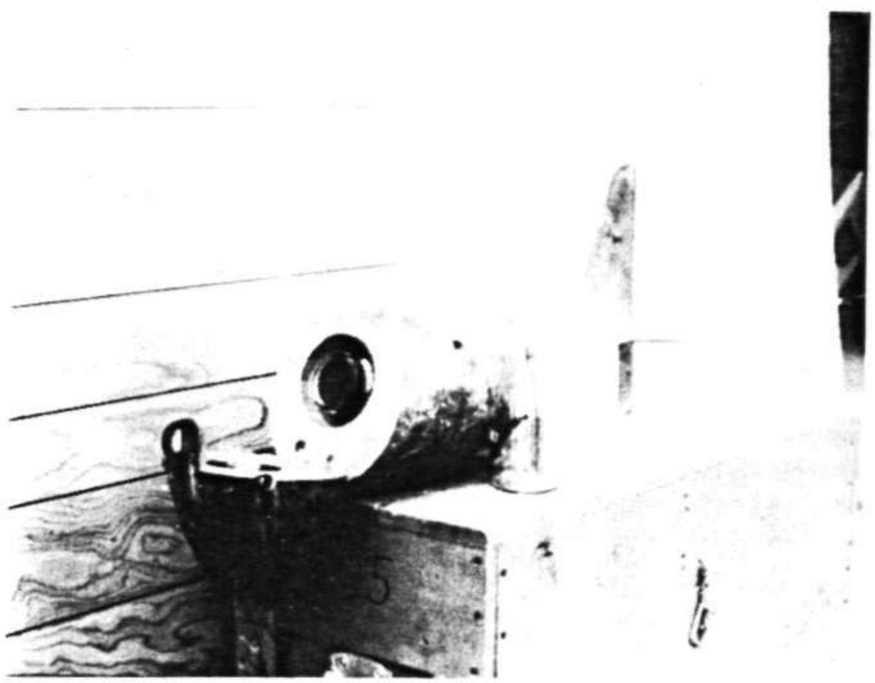


Figure 19. P-61 sampler

pint glass milk bottle is sealed against a gasket in the head cavity of the sampler by a hand-operated spring-tensioned pull-rod assembly at the tail of the sampler. The sample is collected through the intake nozzle (three nozzles are available: calibrated to 1/8, 3/16, or 1/4 inch inside diameter) and is discharged into the bottle. The displaced air from the bottle is ejected downstream through the air exhaust alonside the head of the sampler. Tail fins keep the sampler pointing into the current. The DH-59 is a depth-integrating sampler designed to accumulate a water-sediment sample from a stream vertical at such a rate that the velocity in the intake nozzle is almost identical with the immediate stream velocity, while running the vertical at a uniform speed. The sampler collects and accumulates the sample as it is lowered on a rope or cable to the bottom of the stream and raised back to the surface, all at a constant rate. One drawback to this sampler is that it can be used only in depths up to 15-18 feet (Guy and Norman, 1970:5-6).

The P-61 consists of a 105 pound (48 kg) streamlined cast bronze shell, an inner recess which can hold a pint glass milk bottle or a quart-sized jar, a pressure-equalizing chamber, and a two-position rotary valve operated by a solenoid which controls the sample intake and air exhaust passages. This sampler is pictured in figure 19. The P-72 is a lighter version of the P-61 which is cast aluminum weighing about 60-65 pounds. The sampler was suspended on a cable using a winch (B-reel) and crane apparatus, as shown in figure 20. The P-61 and P-72 are capable of taking either a point-integrated or a depth-integrated sample at depths up to 180 feet. For depth integration in depths around 30 feet, half of the vertical was sampled at once. For example, to sample the bottom half of the vertical, the sampler is lowered to the river bed. The solenoid is

Figure 20. Boat equipped with winch and crane to suspend P-72 sampler

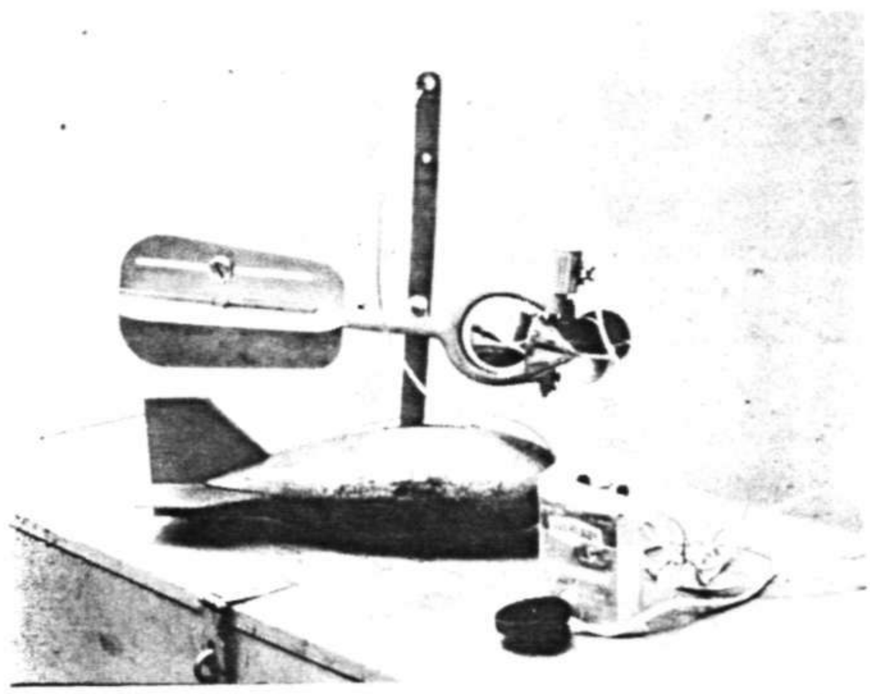


Figure 21. Current meter

energized, thus opening the intake and air exhaust passages. Immediately the sampler is raised at a constant rate to the midpoint of the vertical, where the solenoid is deactivated and the passages closed. The sampler is then raised to the surface where the sample bottle is removed. A point sample can also be taken by lowering the sampler to the desired depth, opening the nozzle long enough to get an adequate sample, then closing the nozzle at that same depth (Guy and Norman, 1970:7-8; Benedict, 1979:166). We experienced some difficulties with these samplers due to frequent malfunctions.

Current Meters

The meter used for our study to measure the velocity of the flowing river was the standard Price-type meter (see figure 21). This meter has a rotor with six cone-shaped cups mounted on a vertical stainless steel shaft. A pivot bearing supports the rotor shaft. The contact chamber houses the upper part of the shaft and an eccentric contact that wipes a bead of solder on a slender bronze wire (cat's whisker) attached to the binding post. We used the setting for the meter which completes this circuit once for every revolution of the rotor. The electrical impulse produces an audible click in a headphone. A tailpiece keeps the meter pointing into the current. The current meter was attached to a 30-1b. weight to keep it from drifting in the current. The meter was suspended with a cable attached to a winch (Steven's sounding reel) and crane apparatus. By placing the current meter at a point in the stream and counting the number of revolutions of the rotor (clicks) during a measured time interval, the velocity at that point is determined (Buchanan and Somers, 1969:4-6). The current meters were generally quite reliable;

occasionally problems occurred with debris clogging the meter and inaccurate readings due to high wind or boat waves.

Sampling Schedule and Procedures

Suspended Sediment

Tow passage event. When the bow of an approaching barge crossed our study transect line, a visible and audible signal was given by boat A as shown in figure 22. At this signal, stopwatches were started in all three boats. This stopwatch time was called "barge elapsed time" to denote the time in minutes after the barge passed.

Boat A was usually in its position on the transect when the tow passed. This was because their station was out of the main channel, thus they were well out of danger from the passing tow. Thus, boat A could begin sampling suspended sediment right away, while boats B and C remained a safe distance from the tow until it had passed, after which they could maneuver into position.

During the first thirty minutes after a tow had passed, one depth-integrated suspended sediment sample was taken every two minutes. For the next thirty minutes, samples were taken at five-minute intervals. During the last thirty minutes of the event, a sample was collected every ten minutes. A total of twenty-four samples would be collected per boat for the full ninety-minute sampling period for an event. If another tow arrived before the ninety minutes was up, it was designated a new event and the sampling routine was restarted.

When using the P-61 or P-72 sampler, this sampling schedule was altered slightly for the two-minute interval sampling period. Since two samples were needed to measure one depth-integrated vertical (half at a

Figure 22. Signal for the start of an event

Figure 23. BMH-60 sampler

time), each vertical was in reality sampled approximately once very three minutes. Also, boat C collected point samples at a specified depth between integrated samples. A four-event rotating schedule was followed for these point samples:

	Boat C Point Sample Depth
1st event	.95 of depth
2nd event	.8 of depth
3rd event	.6 of depth
4th event	.2 of depth

The schedule rotated so that for the fifth event, the depth was the same as for the first event. These depths are based on the surface being zero; thus .95 of the depth would be very near to the river bed.

Background. There were sometimes intervals of several minutes or even hours between barge events when no tows arrived. During those times, one depth-integrated suspended sediment sample was collected every thirty minutes at each station (A, B, and C). Boat C took a point sample at .95 of the depth for every other background sample, in addition to taking depth-integrated background samples. Background or ambient is used herein to denote conditions existing in the river on a particular day anytime a tow passage event was not being sampled.

At Rip Rap Landing (trip 4), samples were collected at several points (usually every twenty feet) along the transect line. These depth-integrated background samples were used to find the total sediment discharge at that cross-section of the river.

Water Velocity Measurement

Tow passage event. Velocity measurements were taken during tow events for trips four and five. Each work boat had a separate stopwatch for use exclusively by persons taking velocity measurements. If boat A was in position before the tow arrived, the crew would start the stopwatch (and velocity readings) about five minutes before the tow crossed the transect. The "velocity time" corresponding to the zero of the "barge elapsed time" was recorded later so the two times could be equated. Since boats B and C were not yet in position, they started their stopwatches when the tow crossed the transect and sampled on "barge elapsed time."

Once the boats were in position, the current meters were lowered to a fixed depth where they remained for the entire event. A four-event rotating schedule was used to determine these depths:

1st event	.95 of depth
2nd event	.8 of depth
3rd event	.6 of depth
4th event	.2 of depth

Note that point suspended sediment samples were taken from boat C at these same depths.

When the current meter was in the water at the proper depth, the person monitoring the meter would begin to count "clicks" in the headphone. The number of clicks during each thirty-second interval was recorded, ie. as soon as the first 30 seconds had passed he/she would record the number of clicks, while at the same time beginning to count the number of clicks for the second 30-second interval. This procedure was continued until ten minutes after the tow had crossed the transect, or until ten minutes of measurements had been obtained (when readings were begun a few minutes after the tow had passed, which was the case for boats B and C).

When all the thirty-second continuous readings were completed, velocity readings were taken each time a suspended sediment sample was collected for the duration of the event. (For the first thirty minutes of the event, readings were taken every two minutes; the next thirty minutes, at five-minute intervals; and for the last thirty minutes, at ten-minute intervals.) The "standard discharge method" of velocity measurement was used for these readings. This entails counting to an even ten number of clicks occurring in a period of forty or more seconds. The number of clicks and seconds were recorded (for example, 40 clicks in 47 seconds).

Background. Every time a background sediment sample was collected (every half hour before, between, or after events), background velocity readings were also taken. These readings used the "standard discharge method" counting an even ten number of clicks for forty or more seconds. Each boat crew took these readings at several depths at their station as follows:

Boat "A" - A normal discharge measurement at .2, .4, .6, and .8 of the depth.

Boat "B" - A normal discharge measurement at .1, .2, .3, .4, .5, .6, .7, .8, and .9 of the depth.

Boat "C" - A normal discharge measurement at .1, .2, .3, .4, .5, .6, .7, .8, .9, and .95 of the depth.

Velocity measurements were taken along the transect line (about every twenty feet) for a water discharge determination at Hadley's Landing and Rip Rap Landing. Velocity was measured at .2 and .8 of the depth at each point on the cross-section, using the "standard method" of measurement.

Other Data Collected

Particle Size. Suspended sediment samples were collected for particle size analysis from boats B and C on trips four and five during four events for each trip. A P-61 or P-72 sampler with a quart jar was used to take point samples at a specified depth. Several samples were collected at this depth and poured into a gallon plastic bucket until a full gallon was collected. Grab samples were also taken at the surface by dipping a pail into the water and filling three plastic gallon buckets. A different sampling depth was used for each of the four events for which particle size samples were taken:

Event no.	Sampling depth
3	.6 of total depth
4	surface
9	.95 of total depth
10	.8 of total depth

This sampling schedule was rather flexible; if a second tow arrived, shortening the event to be sampled, particle size samples were collected during the next event instead. Three samples were collected during each designated event: the first after five minutes had elapsed (+5 minutes), the second at +30 minutes, and the last at +60 minutes. A one-gallon bucket was filled for each sample (except for the surface samples where three gallons were collected), so there would be three gallons of sample collected during each event (except event four, for which there was nine buckets).

Background particle size samples were also collected twice a day, providing no tows had passed within ninety minutes before the samples were taken. These samples were collected at two different depths each time.

One sample was taken at .95 of the total depth (one gallon) and the other was a grab sample at the surface (three gallons).

Bed Material. A US BMH-60 sampler was used to sample river bed material at Rip Rap Landing (trip 4). This is a 30 lb hand-line sampler 22 inches long, made of cast aluminum with tail vanes (see figure 23). The sampler mechanism is a scoop driven by a cross-curved constant-torque motor-type spring that rotates the bucket from front to back. The scoop, when activated by release of tension on the hanger rod, can penetrate into the bed about 1.7 inches and can hold about 175 cc of material. The bucket closes when tension on the hand line is released as will occur when the sampler comes to rest on the streambed (Guy and Norman, 1970:14-15).

Bed material samples were collected at several locations along the transect line at the same time cross-section discharge measurements were taken. Each sample was stored in a plastic ziplock bag for transport to the laboratory for analysis.

Photographic Record. A complete photographic record was taken of all of our sampling trips. Over 800 color slides were taken with a 35 mm camera. These included pictures of tow passage events, sampling boats, shore stations, and equipment. One multiple tow passage at Mosier Landing was photographed continuously from the first sighting until the tows had passed from the area. Super 8 movies were taken of the sites and boat locations on some trips.

Slides were also taken of our sites on aerial and land reconnaissance trips. Photographs were taken with infrared film on one of the aerial trips. It was hoped that resuspension of sediment would be evident in these pictures, but possibly due to high water and sunlight reflection, no useful data was obtained from the infrared photographs.

Laboratory Analysis

Suspended Sediment Concentration

Suspended sediment samples were analyzed by the filtration method at the Illinois State Water Survey Sediment Laboratory. The methods used are after Guy (1969).

1. Samples are checked into the laboratory as soon as practicable after they are received from the field:
   a. Field information is transferred to laboratory forms and a laboratory number is assigned.
   b. Bottles are weighed to the nearest 0.1 gram on a top loading electronic balance for sample volume determination.
   c. Samples are stored in a cool dark room to inhibit evaporation and growth of algae or other organisms.
2. Samples are stored long enough to allow complete settling of all suspended sediment.
3. After solids have settled, the volume of liquid is reduced by suction with a "J" tube to approximately 80 ml.
4. The sample is vacuum filtered through 934 AH glass fiber filters held in gooch crucibles.
5. The weight of the sediment is determined by oven drying and weighing to the nearest 0.1 rag on an analytical balance.
6. Appropriate calculations are made to determine the sediment concentration, in ppm, of the samples.

Particle Size

Suspended sediment and bed material samples were analyzed for particle size by the pipet/sieve methods in the National Handbook of Recommended Methods for Water Data Acquisition (U.S. Geological Survey, 1978). The analysis was conducted in the Illinois State Water Survey Sediment Laboratory as described below.

I. Suspended sediment samples are composited from a given cross section and wet sieved through a 230 mesh (63 microns) sieve to separate the sand from the fine material. If the sand material weighs 0.5 gram or more, the sand is sieved. If the sand weighs less than 0.5 gram, the fraction is reported as a unit greater than 63 microns. If the fine material weights 0.4 gram or more, a pipet analysis is performed. If the fines weigh less than 0.4 gram, they are reported as a unit finer than 63 microns.

   A. Sieve Procedure

      1. Air dry sand is put on top screen of appropriate sieve stack and sieved on shaker with vertical motion for 15 minutes.
      2. The material retained on sieves is weighed to nearest 0.1 gram.
      3. Concentration and the percent finer values are calculated.

   B. Pipet Procedure

      1. Colloidal organics are removed by the sodium hypochlorite method.
      2. Organic free sample is oven dried, weighed and dispersed by shaking the sample in a solution of calgon (50 g/L.) for 12 hours.
      3. Dispersed sample is transferred to pipet chambers and pipetted for 31, 16, 8, 4, and 2 microns according to a predetermined chart of sampling depths for given temperatures.

4. Pipetted sample is oven dried and the weight of the fraction determined to the nearest 0.1 mg.
5. Concentration and the percent finer values are calculated.

II. Bed Material Samples

1. Samples are air dried and split with splitters to appropriate size for 8 or 6 inch sieves. Samples are weighed to the nearest 0.01 gram.
2. Samples are wet sieved through a 63 micron sieve and treated in the same manner as suspended material samples for sieve and pipet procedures.

Percent Volatile Solids

Suspended sediment samples were analyzed to determine the percentage of volatile solids present. This analysis was performed on every third background sample from trips 4 and 5.

The procedure for volatile analysis is identical to that for suspended sediment concentrations up to and including the filtering stage. After the sample has been filtered, it is dried in the oven at 105°C overnight. The sediment is cooled in a desiccator and weighed to determine the dry weight. The sample is then placed in the muffle furnace for 15 minutes at 550°C. It is cooled in a desiccator, weighed again, and the weight loss is used to calculate the percentage of volatile solids that were present in the sample.

PRESENTATION OF DATA.

Field data was collected according to the sampling procedures described in the chapter on field methods. Pertinent information for suspended sediment and water velocity data collection was recorded on the data sheets found in appendix A. These data sheets were copied on different colored paper for handling ease. A brief explanation of each data sheet follows.

Data Sheets

Suspended Sediment

LM/SC - All of the field trips for this report were main channel studies of lateral movement, designated LM.

Trip no. - numbered consecutively 1-5.

River mile pt. - at the study site.

Date

Event no. - Each tow passage was considered a new event. Events were numbered consecutively for each field trip.

Local time - Military notation was used to indicate the time the tow crossed the river transect.

Tow name

No. of Barges

Direction (U/D) - Indicates the tow is moving upstream or downstream.

Draft (ft) - Indicates the maximum draft of the barges.

Speed (mph) - Determined by tracking survey.

Water temp. (°C)

Air temp. (°C)

Water depth (ft)

Station Key - Indicates sampler type (DH-59 or P-61) and nozzle size used.

Station - A, B, or C.

Bottle no. - Sample bottles were numbered consecutively each day.

Time, min. elapsed - Indicates time in minutes after the tow passed . the transect.

Conc., ppm - Suspended sediment concentration in parts per million. The code letter following some concentrations indicates:

B indicates a depth-integrated sample of the bottom half of the water column,

T indicates a depth-integrated sample of the top half of the water column, and

P indicates a point-integrated sample at a specific depth.

Depth (open/close) - When using the P-61 to take B, T, or P samples, indicates the depth at which the sampler nozzle was activated and deactivated.

Water Velocity

LM/SC, Trip no., Date, Event no., Local time, Tow name, and Station - For explanation see section on Suspended Sediment Data Sheet.

Total depth (m)

Sampling depth (m) - Indicates the distance from the water surface at which the velocity was measured.

Barge elapsed time (min: sec) - The time in minutes and seconds after the tow passed the transect.

Velocity time (min: sec) - This time differs from barge elapsed time only when a separate stopwatch, started at a time other than tow passage, was used.

Revolutions - Number of "clicks" from the current meter, counted during a specific time period.

Seconds - Specific time period during which a corresponding number of meter revolutions is counted.

Velocity (ft/sec) - The water velocity was calculated based on the number of clicks per second.

Computer Data Entry

The box numbers included on the data sheets correspond to columns for computer data entry. Data were taken directly from the data sheets and stored in the CYBER 175 computer at the University of Illinois. All data were prepared for inclusion in the appendices to this report by the Data Management Unit with the computer system.

Description of Data Tables

Suspended Sediment

The concentration of suspended sediment during tow passage events is found in appendix B. Data was collected for 45 tow passages on five trips. Samples were taken at three stations on the transect (boats A, B, and C). Exceptions include trip 1 where samples were taken at only two stations, and trip 1 event 5 and trip 5 event 5 where data was collected only at station A.

The ninety-minute sampling schedule (described in this report in the section on field methods) was followed whenever possible. Sampling in boat A usually began 0-4 minutes after tow passage. Boats B and C waited until the tow had completely passed, then repositioned and began sampling after 4-8 minutes had elapsed. Gaps in the data tables sometimes occur due to problems in the sampling boat, such as difficulty in anchoring or mechanical difficulties with the samplers. Sampling did not continue for the full ninety minutes in several events. Usually this was due to the arrival of another barge tow and the start of a new event. A few events were ended early because of dusk, and trip 5 event 7 was terminated by a thunderstorm.

In the case of some multiple tow passages (close together in time although designated separate events), the stopwatches were not restarted.

In these cases, the elapsed time at the passage of the second (or third or fourth) tow would not equal zero. Rather, the elapsed time given for the event was based on the passage time of the first tow in the series. The elapsed time corresponding to the time of passage of these tows can be calculated from the local time of passage and is given in table 3.

Table 3. Time of Passage for Multiple Tow Events

Trip no.	Event no.	Time of tow passage (min. elapsed)
1	2	18
1	4	36
1	5	71
1	6	78
2	2	21
2	3	54
3	11	15
4	8	21

A few tow passages very close together in time were designated as one event. Two tows, traveling side by side, passed the transect at exactly the same time to make trip 4 event 9. Trip 5 events 3 and 9 were made up of three and two tows, respectively, passing very close together in time. The elapsed time for these events is based on the passage time of the first tow.

Mechanical difficulties with the P-61 and P-72 samplers were experienced in boat B for trip 4 events 5-10 and in boat C for trip 5 events 7-9. A DH-59 sampler was used for these events. Since the water depths at these sampling stations were too great to sample the entire water column with a DH-59, only the top 15 feet was sampled. These sample concentrations are followed by the letter T in the appendix.

Overall, the data for suspended sediment concentration is quite consistent. However, occasionally an unexpectedly high concentration is given for a single sample. (Several of these occur in trip 4 event 6, station A.) This could be caused by the sampler landing nozzle-down in the river bed or on the lee face of a dune, or other factors beyond our control. It is difficult to separate such bad samples from those where the sediment concentration really is elevated.

Appendix C contains the background suspended sediment concentrations. Background samples were taken on all trips except trip 1, following the procedure given in the chapter on field methods.

Water Velocity

The water velocity data collected during tow passage events on trips 4 and 5 is given in appendix D. Water velocity was measured from all three work boats (A, B, and C) except for trip 5 event 5, where readings were taken only at station A.

The field procedure described earlier in this report was followed when possible. Boat A began velocity readings before the tow arrived when possible. For these readings, the elapsed time would be a negative number since all times are given in "barge elapsed time". Velocity measurements at stations B and C usually began somewhat later than suspended sediment sampling because a few minutes are needed to set up and lower the current meter.

Gaps sometimes occur in these data tables due to problems anchoring, debris clogging the current meter, etc. Generally speaking, the velocity data given here is quite reasonable and consistent.

The stopwatch was not restarted for trip 4 event 8. See table 3 for the time of passage for this tow. An explanation of shortened events and multiple tow passages is found in the preceding section on suspended sediment data.

Background water velocity data for trips 4 and 5 are found in appendix E.

Volatiles

Percent volatile analysis was conducted on every third background suspended sediment sample from trips 4 and 5. These data are found in appendix F.

DISCUSSION OF RESULTS

Typical plots of suspended sediment and velocity are shown and discussed for the Illinois River at Hadley's Landing, mile 13.2, and for the Mississippi River in Pool 25 at Rip Rap Landing and Mosier Landing, miles 265.1 and 260.2, respectively. Site location maps and site descriptions are contained in the section on "Site Selection". Before a discussion of the field data on resuspension and lateral movement of sediment, a brief outline of traffic characteristics is presented.

Vessel Traffic Characteristics

Table 4 lists the name, size, horsepower, and type of propeller for the towboats we observed while we were collecting data. These tow characteristics were obtained from the "Inland River Record 1981" (Owen, 1981). Table 5 gives direction, draft, time, number of barges, and tow speed for each event. For trips 2 and 3 on the Illinois River, the average towboat horsepower was 2911. The horsepower ranged from 1530 to 5850. Ten of sixteen towboats had between 2000 and 4000 horsepower. Four towboats had Kort nozzles and the other had open propellers. All but one (which had three propellers) had two propellers driven through reduction gearing by diesel prime movers. On the Mississippi River during trips 4 and 5, the average horsepower was 3775. The range was from 1275 to 6450 horsepower. Seven of twenty-one towboats had Kort nozzles. Most of the towboats over 4000 horsepower had Kort nozzles. Two of the towboats had triple screws while the rest all had twin screws.

Tow size, speed, and time of passage were recorded for each event during the five field data collection trips. Additional size and time of

Table 4. Tow Characteristics

Name of tow boat	No. of screw	Size (ft)	Power (HP)	Type of nozzle
Andrew Benedict	2	114×35	4100	Kort
Arthur E. Snider	2	152×34	3200	
Atlas	3	70×26	1275	
Barbara Jeanne Meyer	2	145×27	2200	
Betty Brent	2	135×32	3000	
Chicago Trader	2	90×32.1	1530	
Clark Frame	2	111.8×35	3200	
Colonel George Lambert	2	140×42	4200	Kort
Conti Afton	2	140×44	4200	
Craig M.	2	148×34.7	2400	Kort
Creole Belle	2	130×37	3900	
Fort Pierre	2	135×32	2800	
Frederick B. Wells	2	140×38	3800	
Gordon Jones	2	147×38.5	4200	
Hawkeye	2	150×35	4300	
Herb Schreiner	2	85×26	1700	
Irene Chotin	2	148×34.5	3200	Kort
Joanne				
John M. Warner	2	103×30.8	1800	
Kathy Ellen	2	150.8×34.8	3800	
Leviticus	2	147×37.9	4200	
Lillian Clark	2	180×52	6450	Kort
Luke Gladders	2	150×35	3200	
Lynn B.	2	148×34.7	2400	Kort
Magnolia	2	116×45	3800	
Marvin E. Norman	2	102×34	1800	
Mr. Joey	2	145×48	5600	Kort
New Dawn	2	140×42	5600	Kort
Nohab Express	2	91×30	3000	
Patsy Swank	2	141×38.5	3500	
Prairie Dawn	2	160×40	5000	Kort
Robin Mott	3	148×45	4800	
Rose Marie Walden	2	90×32	2400	
Sally Barton	2	116×27.5	2400	
Sierra Dawn	2	164×40	5000	Kort
Virginia E. Towey	3	140×45	5850	
White Dawn	2	156×35	3200	
White Knight	2	150×33.6	3200	
Yankton	2	125×28	2200	

Table 5. Summary of Events

Trip 1 at Havana
Illinois River, mile 121.5

Date	Event	Local time	Tow name	No. of barges	Traffic direction	Draft (ft)	Tow speed (mph)
5/28/80	1	1321	Lynn B.	11	D*	-	7.2
5/28/80	2	1339	Magnolia	5	D	-	8.8
5/29/80	3	1113	Creole Belle	14	D	-	6.6
5/29/80	4	1149	Andrew Benedict	8	D	-	7.6
5/29/80	5	1224	Patsy Swank	9	U*	-	4.8
5/29/80	6	1231	John M. Warner	3	D	-	6.4

Trip 2 at Hadley's Landing
Illinois River, mile 13.2

Date	Event	Local time	Tow name	No. of barges	Traffic direction	Draft (ft)	Tow speed (mph)
7/23/80	1	1520	Chicago Trader	6	D	8	5.4
7/23/80	2	1541	Herb Schreiner	12	D	9	3.9
7/23/80	3	1614	Marvin E. Norman	15	U	2	5.3
7/24/80	4	0959	Yankton	12	D	9	4.4
7/24/80	5	1145	Fort Pierre	15	D	9	4.6

Trip 3 at Hadley's Landing
Illinois River, mile 13.2

Date	Event	Local time	Tow name	No. of barges	Traffic direction	Draft (ft)	Tow speed (mph)
9/23/80	1	1008	Andrew Benedict	4	U	9	-
9/23/80	2	1236	Leviticus	6	D	9	5.6
9/23/80	3	1454	Craig M.	4	U	9	4.0
9/24/80	4	1315	Irene Chotin	18	U	9	4.8
9/25/80	5	1015	Barbara Jeanne Meyer	8	U	2	5.4
9/25/80	6	1310	Luke Gladders	15	D	9	5.9
9/25/80	7	1450	Fort Pierre	12	D	9	4.1
9/25/80	8	1747	Virginia E. Towey	15	D	-	-
9/26/80	9	0950	Clark Frame	8	U	9	2.2
9/26/80	10	1115	Betty Brent	8	U	9	4.0
9/26/80	11	1130	Lynn B.	12	D	9	5.9

Table 5. Concluded

Trip 4 at Rip Rap Landing
Mississippi River, mile 265.1

Date	Event	Local time	Tow name	No. of barges	Traffic direction	Draft (ft)	Tow speed (mph)
4/08/81	1	0947	Atlas	9	U	2	3.9
4/08/81	2	1044	Prairie Dawn	15	U	2	7.0
4/09/81	3	0823	Lillian Clark	16	U	2	7.9
4/09/81	4	1005	Arthur E. Snider	12	D	9	8.1
4/09/81	5	1129	Rose Marie Walden	9	D	8	-
4/09/81	6	1300	White Dawn	15	D	9	8.7
4/09/81	7	1602	Robin Mott	14	U	2	-
4/09/81	8	1623	Hawkeye	12	D	9	9.1
4/10/81	9	0825	Conti Afton	15	U	2	5.9
		0825	Gordon Jones	13	U	9	5.0
4/10/81	10	1118	Mr. Joey	15	D	9	8.0

Trip 5 at Mosier Landing
Mississippi River, mile 260.2

Date	Event	Local time	Tow name	No. of barges	Traffic direction	Draft (ft)	Tow speed (mph)
5/20/81	1	1258	Colonel George Lambert	15	D	9	8.9
5/20/81	2	1325	Joanne	4	D	9	10.0.
5/21/81	3	0850	Sally Barton	9	U	2	5.8
		0854	Kathy Ellen	12	D	9	9.5
		0908	Marvin E. Norman	9	U	2	0.9
5/21/81	4	1055	Frederick B. Wells	12	D	9	8.9
5/21/81	5	1511	Sierra Dawn	15	U	2	3.2
5/21/81	6	1555	Atlas	6	D	9	7.7
5/22/81	7	0915	New Dawn	15	D	9	9.2
5/22/81	8	1215	Nohab Express	3	U	9	6.7
5/22/81	9	1730	White Knight	15	D	9	9.1
		1741	Colonel George Lambert	15	U	2	6.3

*U=Upstreara, D=Downstream

passage data were collected during June and July, 1981. Recreational boating frequency was also observed.

At Hadley's Landing on the Illinois River in Pool 26, tow traffic was exactly divided between up and down river travel. The average tow contained 8.9 barges. The most common tow sizes were 15 (23 percent), 12 (16 percent), and 8 (11 percent) barges. One tow consisted of 18 barges. Sixty-five percent of the barges were loaded. Tow speed was obtained for 14 events. The average speed was 5.0 mph for downbound tows and 4.3 mph for upbound tows. The average time between tows was 93.3 minutes, which corresponds to 15.4 tow passages per day. The time interval between tows was found to be well described by the exponential distribution. Small boats were recorded at an average time interval of 47.1 minutes on week-days and 5.1 minutes on weekends.

Similar data were compiled for Pool 25 on the Mississippi River. Fifty-three percent of the tows were downbound and 62 percent of the barges were loaded. The average tow size was 10.4 barges. One 16-barge tow was observed. About 41 percent of the tows consisted of 15 barges, and about 11 percent consisted of 12 barges. Speed was determined for 21 tows. The average speed was 8.8 mph for downbound tows and 5.3 mph for upbound tows. The time interval between tows was exponentially distrib-uted with an average of 99.9 minutes between tows, which corresponds to 14.4 tows per day. The time interval between small boat passages was 32.6 minutes for weekdays and 7.1 minutes for the weekend.

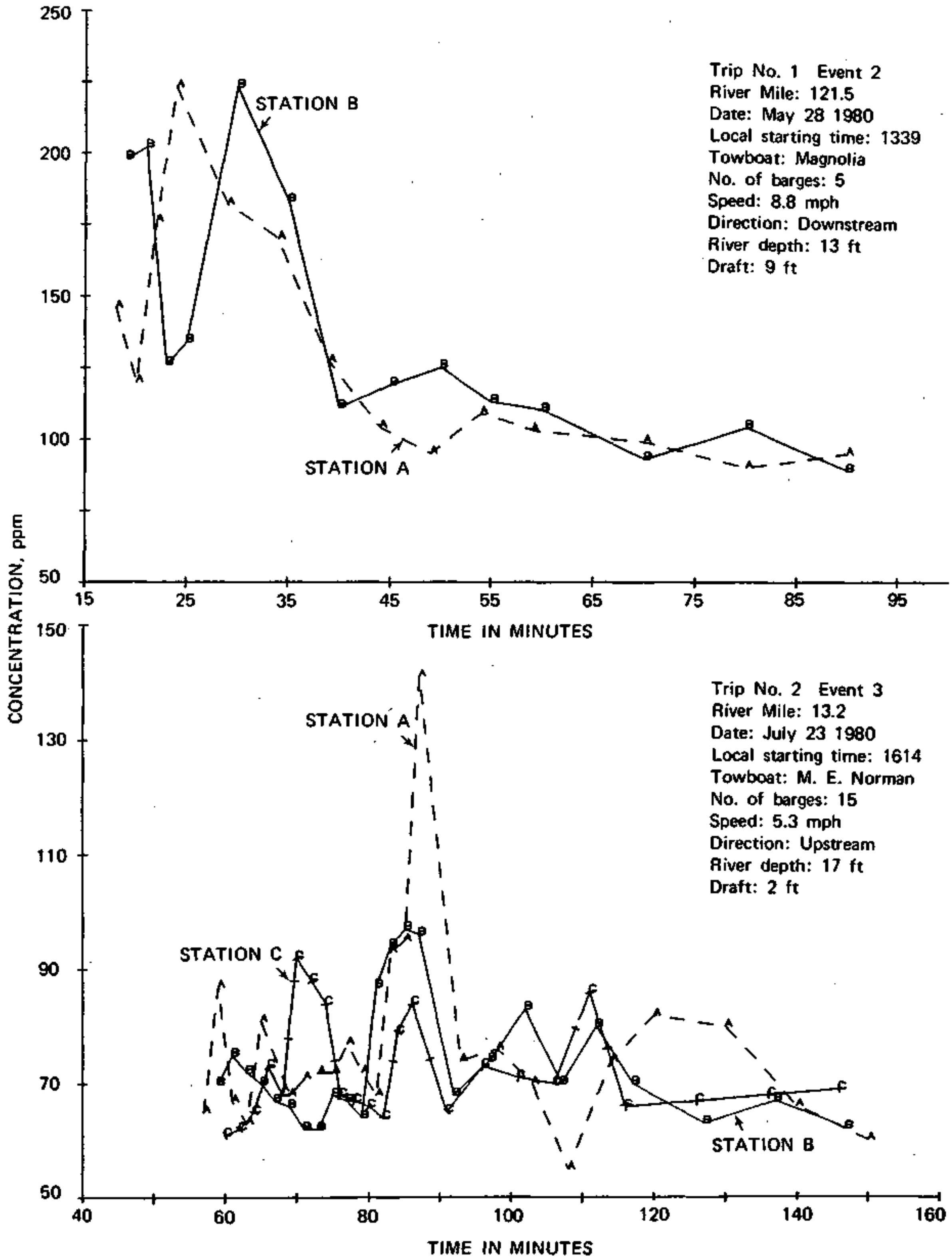
These data are provided for informative purposes only, Observations were recorded during periods which were selected with no intention to achieve valid statistical samples or to evaluate seasonal variations in commercial or recreational traffic. All observations were made during daylight hours and, especially for the sediment data collection trips, the time of observation was determined by the logistics and mobility of our field operation which involved many people, vehicles, and boats.

Resuspension of Sediment

Event Records

Illinois River. Trip 1 to a site near Havana, Illinois, on May 28 and 29, 1980, was a trial effort. The delta post system for locating sampling points, the safe distances for lateral and stern approach to a barge tow, the tow tracking procedure, and the suspended sediment sampling procedure were all given a field trial and were found to be generally sound procedures. Personnel were all new at this combined operation, and several were unable to stay both days. Thus, the time between tow passage and the beginning of sampling is longer than desirable, especially for the second boat on the second day. Our procedures were confirmed by this experience. The importance of good, complete notes, despite the frequency of sampling, was reinforced and remained a priority concern on the remaining field trips.

The data for the trip 1 events listed in table 5 are presented in the appendices for completeness. The plot of suspended sediment concentration versus time for event 2 is given in figure 24. This tow passed the transect 18 minutes after the tow that was recorded in event 1. On trip 1 boat A was located on the tow track and boat B was on the edge of the navigation channel. The initial elevated concentrations and decrease to a relatively constant value about 30 minutes after tow passage are typical of the data for trip 1 at mile 121.5 on the Illinois River.



CONCENTRATION, ppm
Trip No. 1 Event 2
River Mile: 121.5
Date: May 28 1980
Local starting time: 1339
Towboat: Magnolia
No. of barges: 5
Speed: 8.8 mph
Direction: Downstream
River depth: 13 ft
Draft: 9 ft
STATION B
STATION A
250
200
150
100
50
15
25
35
45
55
65
75
85
95
TIME IN MINUTES
Trip No. 2 Event 3
River Mile: 13.2
Date: July 23 1980
Local starting time: 1614
Towboat: M. E. Norman
No. of barges: 15
Speed: 5.3 mph
Direction: Upstream
River depth: 17 ft
Draft: 2 ft
STATION A
STATION C
STATION B
150
130
110
90
70
50
40
60
80
100
120
140
160
TIME IN MINUTES

Figure 24.

Trip 2 in July, 1980, and trip 3 in September, 1980, were conducted at a site on a bend at Hadley's Landing, opposite Twelve Mile Island. Two typical event concentration versus time plots from trip 2 are shown, one in figure 24 and one in figure 25. Table 5 shows that event 3 was the third tow passage in less than one hour. Event 4 was the first tow passage that day. The suspended sediment content varies widely for about an hour after tow passage before returning to values close to the ambient concentration of about 65 ppm. Three typical events from trip 3 are shown in figure 25 (event 2) and figure 26 (events 6 and 9). These are individual events at least 2 hours after the previous tow passage. The return to ambient concentrations occurs after 45 to 60 minutes. One distinct difference between trips 2 and 3 is evident from these graphs. For trip 2 the ambient concentration is similar for the three sampling stations. This is a typical summer flow condition with average or below average water discharge and uniform sediment concentrations in the river. The suspended sediment concentrations during trip 3 are considerably higher and distinctly different at each sampling station. This resulted from a rainfall-runoff event on an upstream tributary which increased the sediment (and debris) load but did not increase the river stage or discharge at our sampling point. For the four days of data, the ambient concentration was 205 ppm at boat A in the channel border position, 283 ppm at boat B on the edge of the navigation channel, and 352 ppm at boat C in the central portion of the channel. Ambient or background conditions are defined to be those on the river on a given day exclusive of the tow passage events.

All of the suspended sediment concentration data for trips 2 and 3 are shown in a series of daily plots presented in figure 27 (trip 2) and

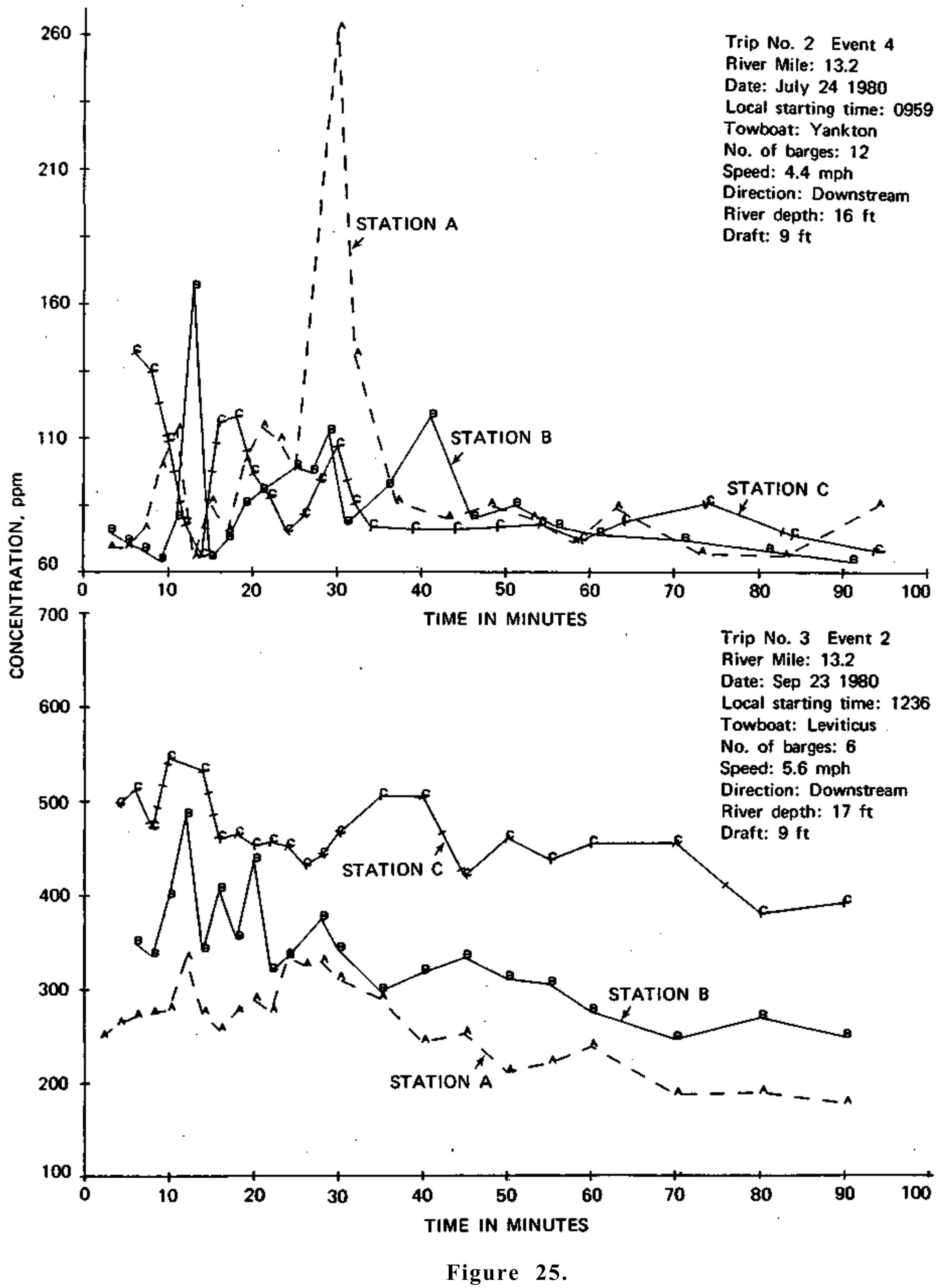

Trip No. 2 Event 4
River Mile: 13.2
Date: July 24 1980
Local starting time: 0959
Towboat: Yankton
No. of barges: 12
Speed: 4.4 mph
Direction: Downstream
River depth: 16 ft
Draft: 9 ft
STATION A
STATION B
STATION C
260
210
160
110
60
0 10 20 30 40 50 60 70 80 90 100
TIME IN MINUTES
CONCENTRATION, ppm
Trip No. 3 Event 2
River Mile: 13.2
Date: Sep 23 1980
Local starting time: 1236
Towboat: Leviticus
No. of barges: 6
Speed: 5.6 mph
Direction: Downstream
River depth: 17 ft
Draft: 9 ft
STATION C
STATION B
STATION A
700
600
500
400
300
200
100
0 10 20 30 40 50 60 70 80 90 100
TIME IN MINUTES

Figure 25.

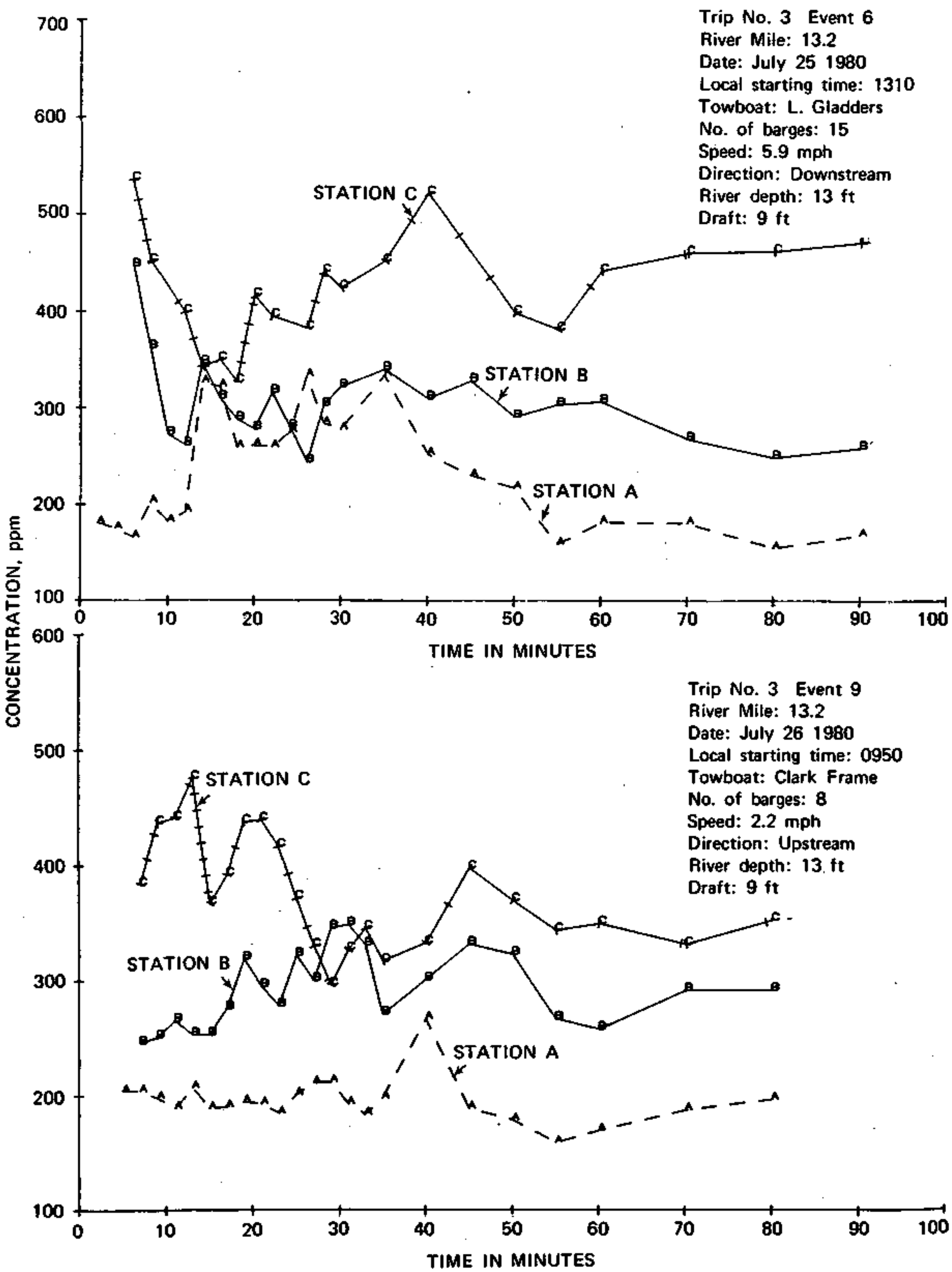

Trip No. 3 Event 6
River Mile: 13.2
Date: July 25 1980
Local starting time: 1310
Towboat: L. Gladders
No. of barges: 15
Speed: 5.9 mph
Direction: Downstream
River depth: 13 ft
Draft: 9 ft
STATION C
STATION B
STATION A
TIME IN MINUTES
CONCENTRATION, ppm
Trip No. 3 Event 9
River Mile: 13.2
Date: July 26 1980
Local starting time: 0950
Towboat: Clark Frame
No. of barges: 8
Speed: 2.2 mph
Direction: Upstream
River depth: 13 ft
Draft: 9 ft
STATION C
STATION B
STATION A
TIME IN MINUTES

Figure 26.

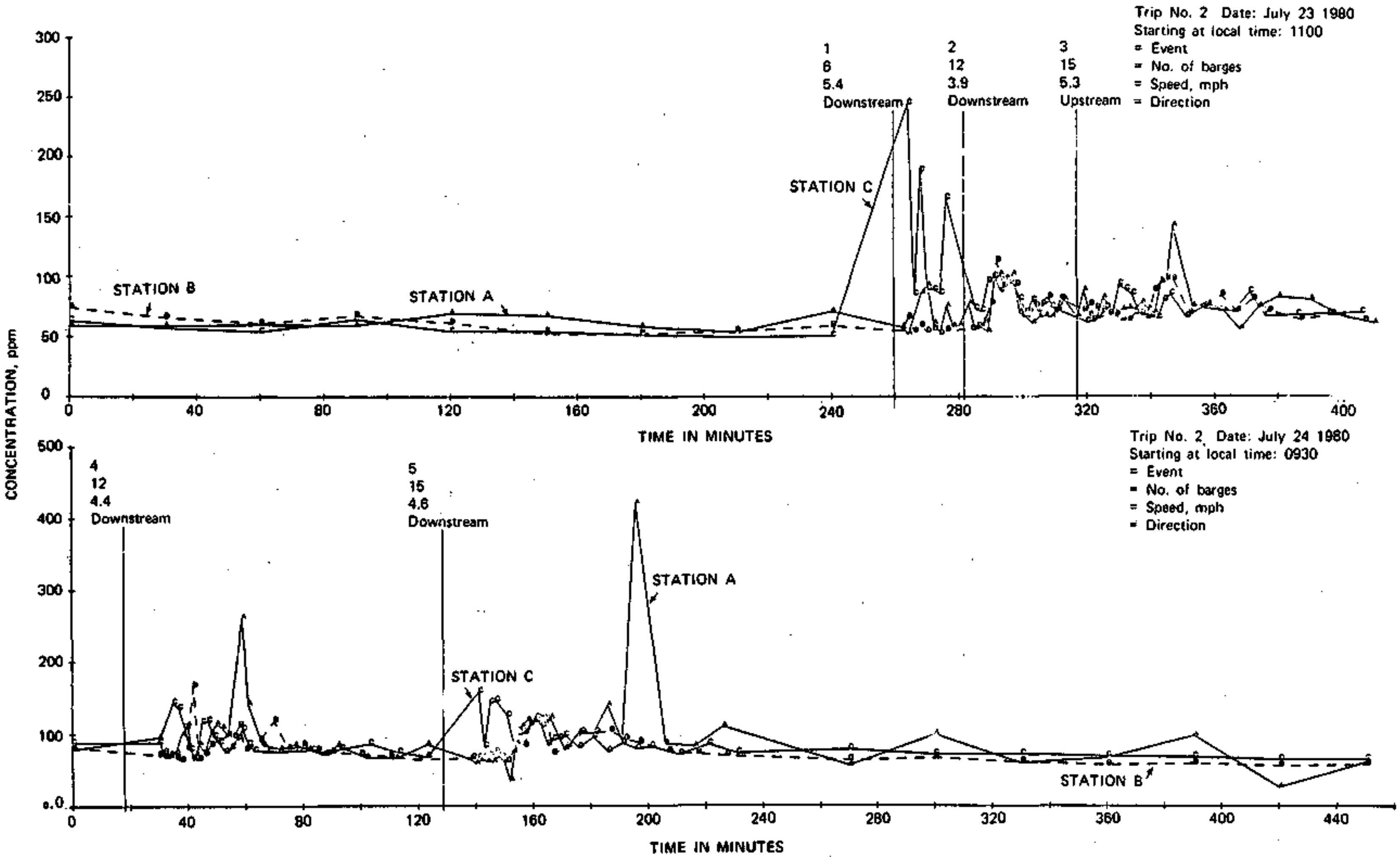

Trip No. 2 Date: July 23 1980
Starting at local time: 1100
= Event
= No. of barges
= Speed, mph
= Direction
1
6
5.4
Downstream
2
12
3.9
Downstream
3
15
5.3
Upstream
STATION C
STATION B
STATION A
CONCENTRATION, ppm
TIME IN MINUTES
Trip No. 2 Date: July 24 1980
Starting at local time: 0930
= Event
= No. of barges
= Speed, mph
= Direction
4
12
4.4
Downstream
5
15
4.6
Downstream
STATION A
STATION C
STATION B
TIME IN MINUTES

Figure 27.

figures 28 and 29 (trip 3). In all of these plots the line between the preceding background concentration and the first event concentration is drawn between the two data points by the computer, though the concentration does not actually increase until the tow passes. The suspended sediment concentration is much more variable and generally above the ambient values for 30 to 60 minutes following tow passage. Successive tow passage extends the time when concentrations are higher and more variable. No inference can be made about the magnitude of concentration increase and multiple tow passages. Statistical analyses of the event concentration data will be presented in a separate section.

The sailing lines followed by each tow were obtained and plotted. The effects of maneuvering for the bend just upstream of the measuring transect could be clearly seen in many of these plots. For compactness, only the range and average of the distance from the west bank (figure 4) at the transect and at survey station "B" are given here. Tow tracks were determined for 14 of 16 events at Hadley's Landing. Distance from shore to the tow centerline varied between 300 and 560 feet, with an average of 457 feet. With reference to the channel shape (figure 5) the tows were all within the full depth portion of the channel. Just upstream, tows came considerably closer to the shore on the outside of the sharp bend at the north end of Twelve Mile Island.

Two geometric parameters are considered important for navigation in constricted waterways: the blocking factor and the depth-to-draft ratio. The blocking factor is the ratio of the channel cross-sectional area to the submerged cross-sectional area of the vessel. For the tow passage events observed at Hadley's Landing the blocking factor varied between 12 for 9-foot draft, 3 barge wide tows and 56 for 2-foot draft, 3 barge wide

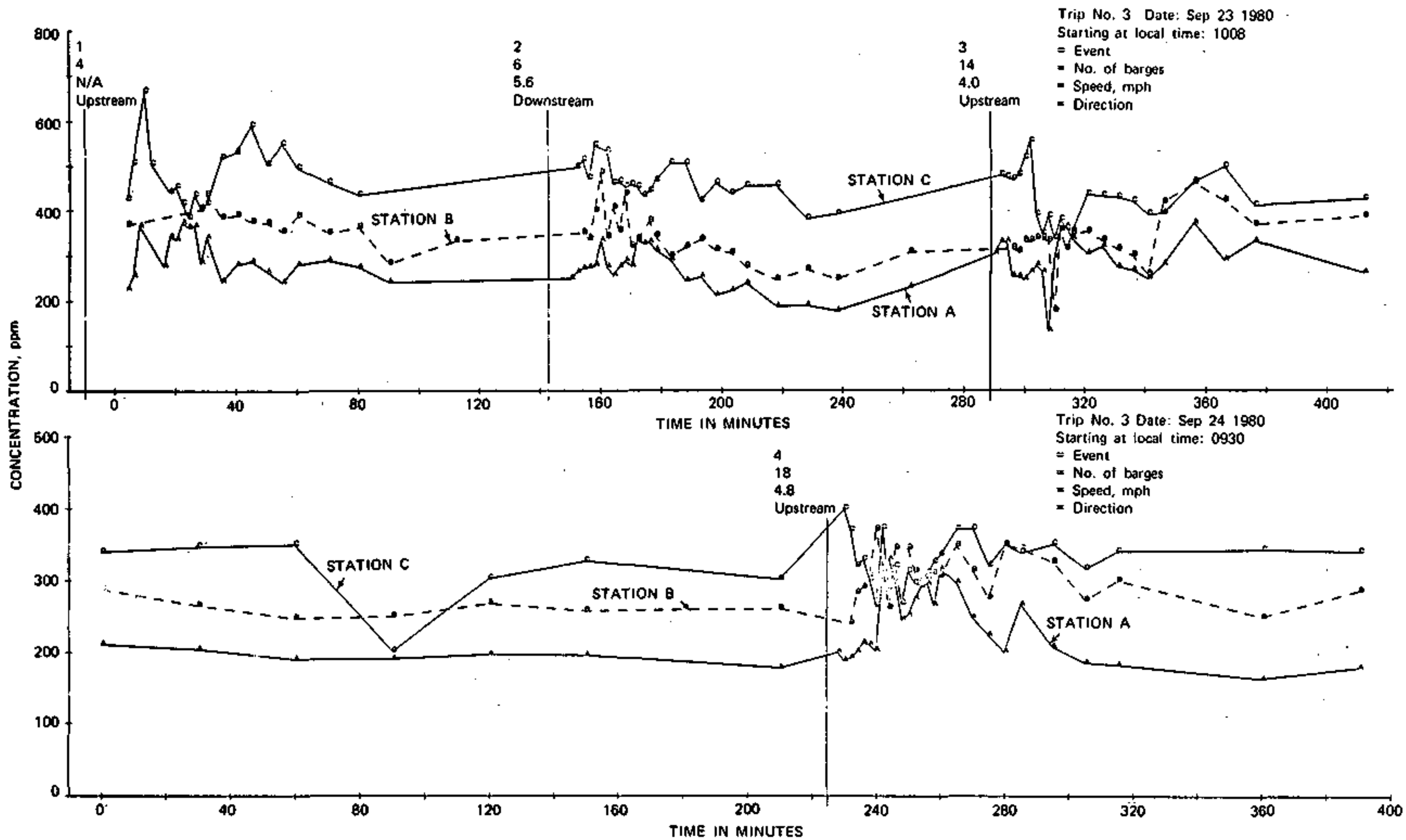

Trip No. 3 Date: Sep 23 1980
Starting at local time: 1008
= Event
= No. of barges
= Speed, mph
= Direction
1
4
N/A
Upstream
2
6
5.6
Downstream
3
14
4.0
Upstream
STATION C
STATION B
STATION A
CONCENTRATION, ppm
TIME IN MINUTES
Trip No. 3 Date: Sep 24 1980
Starting at local time: 0930
= Event
= No. of barges
= Speed, mph
= Direction
4
18
4.8
Upstream
STATION C
STATION B
STATION A
TIME IN MINUTES

Figure 28.

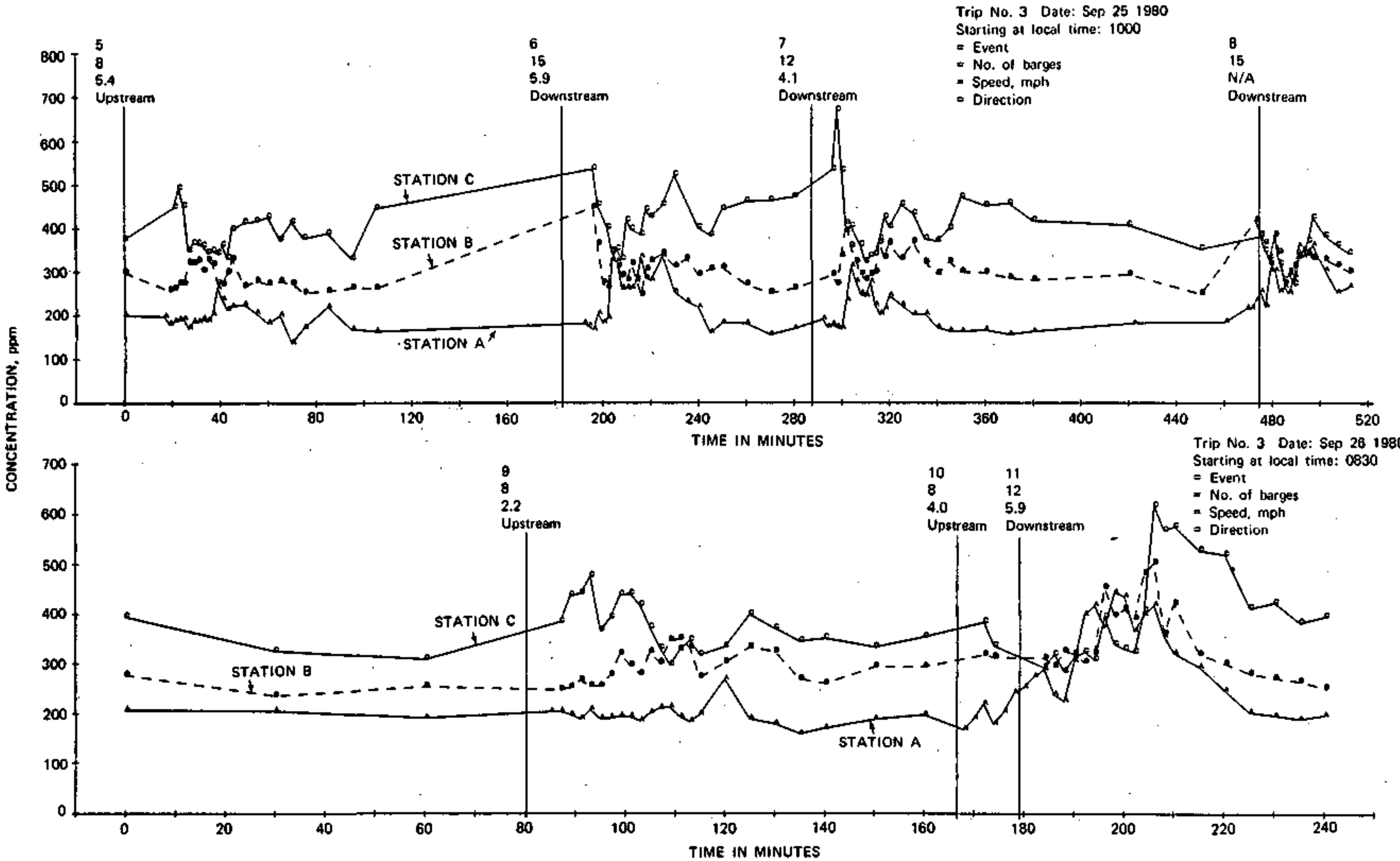

Trip No. 3 Date: Sep 25 1980
Starting at local time: 1000
= Event
= No. of barges
= Speed, mph
= Direction
5
8
6.4
Upstream
6
15
5.9
Downstream
7
12
4.1
Downstream
8
15
N/A
Downstream
STATION C
STATION B
STATION A
CONCENTRATION, ppm
TIME IN MINUTES
Trip No. 3 Date: Sep 26 1980
Starting at local time: 0830
= Event
= No. of barges
= Speed, mph
= Direction
9
8
2.2
Upstream
10
8
4.0
Upstream
11
12
5.9
Downstream
STATION C
STATION B
STATION A
TIME IN MINUTES

Figure 29.

tows. Depth-to-draft ratios were 9 for 2-foot draft and 2 for 9-foot draft, approximately.

Mississippi River. Field trip 4 in April, 1981, to Rip Rap Landing, mile 265.1, and field trip 5 in May, 1981, to Mosier Landing, mile 260.2, produced data for 19 events involving 23 tow passages. Rip Rap Landing was the intended site for both trips, but high water in May prevented land access to that site, so Mosier Landing was selected as an alternate site. The sites are similar in plan and cross section as can be seen in figures 8, 9, 10, and 12. The stage at Rip Rap Landing was about 437, 3 feet above minimum pool elevation. At Mosier Landing the stage was at least 441, 7 feet above minimum pool and had been several feet higher early in the week. Because of the rapidly dropping stage, no discharge-load measurement was attempted there. Because of water depths over 18 feet, actually as great as 36 feet, the P-61 or P-72 samplers were used in boats B and C.

Two event concentration versus time plots from trip 4 are shown in figure 30. Event 5, the third of six events that day, shows an increase in concentration for stations A and B but not for station C. The ambient suspended sediment concentrations were about 120 ppm. Tracking data were not obtained, so it is not known if the tow was near station A's location. It is possible that the additional mixing caused lateral movement of sediment into the channel border area in which boat A was positioned. Event 9 is hardly typical as two tows passed our site headed upstream side by side, but the event data is not particularly different from that for single tow passage events.

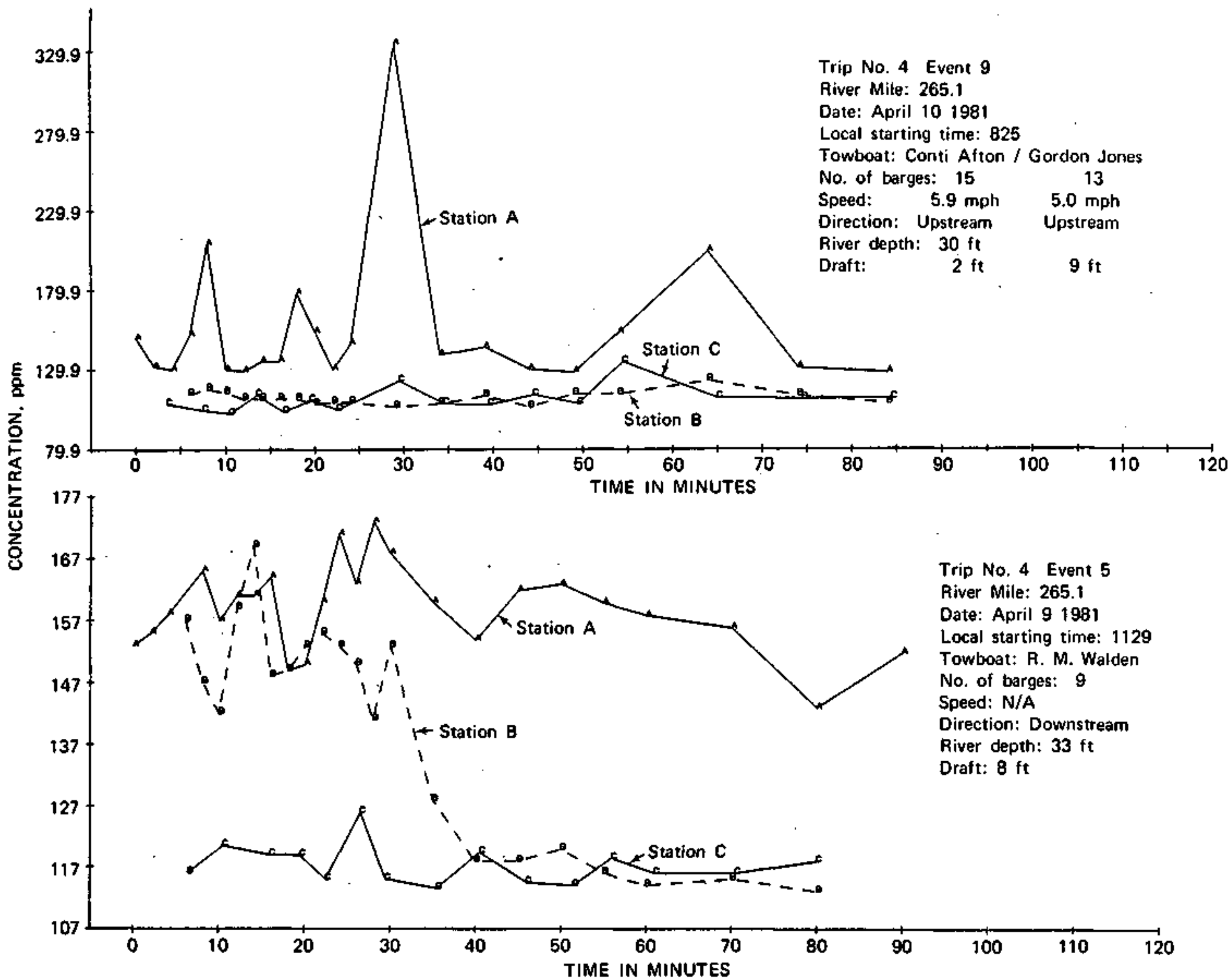
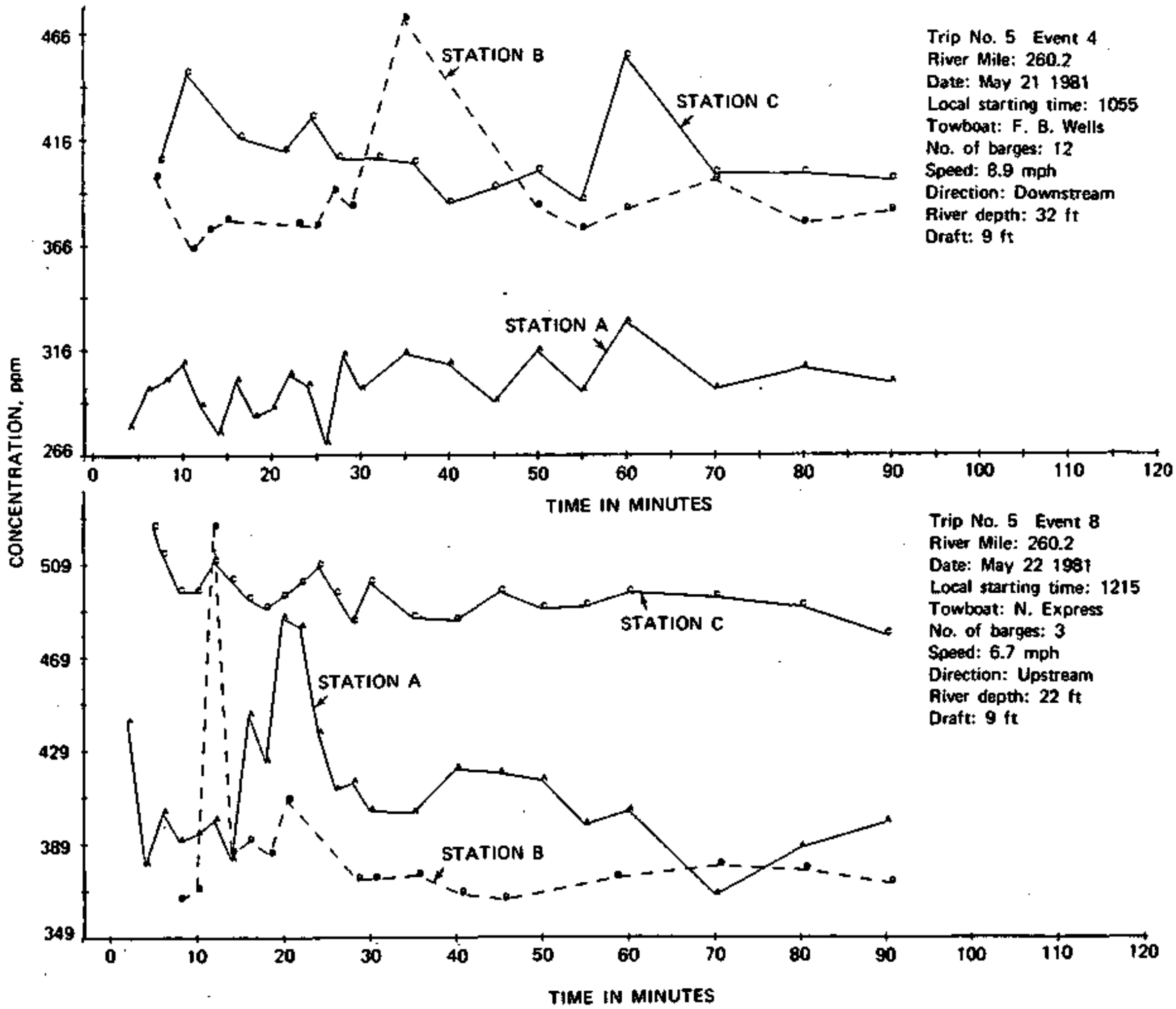

329.9
279.9
229.9
179.9
129.9
79.9
CONCENTRATION, ppm
Station A
Station B
Station C
0 10 20 30 40 50 60 70 80 90 100 110 120
TIME IN MINUTES
Trip No. 4 Event 9
River Mile: 265.1
Date: April 10 1981
Local starting time: 825
Towboat: Conti Afton / Gordon Jones
No. of barges: 15 13
Speed: 5.9 mph 5.0 mph
Direction: Upstream Upstream
River depth: 30 ft
Draft: 2 ft 9 ft
177
167
157
147
137
127
117
107
Station A
Station B
Station C
0 10 20 30 40 50 60 70 80 90 100 110 120
TIME IN MINUTES
Trip No. 4 Event 5
River Mile: 265.1
Date: April 9 1981
Local starting time: 1129
Towboat: R. M. Walden
No. of barges: 9
Speed: N/A
Direction: Downstream
River depth: 33 ft
Draft: 8 ft

Figure 30.

The two event plots for trip 5 in figure 31 are from Mosier Landing with falling stage and ambient sediment concentrations of 300 to 600 ppm. The lateral distribution of ambient concentrations varied from day to day and will be discussed in the statistical section. The maximum concentration appears to occur rather randomly within the 30 minutes following tow passage. Trip 4 event 5 and trip 5 event 4 follow other tow passages by about an hour and a half. Trip 4 event 9 was the first event that day and trip 5 event 8 was three hours after the previous tow passage.

Three days of background and tow passage event data were collected on each of these trips. The daily plots are shown in figures 32, 33, and 34. The plot for April 9, 1981, shows six tow passage events. The concentration scale is compressed by the one value of 604 ppm (figure 32). An extremely high background concentration of 1256 ppm appears on May 20, 1981 (figure 33). This value and five values on April 9, 1981, that exceeded 1000 ppm were excluded from the statistical analysis. The outliers on April 9, 1981, were also excluded from the plot to prevent obscuring all the other data. These are probably bad samples, perhaps the result of the sampler landing on the foreslope of a sand dune on the river bed. However, we have no way to prove this or identify an erroneous laboratory analysis. More likely the sample was not representative when collected. The variations in ambient concentration with time on trip 5 at station C on May 21 and May 22 are real and follow the stage changes as the hydrograph receded at the site.

Tow track data was collected for several tows for which suspended sediment data were not collected at Rip Rap Landing. At the Rip Rap Landing transect, the average distance from shore to the tow track was 350 feet and varied from 75 to 700 feet. If the two tows that passed side by



STATION B
STATION C
STATION A
Trip No. 5 Event 4
River Mile: 260.2
Date: May 21 1981
Local starting time: 1055
Towboat: F. B. Wells
No. of barges: 12
Speed: 8.9 mph
Direction: Downstream
River depth: 32 ft
Draft: 9 ft
CONCENTRATION, ppm
TIME IN MINUTES
Trip No. 5 Event 8
River Mile: 260.2
Date: May 22 1981
Local starting time: 1215
Towboat: N. Express
No. of barges: 3
Speed: 6.7 mph
Direction: Upstream
River depth: 22 ft
Draft: 9 ft
STATION C
STATION A
STATION B
TIME IN MINUTES

Figure 31.

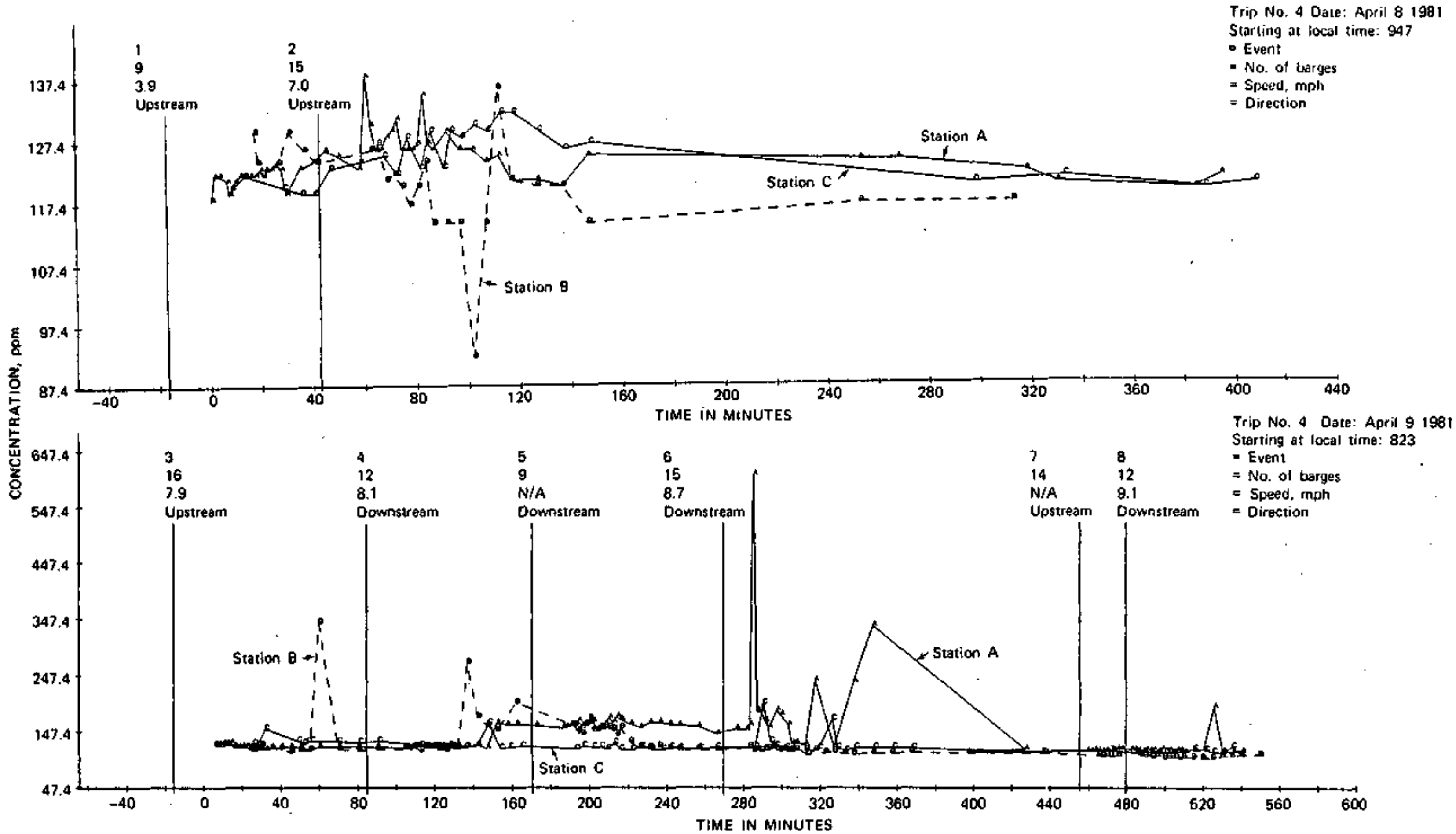

Trip No. 4 Date: April 8 1981
Starting at local time: 947
Event
No. of barges
Speed, mph
Direction
1
9
3.9
Upstream
2
15
7.0
Upstream
Station A
Station C
Station B
CONCENTRATION, ppm
137.4
127.4
117.4
107.4
97.4
87.4
-40
0
40
80
120
160
200
240
280
320
360
400
440
TIME IN MINUTES
Trip No. 4 Date: April 9 1981
Starting at local time: 823
Event
No. of barges
Speed, mph
Direction
3
16
7.9
Upstream
4
12
8.1
Downstream
5
9
N/A
Downstream
6
15
8.7
Downstream
7
14
N/A
Upstream
8
12
9.1
Downstream
Station B
Station A
Station C
647.4
547.4
447.4
347.4
247.4
147.4
47.4
-40
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
TIME IN MINUTES

Figure 32.

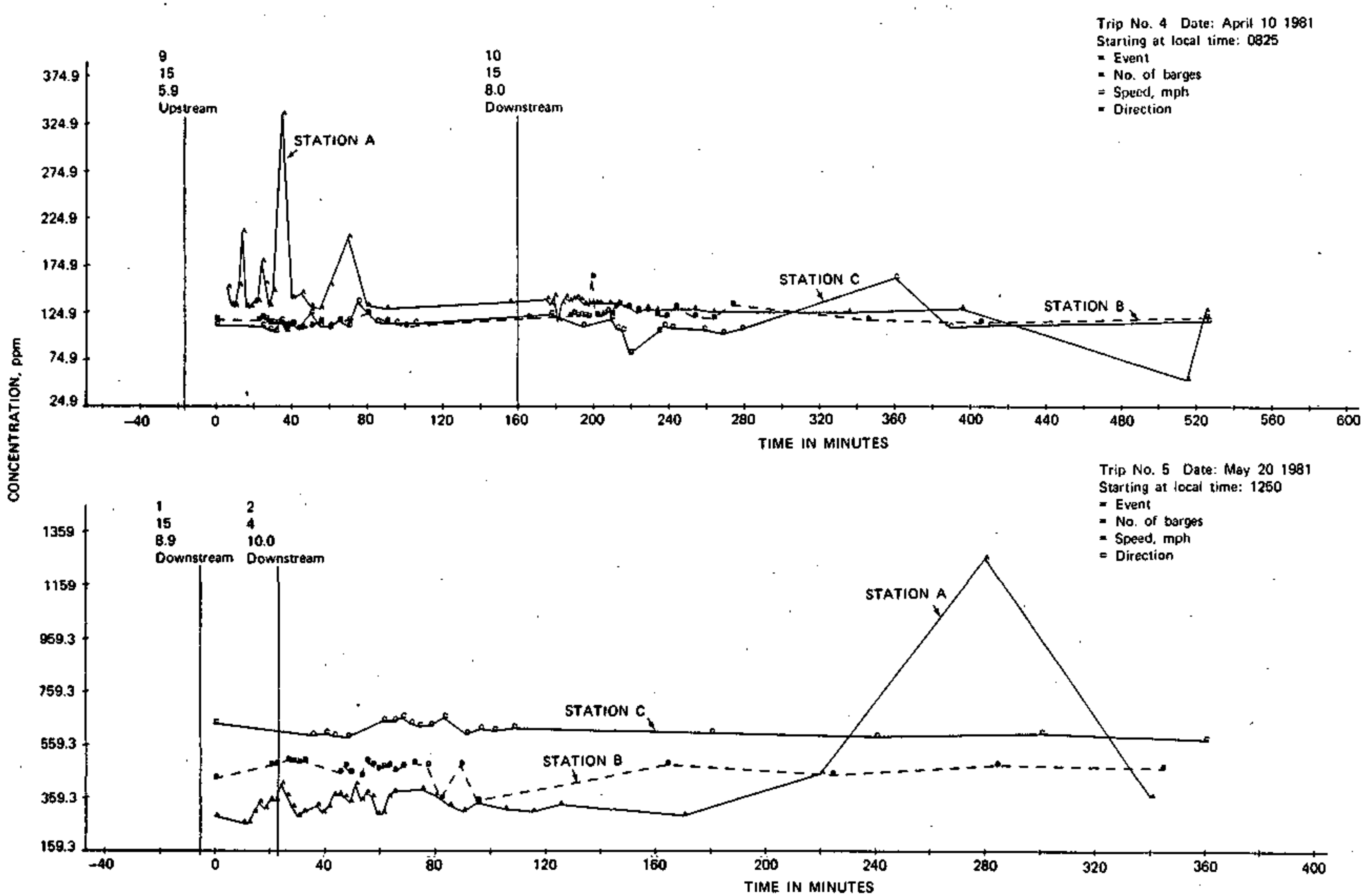

Trip No. 4 Date: April 10 1981
Starting at local time: 0825
= Event
= No. of barges
= Speed, mph
= Direction
9
15
5.9
Upstream
10
15
8.0
Downstream
STATION A
STATION C
STATION B
374.9
324.9
274.9
224.9
174.9
124.9
74.9
24.9
-40 0 40 80 120 160 200 240 280 320 360 400 440 480 520 560 600
TIME IN MINUTES
CONCENTRATION, ppm
Trip No. 5 Date: May 20 1981
Starting at local time: 1250
= Event
= No. of barges
= Speed, mph
= Direction
1
15
8.9
Downstream
2
4
10.0
Downstream
STATION A
STATION C
STATION B
1359
1159
959.3
759.3
559.3
359.3
159.3
-40 0 40 80 120 160 200 240 280 320 360 400
TIME IN MINUTES

Figure 33.

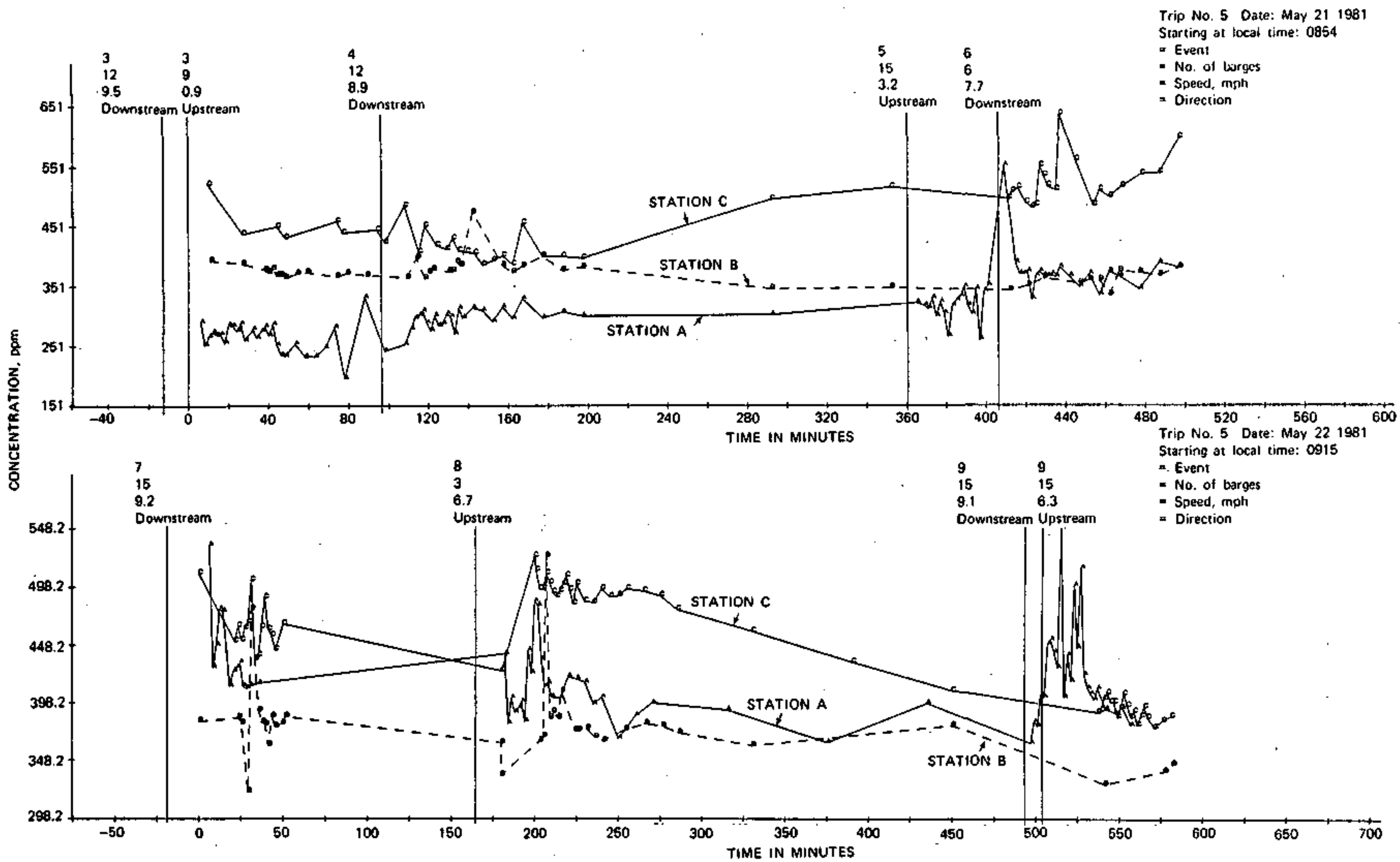

Trip No. 5 Date: May 21 1981
Starting at local time: 0854
= Event
= No. of barges
= Speed, mph
= Direction
3
12
9.5
Downstream
3
9
0.9
Upstream
4
12
8.9
Downstream
5
15
3.2
Upstream
6
6
7.7
Downstream
STATION C
STATION B
STATION A
CONCENTRATION, ppm
651
551
451
351
251
151
-40
0
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
TIME IN MINUTES
Trip No. 5 Date: May 22 1981
Starting at local time: 0915
= Event
= No. of barges
= Speed, mph
= Direction
7
15
9.2
Downstream
8
3
6.7
Upstream
9
15
9.1
Downstream
9
15
6.3
Upstream
STATION C
STATION A
STATION B
548.2
498.2
448.2
398.2
348.2
298.2
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
TIME IN MINUTES

Figure 34.

side are excluded, the distance varied from 275 to 475 feet. At survey station B, the tows were turning away from the east shore and the distance to the sailing line averaged 460 feet and varied from 300 to 650 feet. The blocking factor varied between 25 and 114 and was 20.8 for the double tow passage in event 9. Depth-draft ratios were between 4 and 18.

At Hosier Landing, the geometry is similar except that survey station A and the transect were on the bend and survey station B was on a straight reach. The sailing line distance at the transect varied from 350 to 960 feet and averaged 730 feet. At survey station B the sailing line distance varied from 400 to 725 feet and averaged 590 feet. The blocking factor varied between 34 and 150 and the depth-draft ratio varied between 3 and 18. These values are approximate because of the changing river depth.

Statistical Analysis

Means and standard deviations were calculated for each day's ambient, or background, suspended sediment concentration at each sampling location. The same statistics were also calculated for each tow passage event for four different time periods: 1) all samples from the event, 2) 90 minute minimum time period, 3) 60 minute time period, and 4) until the concentration returned within one standard deviation of the ambient. The last three schemes combine closely spaced events into a continuous event.

The Student t test was used to compare the mean of each 60-minute single or continuous event with the daily mean background concentration. The parameter, t, and a table or graph yields the probability that two means could be obtained from the same population chance by chance. For example, in table 7 for event 1 trip 3 at station A, t equals 2.16 and the P value of 0.05 means that the probability that the event and background average concentrations are from the same population is less than 5 percent but greater than 1 percent. This t corresponds exactly to a probability of 0.045. Similarly for the same event, station B has a t of 3.44, a tabulated probability of 0.01, and an exact probability less than 0.001; and station C has a t of 2.75 which corresponds to a probability of 0.014. Probabilities that the two means could be obtained from the same population by random sampling over 0.2 are indicated by a dash. Such high probabilities do not prove the event and background concentrations are the same, but do raise serious doubts about any significant difference. Preliminary analysis led to the presentation of the statistical parameters for the 60 minute minimum period. There is not much difference between the 60 and 90 minute minimum period except for the number of "continuous" events, or a second tow passage within the minimum time period. If data were collected for the first event in a series, the parameters for each event are each listed as well as the parameters for the continuous event from the first tow passage until 60 minutes after the last tow passage.

Illinois River. The statistical parameters for trips 2 and 3 to Hadley's Landing on the Illinois River are given in table 6. The number of samples, mean, and standard deviation are arranged by trip, date, and event number. On each date, the background or ambient suspended sediment concentration information is given first. Individual event statistics are next, and any continuous event is given last.

For the five events of trip 2, the daily average background suspended sediment concentration was about 65 ppm with a range at the three sampling stations from 55 to 78 ppm. The incremental increase in average concentration during an event was: station A maximum 34 ppm, minimum 6 ppm,

Table 6. Suspended Sediment Concentration Statistics: Illinois River, Hadley's Landing, mile 13.2

A. Trip 2

		Station A			Station B			Station C		
Date	Event	No. of sample	Mean	S.D.*	No. of sample	Mean	S.D.	No. of sample	Mean	S.D.
7/23/80										
	B.G.†	9	61	5.8	9	60	7.5	9	55	5.4
	1	9	67	14.8	8	56	4.4	7	123	65.6
	2	16	73	16.5	15	78	15.5	13	82	11.1
	3	24	76	16.8	24	72	10.9	23	71	9.0
	1-3	45	74	17.0	44	72	14.1	40	83	35.3
7/24/80										
	B.G.	9	73	24.1	9	64	9.0	9	78	10.5
	4	20	99	43.0	20	88	23.6	21	86	22.2
	5	21	107	77.5	21	89	19.7	20	97	24.2

B. Trip 3

		Station A			Station B			Station C		
Date	Event	No. of sample	Mean	S.D.	No. of sample	Mean	S.D.	No. of sample	Mean	S.D.
9/23/80										
	B.G.	7	246	52.5	8	319	50.0	5	405	22.9
	1	17	295	50.0	9	383	24.0	17	500	75.7
	2	21	268	35.8	18	339	53.6	19	471	34.6
	3	20	284	50.6	18	339	59.0	19	417	80.9
9/24/80										
	B.G.	9	183	16.2	9	258	16.0	9	317	47.2
	4	22	252	46.1	19	317	34.2	21	332	36.7
9/25/80										
	B.G.	3	190	10.4	3	293	32.6	3	388	30.8
	5	21	195	25.9	20	285	26.4	19	393.	44.7
	6	21	242	58.5	19	310	44.3	16	423	58.5
	7	21	207	41.8	19	324	36.7	18	412	87.3
	8	18	282	48.2	16	330	37.8	15	350	42.8
9/26/80										
	B.G.	3	202	8.8	3	249	21.9	3	338	45.9
	9	21	196	20.7	20	295	34.4	20	373	50.2
	10	6	198	26.6	2	314	3.5	2	358	33.9
	10-11	28	274	90.3	22	328	73.1	22	403	100.0

* S.D. = standard deviation
† B.G. = ambient

average 19 ppm; station B maximum 25 ppm, minimum -4 ppm, average 15 ppm; and station C maximum 68 ppm, minimum 14 ppm, average (excluding 68 ppm value) 19 ppm. The ratio of the mean concentration during an event to the background concentration varied from 0.93 to 1.49 if the value for station C event 1 is excluded. The average ratio is 1.28 at station A, 1.24 at station B, and 1.28 at station C. Events 1 through 3 were also treated as a multiple event with average concentration increases of 13, 12, and 18 ppm at stations A, B, and C, respectively. The ratio of event to background mean was 1.2 for stations A and B and 1.5 for station C. For the conditions during this trip a ratio of event to background concentration of about 1.25 and an increase in concentration of about 16 ppm was representative of the effect of tow passage on suspended sediment.

During trip 3, the background sediment concentration was much higher than for trip 2 and the trip averages are 192 ppra for station A, 267 ppm for station B, and 348 ppm for station C. The incremental increase in average concentration during events was: station A maximum 92 ppm, minimum 6 ppm, average 38 ppm; station B maximum 64 ppm, minimum 8 ppm, average 32 ppm; and station C maximum 95 ppm, minimum 38 ppm, average 28 ppm. The ratio of event to background concentration varied from 0.90 to 1.48. This ratio averaged 1.18 at station A, 1.11 at station B, and 1.07 at station C. For trip 3, the background concentration was highest at station C in the center of the navigation channel, and lowest at station A on the channel border. The effect of tow passage on suspended sediment concentration was greatest at station A and least at station C, both in magnitude of the change and in relative terms.

The comparisons of event and background means by the Student t test are given in table 7 for the Illinois River suspended sediment data.

Table 7. Results of Student t Test of Suspended Sediment Events on the Illinois River

A. Trip 2, 7/23-24, 1980

Event	Station A t	Station A P*	Station B t	Station B P	Station C t	Station C P
1-3	2.23	.05	2.47	.05	2.40	.05
4	1.67	.20	2.91	.01	1.11	-
5	1.28	.20	3.62	.01	2.35	.01

B. Trip 3, 9/23-26, 1980

Event	Station A t	Station A P	Station B t	Station B P	Station C t	Station C P
1	2.16	.05	3.44	.01	2.75	.05
2	1.28	-	0.89	-	4.04	.01
3	1.73	.05	0.83	-	0.45	-
4	4.30	.01	4.88	.01	0.92	-
5	0.33	-	0.46	-	0.16	-
6	1.52	.20	0.63	-	0.99	-
7	0.72	-	1.40	.20	0.47	-
8	3.23	.01	1.60	.20	1.47	.20
9	0.46	-	2.22	.05	1.12	-
10-11	1.37	.20	1.84	.10	1.09	-

* P is the probability level at which the event mean is significantly different from the background mean.

These results indicate the variability of suspended sediment data. Only four events have probability values less than 0.2 for all three sampling stations. Station C has only 5 of 13 events with probabilities less than 0.2. For trip 3, six events have two stations with probabilities greater than 0.2, and one of these has all three station probabilities greater than 0.2.

Mississippi River. The means and standard deviations for the tow passage events on the Mississippi River during trip 4 at Rip Rap Landing and trip 5 at Mosier Landing are given in table 8.

During trip 4, the average background concentration was about 118 ppm with a daily average maximum of 125 ppm and a minimum of 111 ppm. Stations A and B had nearly the same daily averages and station C had a slightly higher average. The incremental increase in average concentrations during a tow passage event was: station A maximum 67 ppm, minimum 4 ppm, average 26 ppm; station B maximum 40 ppm, minimum -3 ppm, average 12 ppm; and station C maximum 12 ppm, minimum -22 ppm, average -1 ppm. The ratio of event to background mean concentration varied from 0.82 to 1.58. This ratio averaged 1.22 at station A, 1.11 at station B, and 1.00 at station C. Two multiple events were recorded and very small changes in mean sediment concentration were observed.

Trip 5 to Mosier Landing took place during a period of high water and sediment flows. The increase in background concentration at station A on May 22 is due to a change in the location of this sampling site due to the decrease in stage. The lateral increase in concentration from shore to the channel center position is similar to that observed on the Illinois River, trip 3, when suspended sediment concentrations were about the same.

Table 8. Suspended Sediment Concentration Statistics: Mississippi River

A. Trip 4, Rip Rap Landing, mile 265.1

Date	Event	Station A No. of sample	Station A Mean	Station A S.D.*	Station B No. of sample	Station B Mean	Station B S.D.	Station C No. of sample	Station C Mean	Station C S.D.
4/8/81										
	B.G.†	6	121	2.1	2	117	0.0	4	120	0.8
	1	20	123	2.0	7	125	2.7	6	120	1.6
	2	25	125	4.3	18	118	8.8	15	128	3.1
	1-2	42	125	3.9	22	121	8.5	19	125	4.5
4/9/81										
	B.G.	6	115	4.7	6	111	4.4	6	120	10.3
	3	19	120	4.2	10	128	71.2	9	132	9.0
	4	21	129	14.6	17	151	43.7	10	124	13.5
	5	21	160	6.2	19	135	18.2	13	117	3.5
	6	16	182	115.8	19	112	3.5	12	128	26.4
	7-8	31	117	14.3	25	102	2.6	14	111	3.7
4/10/81										
	B.G.	5	115	34.0	5	116	2.3	6	125	20.1
	9	19	160	48.2	17	113	4.1	13	112	8.8
	10	21	132	6.2	20	125	9.5	8	103	10.8

B. Trip 5, Mosier Landing, mile 260.2

Date	Event	Station A No. of sample	Station A Mean	Station A S.D.	Station B No. of sample	Station B Mean	Station B S.D.	Station C No. of sample	Station C Mean	Station C S.D.
5/20/81										
	B.G.	4	341	77.6	5	462	23.0	5	605	23.4
	1	12	323	43.2	6	490	7.0	4	591	5.6
	2	23	339	32.3	16	451	44.0	11	628	20.3
	1-2	32	341	38.7	22	461	40.4	15	619	25.3
5/21/81										
	B.G.	3	301	4.2	4	358	20.2	4	465	64.4
	3	24	262	19.1	10	381	10.1	4	459	42.1
	4	20	301	14.8	12	399	30.5	13	410	21.7
	6	19	374	45.0	8	355	12.8	16	524	39.0
5/22/81										
	B.G.	3	380	19.2	5	364	18.7	5	451	39.5
	7	13	435	37.0	12	385	35.3	14	461	18.2
	8	21	414	28.6	13	383	43.0	20	495	10.6
	9	25	419	44.6	3	335	9.3	19	390	8.6

* S.D. = standard deviation

† B.G. = ambient

Stations B and C indicate a decrease in background concentration from the first to the second day..

No statistical analysis of suspended sediment data is given for event 5 because the tow stopped against the shore just upstream of the sampling transect and waited for the downbound tow of event 6 to pass. Only station A could be occupied until the tow departed. The incremental increase in mean suspended sediment concentration during events was: station A maximum 73 ppm, minimum -39 ppm, average 18 ppm; station B maximum 41 ppm, minimum -29 ppm, and average 11 ppm; and station C maximum 59 ppm, minimum -69 ppm, average 3 ppm. The ratio of event to background mean concentrations ranged between 0.87 and 1.24. This ratio averaged 1.04 at station A, 1.03 at station B, and 1.00 at station C. The one multiple event observed caused no change in mean concentration. At station A the average ratio of means corresponds to an increase of 14 ppm if the background concentration is 340 ppm. On the first day, the average ratio corresponds to an increase of 14 ppm at station B for an event. On the second and third day, this increase is 11 ppm at station B. The average ratio of 1.00 at station C does not increase the mean concentration during an event.

The results of the statistical comparison of event and background means for the Mississippi River suspended sediment data are given in table 9. The results are similar to those on the Illinois River. This statistical comparison neither proves nor disproves the hypothesis that tow passage events increase the suspended sediment concentration.

Summary

The effect of tow passage on suspended sediment concentrations is highly variable in time and space. Greater effects were observed at

Table 9. Results of Student t Test of Suspended Sediment Events on the Mississippi River

A. Trip 4, Rip Rap Landing, 4/8-10, 1981

Event	Station A t	Station A P*	Station B t	Station B P	Station C t	Station C P
1-2	2.16	.05	0.65	-	2.12	.05
3	2.18	.05	0.62	-	2.36	.05
4	2.29	.05	2.27	.05	0.67	-
5	16.49	.01	3.31	.01	0.83	-
6	1.40	-	0.86	-	0.66	-
7-8	0.31	-	6.00	.01	2.93	.01
9	1.95	.10	1.92	.10	1.96	.10
10	2.25	.05	2.04	.10	2.59	.05

B. Trip 5, Mosier Landing, 5/20-22, 1981

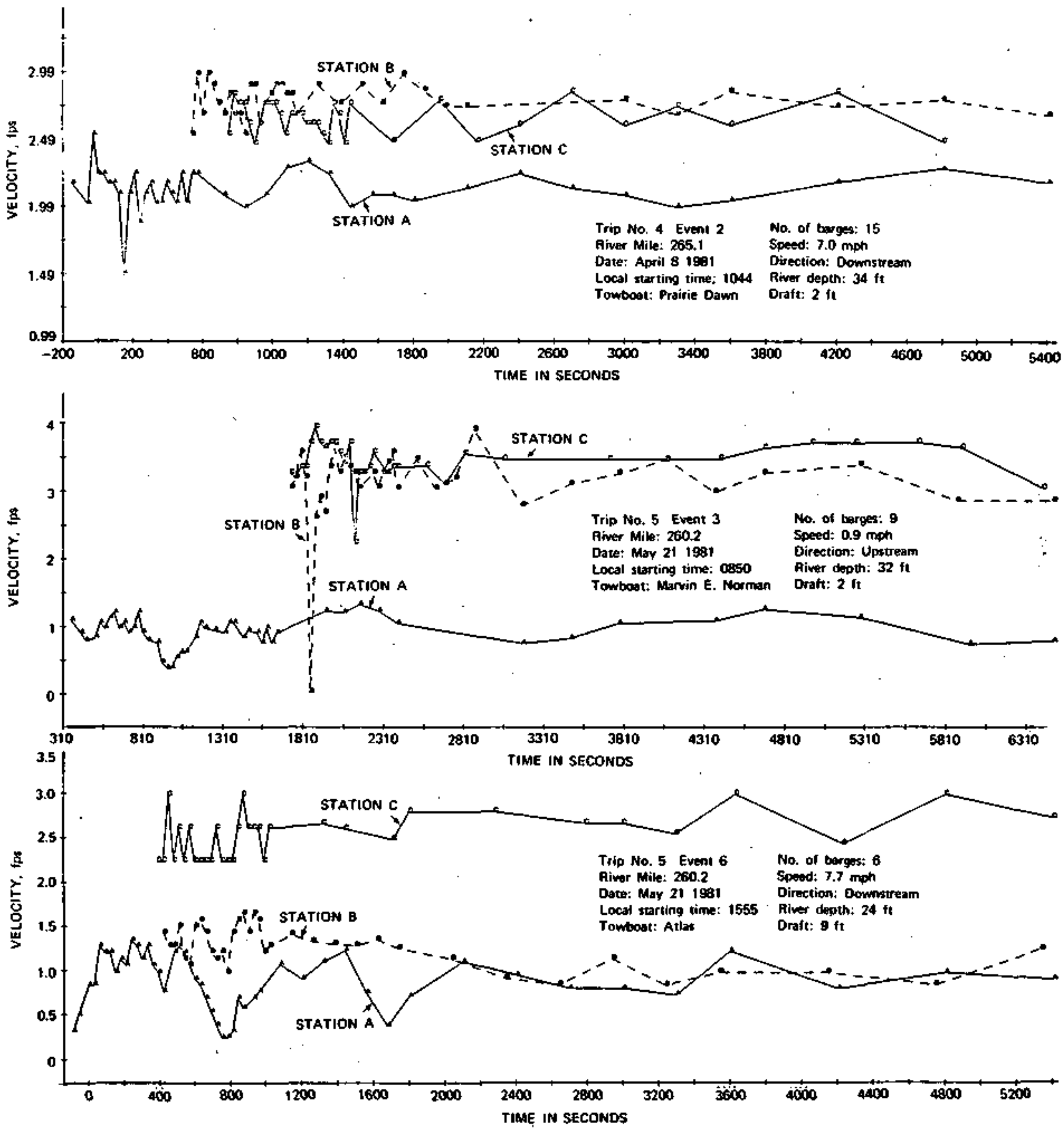
Event	Station A t	Station A P	Station B t	Station B P	Station C t	Station C P
1-2	0.01	-	0.05	-	1.11	-
3	3.52	.01	2.85	.05	0.15	-
4	0.08	-	2.46	.05	2.77	.05
6	2.75	.10	0.36	-	2.38	.05
7	2.47	.05	1.24	-	0.76	-
8	2.02	.10	0.95	-	4.64	.01
9	1.50	.20	2.46	.05	6.50	.01

* P is the probability level at which the event mean is significantly different from the background mean.

station A in a channel border position than at the main channel sampling positions. The increases in suspended sediment were greater on the Illinois River than on the Mississippi River. The differences in channel depth and width are consistent with more significant effects on the Illinois River. These increases are the result of resuspension of sediment and lateral movement of sediment. The channel border sampling site averaged a 20 percent increase in suspended sediment concentration on 3 of 4 periods of data collection. On the Mississippi River with depth-to-draft ratios over 3 and blocking factors over 25 no concentration increase was measured directly behind a tow. An increased concentration at the other two sampling locations was observed on both rivers during two different background concentrations. The range of geometric parameters at a particular site is limited by the fixed river geometry (except for floods) and the standard size and draft of barges and barge tows.

Water Velocity

One of the effects of vessel movement is a velocity pattern in the vessel wake and the high velocity and highly turbulent propeller jet flow. In constricted waterways or rivers a change in flow velocity outside the wake region results from the conservation of mass and energy in open channel flow. The Water Survey has several Price-type current meters. Though they are not meant for turbulence measurement, we used them on trips 4 and 5 as described in the section on methodology. The velocity measurements were taken at various depths following the preset rotation for events. Representative velocity versus time plots for three events are shown in figure 35. Mean velocities and standard deviations were computed for each event with velocity data. These values are given in



STATION B
STATION C
STATION A
VELOCITY, fps
TIME IN SECONDS
Trip No. 4 Event 2
River Mile: 265.1
Date: April 8 1981
Local starting time: 1044
Towboat: Prairie Dawn
No. of barges: 15
Speed: 7.0 mph
Direction: Downstream
River depth: 34 ft
Draft: 2 ft
Trip No. 5 Event 3
River Mile: 260.2
Date: May 21 1981
Local starting time: 0850
Towboat: Marvin E. Norman
No. of barges: 9
Speed: 0.9 mph
Direction: Upstream
River depth: 32 ft
Draft: 2 ft
Trip No. 5 Event 6
River Mile: 260.2
Date: May 21 1981
Local starting time: 1555
Towboat: Atlas
No. of barges: 6
Speed: 7.7 mph
Direction: Downstream
River depth: 24 ft
Draft: 9 ft

Figure 35.

table 10 for trip 4 and in table 11 for trip 5. The omitted events were followed too soon by another tow passage for data collection to be complete. The data are given in appendix D. In table 10 the only differences in mean velocity over 0.10 fps between the first portion of the record within 30-second velocity data and the rest of the data are station C event 1, station B event 3, and station A event 10. In table 11 the same difference in mean velocity occurs for stations B and C event 1, station C event 3, station A event 4, stations B and C events 6, 7, and 9, and stations A and C event 8. The standard deviations in both tables indicate a tendency for the first part of the data to be slightly more variable than the second part. No pattern is apparent in the occurrence of larger differences in mean velocity and event characteristics. Boats B and C are not able to take position soon enough after tow passage to detect high intensity turbulence (at least 5 minutes after tow passage). For an average tow speed of 7 mph, 5 minutes places the sampling boat 3080 feet astern of the tow when sampling begins. No depth of measurement is related to higher variability or greater differences in mean velocity.

Water velocity data were also collected in conjunction with the background suspended sediment samples. The velocity distribution was obtained. Boat A measured velocity at 0.2, 0.4, 0.6, and 0.8 of the depth from the surface. Boats B and C took more data, ideally at each 0.1 from 0.1 to 0.9 depth and 0.95 depth. The three upper semilog graphs in figure 36 show a typical set of background velocity profiles. On days with few tow passage events, several velocity profiles were measured. The lower three graphs in figure 36 show velocity distributions at station A for three different times on the same day. The straight lines through these velocity data points are given by equations of the form:

Table 10. Water Velocity for Trip 4, Rip Rap Landing
(in feet per second)

		Station A		Station B		Station C	
Event	Data	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
1	a*	1.87	0.46	2.41	0.47	1.99	0.47
	b†	1.95	0.33	2.46	0.46	2.18	0.36
2	a	2.11	0.42	2.78	0.36	2.63	0.33
	b	2.13	0.33	2.77	0.30	2.66	0.39
3	a	2.50	0.40	2.87	0.63	3.09	0.45
	b	2.51	0.35	3.18	0.41	3.08	0.39
4	a	2.67	0.36	3.53	0.35	3.71	0.40
	b	2.68	0.30	3.50	0.22	3.70	0.28
5	a	1.67	0.30	2.05	0.53	2.33	0.54
	b	1.69	0.32	2.10	0.28	2.34	0.40
6	a	1.93	0.41	2.93	0.47	2.77	0.46
	b	1.95	0.33	2.88	0.44	2.76	0.44
8	a	2.17	0.39	3.19	0.42	2.99	0.40
	b	2.22	0.36	3.17	0.40	2.99	0.44
9	a	2.68	0.35	3.60	0.40	3.85	0.33
	b	2.74	0.37	3.57	0.45	3.81	0.28
10	a	1.83	0.42	2.53	0.48	2.31	0.51
	b	2.01	0.30	2.61	0.44	2.30	0.37

* continuous data for 30-second intervals
† intermittent data at variable time intervals

Table 11. Water Velocity for Trip 5, Mosier Landing
(in feet per second)

		Station A		Station B		Station C	
Event	Data	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
2	a*	0.98	0.42	2.55	0.24	2.71	0.30
	b†	1.04	0.26	2.44	0.20	2.57	0.42
3	a	0.90	0.22	3.09	0.73	3.41	0.33
	b	0.98	0.22	3.15	0.32	3.51	0.22
4	a	1.20	0.37	3.60	0.20	3.63	0.20
	b	1.56	0.22	3.69	0.24	3.67	0.17
6	a	0.87	0.33	1.35	0.20	2.49	0.25
	b	0.90	0.22	1.02	0.22	2.71	0.17
7	a	1.87	0.10	2.32	0.22	2.49	0.17
	b	1.87	0.10	2.22	0.22	2.36	0.10
8	a	2.39	0.14	2.84	0.22	3.05	0.20
	b	2.11	0.24	2.82	0.17	3.18	0.14
9	a	1.90	0.17	3.19	0.17	2.98	0.30
	b	1.95	0.10	3.08	0.10	3.49	0.17

* continuous data for 30-second intervals
† intermittent data at variable time intervals

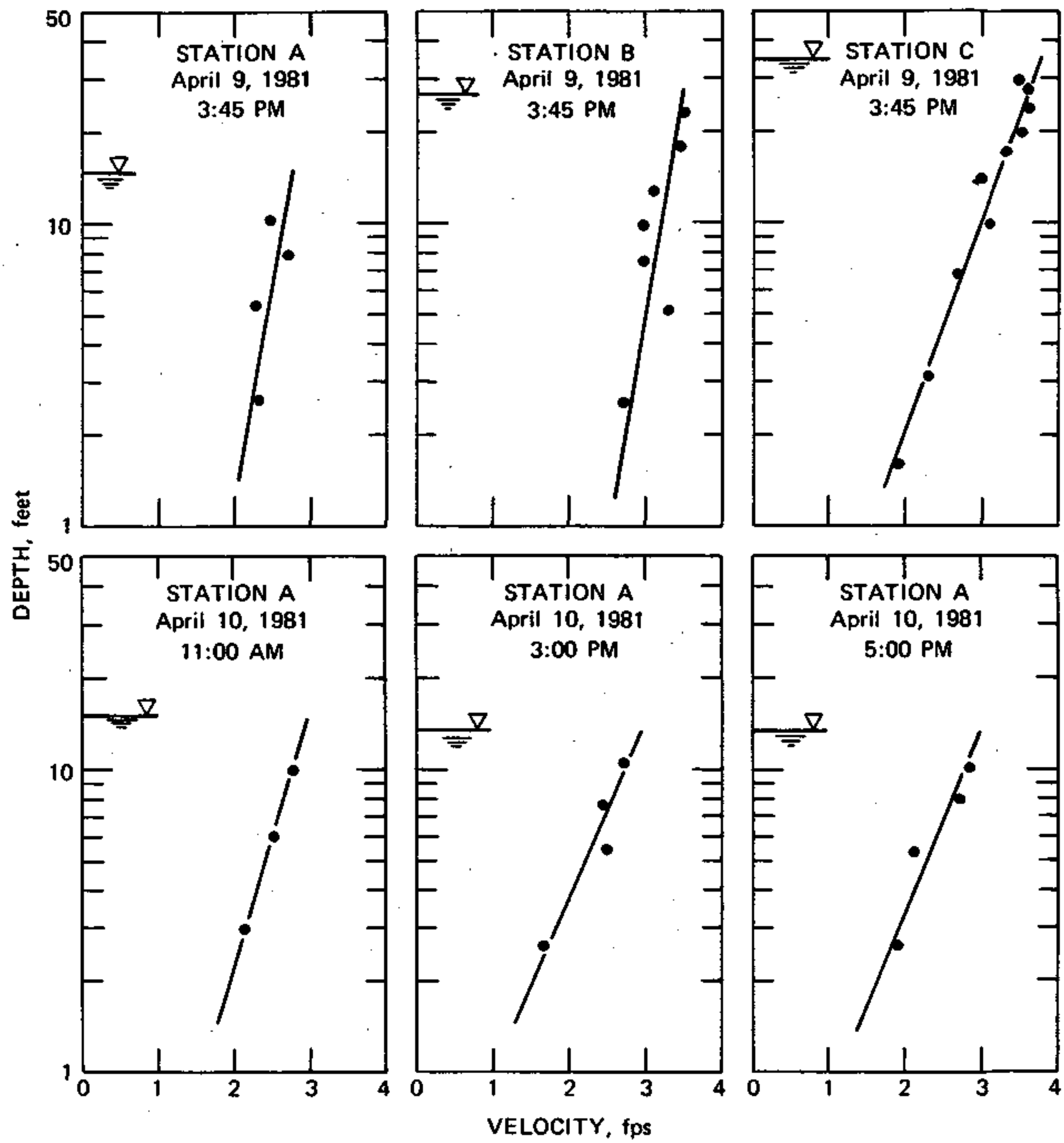


Figure 36. Background water velocity profiles for trip 4

$$U = A + B \log y$$

The coefficients A and B for each velocity distribution are given in table 12. Though there is a lot of variation, on a given day there is consistency for each station. Because of the dynamic location of sampling boats each time, the exact position is slightly different for each data set. On trip 5, boats A and B changed location on May 22 because of the drop in stage since sampling locations were first determined on May 20. The velocity distributions are typical of open channel flow. If the river's energy slope were known on the days the velocity data was obtained, additional analysis based on fundamental fluid mechanics could be done. This would attempt to develop a relationship between velocity, slope, depth, and bed roughness.

For the discharge measurement at Rip Rap Landing on April 10, the 0.2 and 0.8 depth method was used so only the distribution of velocity across the channel was obtained. The influence of the bend upstream and the shallow border area along the islands is clear. In the deeper, east half in the main channel and on the outside of the bend, the average velocity is about 3.3 fps. In the shallower, western half, the average velocity is about 2.5 fps.

Table 12. Coefficients for Background Velocity Distribution Equation, Trips 4 and 5

A. Trip 4, Rip Rap Landing

Date	Time (hrs)	Station A		Station B		Station C	
		A	B	A	B	A	B
4/8/81	14:10	0.85	1.75	2.45	0.75	-	-
	15:10	0.95	1.50	2.10	0.95	1.55	1.35
	16:10	1.80	0.70	-	-	1.75	1.20
4/9/81	15:45	1.90	0.75	2.50	0.70	1.55	1.45
4/10/81	11:00	1.60	1.15	1.20	2.10	1.10	1.90
	14:00	2.10	0.65	0.70	2.00	1.70	1.30
	15:00	1.10	1.45	-	-	1.80	1.40
	17:00	1.10	1.70	-	-	-	-

B. Trip 5, Mosier Landing

Date	Time (hrs)	Station A		Station B		Station C	
		A	B	A	B	A	B
5/20/81	15:40	0.60	0.60	-	-	-	-
	16:30	0.75	0.30	-	-	-	-
	17:30	0.90	0.35	-	-	-	-
5/21/81	14:00	-	-	2.20	0.90	2.60	0.90
5/22/81	14:30	1.50	0.70	2.10	0.65	-	-
	16:30	1.10	0.90	2.00	1.00	-	-

SUMMARY AND CONCLUSIONS

This report presents the results of the reduced field data collection program for lateral movement of sediment caused by tow traffic. New data on the effects of commercial tow traffic on suspended sediment concentrations was obtained on both the Illinois and Mississippi Rivers during periods with ambient suspended sediment concentrations at low (about 100 ppm) and high (300 to 500 ppm) levels. Our scientists consulted with others who have studied navigation effects at two Corps of Engineer facilities: the Waterways Experiment Station and the Huntington District.

Time constraints did not permit the laboratory to complete particle size analysis of suspended sediment samples in time for inclusion of the data in this report. The short time between completion of laboratory analyses of the suspended sediment samples and the due date of this report (July 1 to August 31) precluded any mathematical modeling or investigation of applicability of theories for the resuspension and lateral movement of sediment. Without a theory for lateral movement, no estimation of the flux of suspended sediment into side channels due to lateral movement could be made.

We intend to pursue the mathematical analyses of the effects of tow traffic on suspended sediment as time and support are available. About half of the boundary of Illinois is inland waterway and the state is bisected by the Illinois Waterway. The total length of waterways in and around Illinois is over 1000 miles. Thus, navigation traffic volumes and the effects of vessel traffic on the physical and biological environment of these waterways is of vital concern to the state and to the three scientific surveys of the Illinois Institute of Natural Resources.

The brief analysis of data given herein supports the general validity of the hypothesis that sediment is moved in a lateral direction. Specific points are:

1. Tow passage increases suspended sediment concentrations.
2. The increase in concentration is greater in channel border areas than in the navigation channel.
3. The increase is more significant when the ambient suspended sediment concentration is low.
4. The concentration is increased for 60 to 90 minutes after tow passage.
5. Successive tow passages at time intervals of less than 90 minutes result in extended periods of increased sediment concentration, though the average increase for a multiple event is less than the average increase for an isolated event.
6. The effects of tow passage are greater on the Illinois River than on the Mississippi River. This is consistent with the differences in channel dimensions.
7. The ambient suspended sediment concentration was higher in the channel than in the channel border when the sediment load was increased by upstream runoff or flood flows.

No information on the redistribution of the resuspended or laterally displaced sediment was obtained. Some data (Schnepper et al., 1981) on the Illinois River indicate that fine sand and silt is present in channel border areas but not in the navigation channel. Additional data and much more detailed analyses are needed to establish a model for the resuspension and movement of sediment caused by vessel traffic on inland waterways.

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APPENDICES

APPENDIX A. Data Sheets

APPENDIX B. Suspended Sediment Concentration During Tow Passage Events

APPENDIX C. Background Suspended Sediment Concentration Data

APPENDIX D. Water Velocities During Tow Passage Events

APPENDIX E. Background Water Velocity Data

APPENDIX F. Background Percent Volatiles

APPENDIX A

DATA SHEETS

SUSPENDED SEDIMENT
DATA COLLECTION

LM/SC LATERAL MOVEMENT OR SIDE CHANNEL [1] [2]

TRIP No. [4] [5]

RIVER MILE PT. [7] [ ] [ ] . [10]

DATE [12] [ ] – [ ] [ ] – [ ] [17]
MONTH DAY YEAR

EVENT No. [19] [20]

LOCAL TIME [22] [ ] [ ] [25]

TOW NAME 27 ______________________ 38

No. OF BARGES [40] [41]

DIRECTION (U/D) [43]

DRAFT (ft.) [45] [46]

SPEED (mph) [48] . [49]

Page ____ of ________

Recorder ____________

Party ______________

WATER TEMP. (°C)

Start [51] [52]

Finish [54] [55]

AIR TEMP. (°C) [57] [58]

WATER DEPTH (ft.) [60] [61]

STATION KEY [63] – [64]

Sampler	59	61	
Nozzle	1/8	3/16	1/4
Key =	1	2	3

Remarks:

Event	Station (66)	Bottle No. (68–70)	Time Min Elapsed (72–74)	Conc. ppm (76–79)	Depth open	Depth close	Remarks

VELOCITY DATA FOR BARGE EVENT

LM/SC ___ ___ (1, 2)   EVENT NO. ___ ___ (19, 20)   STATION ___ (40) RECORDER ___

TRIP NO. ___ ___ (4, 5)   LOCAL TIME __ __ __ __ (22–25)   TOTAL DEPTH (m) __ __ . __ __ (42–45)

DATE __ __ - __ __ - __ __ (month, day, year; 12–17)   TOW NAME ________ (27–38)   SAMPLING DEPTH (m) __ __ . __ __ (47–50)

52–57 BARGE ELAPSED TIME (± MIN:SEC)	59–63 VELOCITY TIME (MIN:SEC)	65–66 REVOLUTIONS	71–74 VELOCITY (FT/SEC)	52–57 BARGE ELAPSED TIME (± MIN:SEC)	59–63 VELOCITY TIME (MIN:SEC)	65–66 REVOLUTIONS	71–74 VELOCITY (FT/SEC)
:	0:30		.	:	15:30		.
:	1:00		.	:	16:00		.
:	1:30		.	:	16:30		.
:	2:00		.	:	17:00		.
:	2:30		.	:	17:30		.
:	3:00		.	:	18:00		.
:	3:30		.	:	18:30		.
:	4:00		.	:	19:00		.
:	4:30		.	:	19:30		.
:	5:00		.	:	20:00		.
:	5:30		.	:	20:30		.
:	6:00		.	:	21:00		.
:	6:30		.	:	21:30		.
:	7:00		.	:	22:00		.
:	7:30		.	:	22:30		.
:	8:00		.	:	23:00		.
:	8:30		.	:	23:30		.
:	9:00		.	:	24:00		.
:	9:30		.	:	24:30		.
:	10:00		.	:	25:00		.
:	10:30		.	:	25:30		.
:	11:00		.	:	26:00		.
:	11:30		.	:	26:30		.
:	12:00		.	:	27:00		.
:	12:30		.	:	27:30		.
:	13:00		.	:	28:00		.
:	13:30		.	:	28:30		.
:	14:00		.	:	29:00		.
:	14:30		.	:	29:30		.
:	15:00		.	:	30:00		.

BACKGROUND VELOCITY DATA

LM/SC ___ ___ (1, 2) TRIP NO. ___ ___ (4, 5) DATE __ __ __ __ __ __ (month 12, day, year 17) RECORDER ______________

22 Local 25 (military)	27 38	40 Station	Depth (m)		65 Revolutions 66	68 Seconds 69	71 Velocity (ft/sec) 74	Remarks
			42 Total 45	47 Sample 50				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
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	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				
	BG		.	.				

APPENDIX B

SUSPENDED SEDIMENT CONCENTRATION DURING TOW PASSAGE EVENTS

Site: Havana
River mile 121.5
Trip no. 1
Event no: 1
Date: 05-28-80

Starting time: 1321
Tow name: Lynn B.
No. of barges: 11
Draft: ----
Traffic direction: Downstream
Tow speed: 7.2 mph

Station A		Station B	
Water temp.: ----		Water temp.: ----	
Water depth: ----		Water depth: 13 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
4	411	0	100
6	583	2	88
8	344	4	86
10	336	6	156
15	664	8	232
		10	277
		12	366
		15	338
		17	297

Site: Havana
River mile 121.5
Trip no. 1
Event no: 2
Date: 05-28-80

Starting time: 1339
Tow name: Magnolia
No. of barges: 5
Draft: ----
Traffic direction: Downstream
Tow speed: 8.8 mph

Station A		Station B	
Water temp.: ----		Water temp.: ----	
Water depth: ----		Water depth: 13 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
18	146	19	198
20	120	21	202
22	176	23	126
24	223	25	134
29	182	30	223
34	170	35	183
39	127	40	111
44	104	45	119
49	95	50	125
54	109	55	113
59	103	60	110
70	99	70	93
80	90	80	104
90	95	90	89

Site: Havana
River mile 121.5
Trip no. 1
Event no: 3
Date: 05-29-80

Starting time: 1113
Tow name: Creole Belle
No. of barges: 14
Draft: ----
Traffic direction: Downstream
Tow speed: 6.6 mph

Station A
Water temp.: 24 C
Water depth: ----

Time (minutes elapsed)	Suspended sediment conc. (ppm)
0	86
2	73
4	118
6	218
8	191
10	271
15	358
20	144
25	124
30	105
35	89

Station B
Water temp.: 24 C
Water depth: 14 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
15	470
20	147
25	121
30	106

Site: Havana
River mile 121.5
Trip no. 1
Event no: 4
Date: 05-29-80

Starting time: 1149
Tow name: Andrew Benedict
No. of barges: 8
Draft: ----
Traffic direction: Downstream
Tow speed: 7.6 mph

Station A
Water temp.: ----
Water depth: ----

Time (minutes elapsed)	Suspended sediment conc. (ppm)
37	81
39	277
41	254
43	165
45	167
47	216
52	263
57	185
62	155
67	116

Station B
Water temp.: ----
Water depth: 14 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
52	115
57	154
62	122

Site: Havana
River mile 121.5
Trip no. 1
Event no: 5
Date: 05-29-80

Starting time: 1224
Tow name: Patsy Swank
No. of barges: 9
Draft: ----
Traffic direction: Upstream
Tow speed: 4.8 mph

Station A
Water temp.: ----
Water depth: ----

Time (minutes elapsed)	Suspended sediment conc. (ppm)
73	102
75	115

Site: Havana
River mile 121.5
Trip no. 1
Event no: 6
Date: 05-29-80

Starting time: 1231
Tow name: John M. Warner
No. of barges: 3
Draft: ----
Traffic direction: Downstream
Tow speed: 6.4 mph

Station A
Water temp.: ----
Water depth: ----

Time (minutes elapsed)	Suspended sediment conc. (ppm)
79	99
81	64
83	79
85	116
87	142
89	147
94	138
99	133
104	157
109	121
114	113
119	97
124	87
129	98
134	85
139	95

Station B
Water temp.: ----
Water depth: 12 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
94	130
99	116
104	135
109	111
114	123
119	117
124	97
129	84
134	92

Site: Hadley's Landing
River mile 13.2
Trip no. 2
Event no: 1
Date: 07-23-80

Starting time: 1520
Tow name: Chicago Trader
No. of barges: 6
Draft: 8 ft
Traffic direction: Downstream
Tow speed: 5.4 mph

Station A		Station B		Station C	
Water temp.: 31 C		Water temp.: 31 C		Water temp.: 30 C	
Water depth: ----		Water depth: ----		Water depth: 13 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc, (ppm)
2	57	2	54	4	244
4	51	4	65	6	84
8	85	6	53	8	187
10	92	8	58	10	89
12	60	10	53	12	88
14	53	12	55	14	85
16	74	14	51	16	164
18	58	16	54		
20	58				

Site: Hadley's Landing
River mile 13.2
Trip no. 2
Event no: 2
Date: 07-23-80

Starting time: 1541
Tow name: Herb Schreiner
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 3.9 mph

Station A		Station B		Station C	
Water temp.: 30 C		Water temp.: 30 C		Water temp.: 30 C	
Water depth: 13 ft		Water depth: ----		Water depth: ----	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
23	76	24	55	25	72
25	55	26	57	27	70
27	57	28	61	29	95
29	53	30	76	31	99
31	95	32	112	33	87
33	101	34	91	35	97
35	97	36	94	37	93
37	101	38	92	39	80
39	69	40	66	41	70
41	65	42	70	43	79
43	60	44	74	45	70
45	65	46	75	47	77
47	66	48	81	49	73
49	65	50	69		
51	71	52	80		
53	79				

Site: Hadley's Landing
River mile 13.2
Trip no. 2
Event no: 3
Date: 07-23-80

Starting time: 1614
Tow name: Marvin E. Norman
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 5.3 mph

Station A Water temp.: 30 C Water depth: ----		Station B Water temp.: 31 C Water depth: 15 ft		Station C Water temp.: 30 C Water depth: 17 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
57	65	59	70	60	61
59	87	61	75	62	62
61	67	63	72	64	65
63	63	65	70	66	73
65	81	67	67	68	68
69	68	69	66	70	92
71	71	71	62	72	88
73	72	73	62	74	84
75	72	75	68	76	68
77	77	77	67	78	67
79	72	79	64	80	66
81	68	81	87	82	64
83	93	83	94	84	79
85	95	85	97	86	84
87	141	87	96	91	65
93	74	92	68	96	73
98	76	97	74	101	71
103	70	102	83	106	70
108	55	107	70	111	86
114	74	112	80	116	66
120	82	117	70	126	67
130	80	127	63	136	68
140	66	137	67	146	69
150	60	147	62		

Site: Hadley's Landing
River mile 13.2
Trip no. 2
Event no: 4
Date: 07-24-80

Starting time: 0959
Tow name: Yankton
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 4.4 mph

Station A Water temp.: 29 C Water depth: 12 ft		Station B Water temp.: 29 C Water depth: 16 ft		Station C Water temp.: 29 C Water depth: 16 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
3	69	3	75	6	142
5	69	5	71	8	135
7	76	7	68	10	109
9	99	9	64	12	78
11	113	11	80	14	66
13	65	13	166	16	116
15	86	15	65	18	118
17	75	17	72	20	97
19	101	19	85	22	88
21	114	21	90	24	75
23	109	25	99	26	81
25	98	27	97	28	94
30	262	29	112	30	107
32	141	31	78	32	86
37	86	36	92	34	77
43	80	41	118	39	76
48	85	46	80	44	76
53	80	51	85	49	77
58	71	56	77	54	78
63	84	61	74	59	72
73	67	71	72	64	79
83	66	81	68	74	86
94	85	91	64	84	74
				94	68

Site: Hadley's Landing
River mile 13.2
Trip no. 2
Event no: 5
Date: 07-24-80

Starting time: 1145
Tow name: Fort Pierre
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 4.6 mph

Station A		Station B		Station C	
Water temp.: 30 C		Water temp.: 29 C		Water temp.: 30 C	
Water depth: 13 ft		Water depth: ----		Water depth: 17 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
3	65	4	66	6	157
5	59	6	66	8	82
7	64	8	66	10	142
9	62	10	69	12	145
11	61	12	74	16	124
13	68	14	67	18	89
15	61	16	61	20	99
17	35	18	75	22	101
19	86	20	102	26	121
21	109	22	83	28	110
23	118	24	112	30	85
25	115	26	117	32	92
27	120	28	118	34	93
29	120	30	118	36	97
31	121	32	72	41	81
36	78	37	82	46	95
41	101	42	101	51	76
46	100	47	101	56	87
51	138	52	103	61	79
56	90	57	92	66	82
61	420	62	87	76	71
71	86	72	75	86	85
81	82	82	72	96	73
91	109	92	69		

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 1
Date: 09-23-80

Starting time: 1008
Tow name: Andrew Benedict
No. of barges: 4
Draft: 9 ft
Traffic direction: Upstream
Tow speed: ----

Station A		Station B		Station C	
Water temp.: 20 C		Water temp.: 20 C		Water temp.: 22 C	
Water depth: ----		Water depth: 15 ft		Water depth: 18 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
4	226	4	367	4	424
6	255	28	401	6	506
8	365	30	436	10	664
16	276	35	383	12	504
18	342	40	388	18	441
20	334	45	374	20	453
22	372	50	371	22	415
24	362	55	352	24	383
26	364	60	387	26	434
28	284	70	349	28	405
30	339	80	361	30	415
35	242	90	282	35	518
40	280			40	530
45	287			45	589
50	264			50	503
55	240			55	548
60	280			60	495
70	289			70	462
80	274			80	434
90	240				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 2
Date: 09-23-80

Starting time: 1236
Tow name: Leviticus
No. of barges: 6
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 5.6 mph

Station A Water temp.: 20 C Water depth: 10 ft		Station B Water temp.: 20 C Water depth: ----		Station C Water temp.: 21 C Water depth: 17 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	249	6	349	4	496
4	263	8	335	6	512
6	271	10	398	8	471
8	274	12	484	10	545
10	278	14	340	14	532
12	332	16	405	16	460
14	274	18	353	18	464
16	256	20	436	20	452
18	275	22	318	22	456
20	288	24	334	24	451
22	275	28	374	26	431
24	333	30	341	28	442
26	324	35	297	30	465
28	328	40	317	35	505
30	310	45	333	40	504
35	289	50	310	45	420
40	243	55	304	50	460
45	252	60	275	55	437
50	211	70	246	60	454
55	221	80	269	70	455
60	238	90	248	80	380
70	187			90	391
80	189				
90	177				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 3
Date: 09-23-80

Starting time: 1454
Tow name: Craig M.
No. of barges: 4
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 4.0 mph

Station A Water temp.: 20 C Water depth: 13 ft		Station B Water temp.: 20 C Water depth: 17 ft		Station C Water temp.: 21 C Water depth: ----	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
4	303	10	314	6	478
6	328	12	307	8	473
8	329	14	330	10	468
10	254	16	330	12	478
12	253	18	335	14	516
14	246	20	334	16	553
16	263	22	330	18	388
18	277	24	176	20	345
20	263	26	354	22	384
22	131	28	313	24	336
24	292	30	346	26	377
26	352	35	350	28	356
28	362	40	331	30	351
30	335	45	313	35	434
35	303	50	299	40	431
40	318	55	258	45	428
45	275	60	417	50	419
50	267	70	460	55	389
55	248	80	421	60	391
60	279	90	366	70	464
70	370			80	497
80	290			90	410
90	331				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 4
Date: 09-24-80

Starting time: 1315
Tow name: Irene Chotin
No. of barges: 18
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 4.8 mph

Station A		Station B		Station C	
Water temp.: 21 C		Water temp.: 20 C		Water temp.: 21 C	
Water depth: ----		Water depth: ----		Water depth: ----	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
3	200	7	239	5	400
5	188	9	282	7	370
7	192	11	290	9	321
9	200	13	309	11	330
11	213	15	371	13	301
13	210	17	321	15	264
15	202	19	261	17	373
17	312	21	345	19	288
19	331	25	345	21	320
21	296	27	313	23	267
23	245	29	298	25	313
25	251	31	303	27	296
27	274	33	310	29	294
29	291	35	306	31	311
31	295	40	349	33	326
33	265	45	314	35	337
35	316	50	275	40	371
40	297	55	350	45	372
45	247	60	344	50	321
50	223	70	326	55	350
55	200	80	272	60	339
60	266	90	300	70	351
70	207			80	317
80	185			90	341
90	182				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 5
Date: 09-25-80

Starting time: 1015
Tow name: Barbara Jeanne Meyer
No. of barges: 8
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 5.4 mph

Station A Water temp.: 21 C Water depth: 13 ft		Station B Water temp.: 21 C Water depth: 17 ft		Station C Water temp.: 21 C Water depth: ----	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	197	4	256	6	448
4	180	6	260	8	492
6	186	8	272	10	451
8	191	10	272	12	348
10	192	12	320	14	365
12	171	14	319	16	364
14	186	16	325	18	359
16	185	18	301	20	344
18	192	20	327	22	348
20	187	22	316	24	342
22	201	24	273	26	361
24	262	26	270	28	331
26	236	28	298	30	397
28	213	30	329	35	413
30	220	35	266	40	416
35	225	40	278	45	426
40	205	45	271	50	373
45	182	50	278	55	414
50	200	55	272	60	377
55	137	60	251	70	388
60	172	70	255	80	330
70	219	80	262	90	445
80	168	90	260		
90	163				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 6
Date: 09-25-80

Starting time: 1310
Tow name: Luke Gladders
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 5.9 mph

Station A		Station B		Station C	
Water temp.: 22 C		Water temp.: 21 C		Water temp.: ----	
Water depth: 13 ft		Water depth: 17 ft		Water depth: ----	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	181	6	447	6	536
4	175	8	362	8	452
6	166	10	272	12	399
8	202	12	261	14	342
10	182	14	346	16	350
12	192	16	310	18	327
14	326	18	288	20	416
16	322	20	278	22	395
18	259	22	316	26	383
20	261	24	280	28	441
22	259	26	244	30	424
24	275	28	303	35	452
26	333	30	322	40	522
28	284	35	340	50	399
30	278	40	310	55	382
35	334	45	328	60	442
40	252	50	291	70	461
45	230	55	304	80	463
50	217	60	307	90	472
55	159	70	268		
60	182	80	249		
70	181	90	259		
80	155				
90	169				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 7
Date: 09-25-80

Starting time: 1450
Tow name: Fort Pierre
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 4.1 mph

Station A Water temp.: 22 C Water depth: 13 ft		Station B Water temp.: 21 C Water depth: 17 ft		Station C Water temp.: 21 C Water depth: 12 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	190	6	290	6	534
4	172	8	269	8	669
6	178	10	334	10	532
8	172	12	409	12	390
10	168	14	356	14	402
12	232	16	321	18	359
14	310	18	292	20	321
16	274	20	279	22	334
18	246	22	291	24	337
20	242	24	296	26	373
22	273	26	365	28	423
24	221	28	330	30	400
26	201	30	363	35	453
28	213	35	327	40	432
30	243	40	366	45	373
35	221	45	319	50	369
40	201	50	292	55	397
45	201	55	321	60	471
50	171	60	297	70	451
55	163	70	295	80	456
60	162	80	283	90	415
70	165	90	278		
80	155				
90	162				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 8
Date: 09-25-80

Starting time: 1747
Tow name: Virginia E. Towey
No. of barges: 15
Draft: ----
Traffic direction: Downstream
Tow speed: ----

Station A
Water temp.: 22 C
Water depth: 13 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	215
4	214
6	233
8	252
10	219
12	302
14	301
16	252
18	263
20	249
22	288
24	358
26	333
28	344
30	360
35	301
40	252
45	263

Station B
Water temp.: 21 C
Water depth: 17 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
6	416
8	384
10	365
12	315
14	383
16	343
18	270
20	297
22	312
24	334
26	346
28	339
30	330
35	326
40	312
45	298

Station C
Water temp.: 21 C
Water depth: ----

Time (minutes elapsed)	Suspended sediment conc. (ppm)
8	380
10	346
12	331
14	382
16	316
18	278
20	293
22	269
24	331
26	347
28	369
30	423
35	381
40	360
45	341

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 9
Date: 09-26-80

Starting time: 0950
Tow name: Clark Frame
No. of barges: 8
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 2.2 mph

Station A Water temp.: 21 C Water depth: 13 ft		Station B Water temp.: 20 C Water depth: ----		Station C Water temp.: ---- Water depth: ----	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
5	204	7	246	7	384
7	204	9	251	9	437
9	198	11	265	11	441
11	189	13	253	13	476
13	207	15	253	15	367
15	189	17	276	17	392
17	191	19	319	19	438
19	195	21	295	21	440
21	193	23	278	23	417
23	185	25	322	25	372
25	201	27	300	27	330
27	211	29	346	29	296
29	212	31	349	31	327
31	193	33	331	33	346
33	184	35	271	35	317
35	198	40	301	40	333
40	267	45	332	45	398
45	189	50	323	50	370
50	179	55	267	55	344
55	159	60	258	60	350
60	170	70	292	70	332
70	188	80	292	80	353
80	197				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 10
Date: 09-26-80

Starting time: 1115
Tow name: Betty Brent
No. of barges: 8
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 4.0 mph

Station A		Station B		Station C	
Water temp.: 21 C		Water temp.: 20 C		Water temp.: 20 C	
Water depth: 13 ft		Water depth: ----		Water depth: 17 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
3	167	7	316	7	382
5	189	9	311	9	334
7	218				
9	178				
11	202				
13	239				

Site: Hadley's Landing
River mile 13.2
Trip no. 3
Event no: 11
Date: 09-26-80

Starting time: 1130
Tow name: Lynn B.
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 5.9 mph

Station A		Station B		Station C	
Water temp.: 21 C		Water temp.: 20 C		Water temp.: ----	
Water depth: 13 ft		Water depth: 17 ft		Water depth: ----	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
15	250	19	309	19	290
17	272	21	292	21	317
19	286	23	323	23	282
21	236	25	318	25	311
23	224	27	301	27	322
25	302	29	319	29	306
27	397	31	452	31	393
29	416	33	395	33	337
31	372	35	408	35	328
33	442	37	389	37	321
35	434	39	480	39	405
37	364	41	501	41	614
39	397	43	359	43	565
41	417	45	419	45	573
43	353	50	317	50	525
45	319	55	298	55	517
50	291	60	278	60	410
55	245	65	269	65	421
60	202	70	263	70	381
65	196	75	250	75	394
70	189				
75	197				

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 1
Date: 04-08-81

Starting time: 0947
Tow name: Atlas
No. of barges: 9
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 3.9 mph

Station A
Water temp.: 13 C
Water depth: 10 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
0	118
2	122
4	122
7	121
8	119
10	121
12	122
14	122
16	122
18	122
20	123
22	123
24	123
26	124
28	123
30	119
35	123
40	124
45	126
50	125

Station B
Water temp.: 13 C
Water depth: 29 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
18	139B
18	119T
19	130B
19	117T
21	123B
21	120T
27	124B
27	123T
31	123T
31	135B
37	126T
37	125B
42	124T
42	124B

Station C
Water temp.: 13 C
Water depth: 35 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
7	121B
10	119T
12	130P
13	123B
15	121T
24	128P
28	123B
29	116T
32	128P
35	124B
37	113T
39	122P
40	123B
42	115T
43	126P
45	133B
48	112T
49	122P

NOTE: The letter B,T,or P follows some suspended sediment concentrations.
B indicates a depth-integrated sample of the bottom half of the water column
T indicates a depth-integrated sample of the top half of the water column
P indicates a point-integrated sample at a specific depth
All others are depth-integrated samples of the entire water column

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 2
Date: 04-08-81

Starting time: 1044
Tow name: Prairie Dawn
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 7.0 mph

Station A
Water temp.: 13 C
Water depth: 10 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
0	123
2	124
4	138
6	130
8	126
10	126
12	128
14	129
16	131
18	126
20	126
22	126
24	127
26	135
28	127
30	126
35	129
40	126
45	126
50	124
55	125
60	121
70	121
80	120
90	125

Station B
Water temp.: 13 C
Water depth: 26 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
6	124T
6	128B
9	130B
9	124T
12	123B
12	119T
15	125B
15	118T
18	122B
18	117T
21	116T
21	118B
24	117T
24	122B
27	126T
27	122B
30	114T
30	114B
35	121B
35	107T
40	114B
40	114T
45	70B
45	114T
50	114B
50	114T
55	153B
55	119T
60	123B
60	119T
70	118T
70	121B
80	122B
80	118T
90	118B
90	110T

Station C
Water temp.: 13 C
Water depth: 34 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
9	129B
12	120T
14	133P
15	130B
16	114T
17	129P
19	132B
21	123T
22	131P
24	131B
25	115T
27	128P
28	136B
30	122T
31	132P
33	128B
34	117T
35	134P
36	134B
37	123T
39	134P
40	136B
42	120T
43	134P
45	136B
47	123T
48	130P
50	134B
52	123T
53	137P
55	136B
56	127T
57	136P
60	140B
61	124T
62	135P
70	136B
71	121T

(Continued)

Station A Water temp.: 13 C Water depth: 10 ft		Station B Water temp.: 13 C Water depth: 26 ft		Station C Water temp.: 13 C Water depth: 34 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
				72	131P
				80	132B
				82	120T
				83	129P
				90	128B
				91	126T
				92	129P

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 3
Date: 04-09-81

Starting time: 0823
Tow name: Lillian Clark
No. of barges: 16
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 7.9 mph

Station A Water temp.: 13 C Water depth: 06 ft		Station B Water temp.: 12 C Water depth: 28 ft		Station C Water temp.: 12 C Water depth: 35 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
8	125	6	126B	10	125B
10	127	6	119T	11	120T
12	126	24	118	12	122P
14	128	27	118	25	128B
16	121	30	123	26	123T
18	120	35	118	27	125B
20	121	40	117	28	121T
22	121	45	111	29	123P
24	116	50	114	31	124B
26	113	55	114	32	179T
28	117	60	339	34	123B
30	116	70	115	48	130B
32	116	80	114	50	132T
35	118	90	115	51	130B
40	120			52	122T
45	121			53	132B
50	120			54	126T
55	115			55	133B
60	120			56	127T
70	119			69	130B
80	121			70	128T
90	119			71	132P
				80	131B
				81	125T
				90	133B
				92	126T
				93	121P

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 4
Date: 04-09-81

Starting time: 1005
Tow name: Arthur E. Snider
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.1 mph

Station A
Water temp.: 13 C
Water depth: 12 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	118
4	118
6	119
8	122
10	123
12	121
14	121
16	120
18	122
20	122
22	122
24	120
26	121
28	121
30	121
35	120
40	124
45	117
50	162
55	159
60	160
70	157

Station B
Water temp.: 12 C
Water depth: 26 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
5	116
8	120
11	112
14	120
16	119
18	121
20	115
22	116
24	113
26	122
28	116
30	117
35	269
40	172
45	158
50	149
60	198

Station C
Water temp.: 12 C
Water depth: 35 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
10	126B
11	119T
12	120P
17	125B
19	114T
20	118P
23	121B
24	116T
26	114P
28	120B
30	113T
31	115P
33	121B
34	116T
35	113P
39	128B
41	115T
42	68P
45	204B
46	119T
48	117P
51	119B
52	115T
53	112P
56	122B
58	116T
59	116P
63	117T
63	124B
64	117P

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 5
Date: 04-09-81

Starting time: 1129
Tow name: Rose Marie Walden
No. of barges: 9
Draft: 8 ft
Traffic direction: Downstream
Tow speed: ----

Station A
Water temp.: 14 C
Water depth: 12 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
0	153
2	155
4	158
6	2390
8	165
10	157
12	161
14	161
16	164
18	149
20	150
22	160
24	171
26	163
28	173
30	168
35	160
40	154
45	162
50	163
55	160
60	158
70	156
80	143
90	152

Station B
Water temp.: 12 C
Water depth: 27 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
6	157T
8	147T
10	142T
12	159T
14	169T
16	148T
18	149T
20	153T
22	155T
24	153T
26	150T
28	141T
30	153T
35	128T
40	118T
45	118T
50	120T
55	116T
60	114T
70	115T
80	113T

Station C
Water temp.: 12 C
Water depth: 33 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
6	120B
7	112T
9	123P
10	123B
11	118T
13	123P
16	117T
16	121B
17	126P
19	119B
20	119T
21	122P
22	117B
23	113T
24	122P
26	122B
27	130T
28	108P
29	117B
30	113T
31	119P
35	112B
36	115T
37	117P
40	125B
41	114T
42	117P
45	120B
47	109T
48	123P
51	117B
52	111T
53	120P
55	122B
57	115T
58	128P
60	117B
62	115T

(Continued)

Station A Water temp.: 14 C Water depth: 12 ft		Station B Water temp.: 12 C Water depth: 27 ft		Station C Water temp.: 12 C Water depth: 33 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
				63	122P
				70	119B
				71	113T
				72	122P
				80	115T
				80	121B
				81	123P

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 6
Date: 04-09-81

Starting time: 1300
Tow name: White Dawn
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.7 mph

Station A Water temp.: 14 C Water depth: 12 ft		Station B Water temp.: 14 C Water depth: 27 ft		Station C Water temp.: 14 C Water depth: 34 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
4	150	6	119T	8	121B
6	157	8	111T	9	114T
8	604	10	113T	11	120P
10	182	12	111T	12	273B
12	180	14	114T	13	118T
14	165	16	114T	14	119P
16	153	18	120T	16	138B
18	10311	20	114T	17	119T
20	184	22	112T	18	122P
22	176	24	114T	19	122B
24	1018	26	111T	21	117T
26	159	28	112T	21	172P
28	125	30	113T	24	119B
30	127	35	114T	25	114T
35	123	40	113T	27	118P
40	238	45	108T	28	123B
50	119	50	110T	29	118T
55	3551	55	107T	30	115P
60	235	60	106T	35	98B
70	335	70	108T	36	111T
80	1735	80	108T	37	119P
90	4752	90	109T	41	120B
				42	113T
				48	222B
				49	114T
				50	119P
				51	121B
				52	113T
				53	119P
				55	115B
				56	108T
				57	113P
				60	118B
				61	117T
				62	122P
				70	123B
				71	113T
				72	113P

(Continued)

Station A Water temp.: 14 C Water depth: 12 ft		Station B Water temp.: 14 C Water depth: 27 ft		Station C Water temp.: 14 C Water depth: 34 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
				80	124B
				82	113T
				83	115P
				90	119B
				91	114T
				92	115P

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 7
Date: 04-09-81

Starting time: 1602
Tow name: Robin Mott
No. of barges: 14
Draft: 2 ft
Traffic direction: Upstream
Tow speed: ----

Station A		Station B		Station C	
Water temp.: 13 C		Water temp.: 13 C		Water temp.: 13 C	
Water depth: 12 ft		Water depth: 27 ft		Water depth: 36 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
0	112	6	104T	11	117B
2	111	8	102T	13	111T
4	114	10	104T	14	111P
6	112	12	103T	16	110B
8	112	14	103T	17	110T
10	112	16	104T	19	114P
13	113				
14	114				
16	116				
18	116				

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 8
Date: 04-09-81

Starting time: 1623
Tow name: Hawkeye
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.1 mph

Stasion A Water temp.: 14 C Water depth: 12 ft		Station B Water temp.: 14 C Water depth: 26 ft		Station C Water temp.: 14 C Water depth: 35 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
23	114	26	109T	29	115B
25	114	28	104T	30	105T
27	112	30	102T	32	114P
29	110	32	105T	33	114B
31	113	34	100T	34	105T
33	113	36	103T	35	110P
35	112	38	104T	37	108B
37	110	40	99T	38	109T
39	115	42	100T	39	111P
41	112	44	100T	40	111B
43	113	46	100T	41	106T
45	107	48	99T	43	108P
47	112	50	100T	44	109B
49	110	55	100T	46	108T
51	110	60	99T	47	114P
56	113	65	98T	48	112B
61	113	70	102T	50	110T
66	190	75	102T	52	109P
71	111	80	105T	55	113B
76	110	90	105T	57	118T
81	112			58	111P
				61	117B
				62	108T
				63	109P
				65	112B
				67	105T
				68	106P
				70	108B
				71	107T
				72	109P
				75	135B
				77	103T
				78	106P
				80	106B
				82	101T
				83	104P

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 9
Date: 04-10-81

Starting time: 0825
Tow name: Conti Afton(W)
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 5.9 mph

Starting time: 0825
Tow name: Gordon Jones(E)
No. of barges: 13
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 5.0 mph

Station A
Water temp.: 14 C
Water depth: ----

Time (minutes elapsed)	Suspended sediment conc. (ppm)
6	150
8	132
10	130
12	152
14	209
16	130
18	129
20	135
22	135
24	178
26	154
28	130
30	146
35	334
40	139
45	144
50	130
55	128
60	153
70	204
80	131
90	128

Station B
Water temp.: 15 C
Water depth: 27 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
12	115T
14	118T
16	116T
18	112T
20	112T
22	112T
24	112T
26	109T
28	110T
30	110T
35	107T
40	109T
45	114T
50	107T
55	115T
60	115T
70	123T
80	114T
90	109T

Station C
Water temp.: 15 C
Water depth: 30 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
9	113B
10	105T
12	102P
13	106B
14	104T
15	101P
16	109B
17	97T
18	99P
19	119B
20	110T
21	102P
22	106B
23	102T
24	99P
25	116B
26	107T
27	108P
28	107B
29	104T
30	104P
35	141B
36	105T
37	105P
40	113B
41	105T
42	105P
45	116B
46	101T
47	105P
50	113B

(Continued)

Station A Water temp.: 14 C Water depth: ----		Station B Water temp.: 15 C Water depth: 27 ft		Station C Water temp.: 15 C Water depth: 30 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
				51	116T
				52	106P
				55	112B
				56	106T
				57	103P
				60	116B
				61	153T
				62	156P
				70	115B
				72	110T
				73	104P
				80	111B
				81	113T
				82	105P
				90	114B
				91	HOT
				92	106P

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 10
Date: 04-10-81

Starting time: 1118
Tow name: Mr. Joey
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.0 mph

Station A Water temp.: 15 C Water depth: 11 ft		Station B Water temp.: 16 C Water depth: 27 ft		Station C Water temp.: 16 C Water depth: 35 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	138	4	120T	6	108B
4	132	6	123T	8	109T
6	141	8	120T	9	113P
8	115	10	121T	21	122B
10	133	12	120T	22	111T
12	140	14	119T	23	111P
14	136	16	162T	24	112B
16	138	18	121T	25	99T
18	140	20	120T	26	105P
20	137	22	122T	27	106B
22	133	24	125T	28	102T
24	133	26	122T	29	103P
26	134	28	129T	31	100B
28	134	30	132T	32	59T
30	134	35	129T	33	103P
35	134	40	126T	46	103B
40	133	45	126T	47	103T
45	130	50	121T	48	110P
50	123	55	119T	49	113B
55	128	60	129T	50	105T
60	126	70	119T	51	110P
70	127	80	117T	53	105B
80	127	90	132T	54	108T
90	124			55	106P
				70	106B
				71	104T
				72	107P
				80	102B
				81	99T
				82	108P
				90	107B
				91	105T
				92	105P

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 1
Date: 05-20-81

Starting time: 1258
Tow name: Colonel George Lambert
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.9 mph

Station A Water temp.: 14 C Water depth: 13 ft		Station B Water temp.: ---- Water depth: 35 ft		Station C Water temp.: ---- Water depth: 35 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
6	299	8	497B	9	575P
8	336	8	463T	11	584B
2	261	10	493B	6	590B
4	259	10	472T	7	591T
10	312	14	485T	12	611T
12	348	14	510B	13	570P
14	343	16	496T	14	576B
16	408	16	488B	15	599T
18	362	18	492B	16	562P
20	318	18	485T	19	583B
22	284	20	483T	20	587T
24	302	20	506B	22	569P

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 2
Date: 05-20-81

Starting time: 1325
Tow name: Joanne
No. of barges: 4
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 10.0 mph

Station A		Station B		Station C	
Water temp.: 14 C		Water temp.: ----		Water temp.: ----	
Water depth: 10 ft		Water depth: 30 ft		Water depth: 30 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	326	6	455B	6	626T
4	298	6	448T	6	666B
6	319	8	486T	8	591P
8	366	8	465B	9	627B
10	369	10	473B	10	664T
12	357	10	430T	11	624P
14	337	13	435T	12	659B
16	407	14	444B	13	659T
18	344	15	491T	14	684P
20	375	16	498B	15	632B
22	358	17	473T	16	639T
24	294	18	487B	17	610P
26	296	19	470T	18	604B
28	358	20	459B	19	648T
30	380	21	466T	20	588P
40	389	22	480B	22	612B
45	365	23	476T	23	646T
50	327	24	477B	25	620P
55	304	25	466T	27	675B
60	337	26	450B	28	641T
70	313	27	482T	29	649P
80	304	30	467B	35	571B
90	331	31	495T	37	622T
		35	480B	38	577P
		36	475T	40	608B
		40	480B	41	624T
		41	448T	42	624P
		45	260B	45	613B
		46	447T	47	604T
		50	482	48	602P
		55	448B	51	618B
		56	243T	54	620T
				54	597P

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 3
Date: 05-21-81

Starting time: 0850
Tow name: Sally Barton
No. of barges: 9
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 5.8 mph

Starting time: 0854
Tow name: Kathy Ellen
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.5 mph

Starting time: 0908
Tow name: Marvin E. Norman
No. of barges: 9
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 0.9 mph

Station A
Water temp.: 14 C
Water depth: 09 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
4	279
6	291
8	252
10	267
12	275
14	270
16	271
18	256
20	286
22	284
24	276
26	288
28	260
32	279
34	264
36	275
38	283
40	268
42	287
44	252
46	235
48	233
53	254
58	232
63	232
68	247
73	282
78	195
88	332
98	242
108	253

Station B
Water temp.: 13 C
Water depth: 33 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
10	399B
12	388T
26	399B
27	376T
37	378B
38	377T
39	375B
40	372T
41	362B
42	398T
43	378B
44	360T
45	376B
46	361T
47	371B
48	358T
53	375B
54	368T
58	379B
59	368T
73	359B
74	374T
78	364B
79	380T
88	363B
89	374T
108	369B
109	361T

Station C
Water temp.: ----
Water depth: 30 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
9	503B
10	540T
11	445P
24	420B
30	433P
30	454T
43	447B
44	453T
45	443P
47	421B
48	441T
49	432P
73	459B
75	459T
76	418P
77	439
78	426P
94	444
97	422P
98	423
99	440P
108	485
111	419P

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 4
Date: 05-21-81

Starting time: 1055
Tow name: Frederick B. Wells
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.9 mph

Station A Water temp.: 15 C Water depth: 11 ft		Station B Water temp.: ---- Water depth: 33 ft		Station C Water temp.: ---- Water depth: 32 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
4	279	7	409B	7	3993
6	297	7	386T	8	414T
8	301	11	362T	9	419P
10	309	11	365B	10	419B
12	289	13	381T	11	482T
14	276	13	366B	15	417P
16	301	15	369B	16	405B
18	284	15	388T	17	431T
20	288	23	365T	18	419P
22	304	23	385B	21	402B
24	299	25	362B	22	421T
26	271	25	390T	23	409P
28	313	27	383T	24	404B
30	297	27	399B	25	454T
35	314	29	389T	26	410P
40	309	29	380B	27	392B
45	291	35	388T	28	425T
50	315	35	560B	29	410P
55	296	50	388T	32	407
60	329	50	381B	34	425P
70	297	55	382T	36	405
80	307	55	366B	37	409P
90	300	60	397T	40	386
		60	371B	41	402P
		70	427T	45	393
		70	373B	46	410P
		80	372B	50	401
		80	381T	51	405P
		90	381T	55	387
		90	383B	56	410P
				60	455
				61	407P
				70	400
				71	406P
				80	400
				81	414P
				90	397
				91	415P

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 5
Date: 05-21-81

Starting time: 1511
Tow name: Sierra Dawn
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 3.2 mph

Station A
Water temp.: 15 C
Water depth: 10 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	322
6	317
8	312
10	329
12	299
14	323
16	304
18	266
20	316
22	325
24	332
26	348
28	316
30	302
32	344
34	260
36	340
38	350

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 6
Date: 05-21-81

Starting time: 1555
Tow name: Atlas
No. of barges: 6
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 7.7 mph

Station A
Water temp.: 15 C
Water depth: 10 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	551
8	388
10	370
12	370
14	374
16	327
18	366
20	374
22	367
24	366
26	369
28	364
30	381
35	366
40	348
45	370
50	334
55	374
60	366
70	344
80	389
90	381

Station B
Water temp.: ----
Water depth: 22 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
5	342
14	350
22	363
40	354
45	360
50	360
55	334
60	375
70	372
80	368
90	381

Station C
Water temp.: ----
Water depth: 24 ft

Time (minutes elapsed)	Suspended sediment conc. (ppm)
4	496
5	491P
6	508
7	486P
9	514
12	503P
13	489
14	483P
16	481
17	453P
18	485
19	507P
20	550
21	552P
22	534
23	558P
24	517
25	491P
28	510
29	529P
30	635
31	517P
38	560
41	520P
47	485
48	474P
50	510
53	503P
55	499
56	499P
61	516
63	517P
71	537
75	538P
80	539
85	545P
90	597
92	603P

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 7
Date: 05-22-81

Starting time: 0915
Tow name: New Dawn
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.2 mph

Station A		Station B		Station C	
Water temp.: 16 C		Water temp.: ----		Water temp.: ----	
Water depth: 12 ft		Water depth: 28 ft		Water depth: 28 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
6	534	8	385	6	451T
8	429	10	380	8	464T
10	448	14	321	10	452T
12	479	16	479	12	462T
14	477	20	391	14	467T
18	412	22	381	16	504T
20	425	24	379	18	436T
22	428	26	361	20	439T
24	433	28	386	22	463T
26	412	30	377	24	489T
28	410	34	380	26	461T
30	413	36	386	28	456T
35	415			30	444T
				35	466T

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 8
Date: 05-22-81

Starting time: 1215
Tow name: Nohab Express
No. of barges: 3
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 6.7 mph

Station A Water temp.: 16 C Water depth: 15 ft		Station B Water temp.: ---- Water depth: 28 ft		Station C Water temp.: ---- Water depth: 22 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	441	8	365	5	525T
4	380	10	369	6	513T
6	402	12	525	8	497T
8	390	14	385	10	497T
10	393	16	390	12	510T
12	399	18	382B	14	502T
14	382	19	387T	16	494T
16	444	20	365B	18	490T
18	424	21	450T	20	495T
20	486	22	355B	22	501T
22	482	28	373B	24	508T
24	436	29	374T	26	496T
26	412	30	373B	28	484T
28	415	31	375T	30	501T
30	403	35	373B	35	486T
35	402	36	378T	40	485T
40	421	40	360B	45	497T
45	419	41	375T	50	490T
50	416	45	363B	55	491T
55	397	46	367T	60	497T
60	403	50	370B	70	495T
70	367	55	386B	80	491T
80	387	62	363T	90	479T
90	398	70	371B		
		71	388T		
		80	376B		
		81	379T		
		90	366B		
		91	378T		

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 9
Date: 05-22-81

Starting time: 1730
Tow name: White Knight
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.1 mph

Starting time: 1741
Tow name: Colonel George Lambert
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 6.3 mph

Station A		Station B		Station C	
Water temp.: 17 C		Water temp.: ----		Water temp.: ----	
Water depth: 10 ft		Water depth: 28 ft		Water depth: 24 ft	
Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)	Time (minutes elapsed)	Suspended sediment conc. (ppm)
2	363	19	320B	16	390T
4	382	20	336T	18	392T
6	378	56	339T	20	402T
8	405	61	345T	22	407T
10	403			24	399T
12	449			26	399T
14	453			28	386T
16	442			30	394T
18	429			32	406T
20	549			34	396T
22	403			36	386T
24	440			38	391T
26	417			40	379T
28	500			42	387T
30	446			44	395T
32	515			46	386T
34	423			50	377T
36	411			55	383T
38	406			60	387T
40	401				
42	411				
47	393				
52	390				
57	394				
62	379				

APPENDIX C

BACKGROUND SUSPENDED SEDIMENT CONCENTRATION DATA

Site: Hadley's Landing
River mile 13.2
Trip no. 2

Station A			Station B			Station C		
Date	Time	Suspended sediment Conc.(ppm)	Date	Time	Suspended sediment Conc.(ppm)	Date	Time	Suspended sediment Conc.(ppm)
07-23-80	1100	114	07-23-80	1100	74	07-23-80	1100	63
07-23-80	1130	59	07-23-80	1130	66	07-23-80	1130	57
07-23-80	1200	60	07-23-80	1200	61	07-23-80	1200	54
07-23-80	1230	59	07-23-80	1230	67	07-23-80	1230	64
07-23-80	1300	69	07-23-80	1300	61	07-23-80	1300	54
07-23-80	1330	67	07-23-80	1330	52	07-23-80	1330	54
07-23-80	1400	58	07-23-80	1400	52	07-23-80	1400	51
07-23-80	1430	53	07-23-80	1430	54	07-23-80	1430	49
07-23-80	1500	70	07-23-80	1500	58	07-23-80	1500	50
07-24-80	0930	79	07-24-80	0930	82	07-24-80	0930	88
07-24-80	1000	96	07-24-80	1000	71	07-24-80	1000	88
07-24-80	1400	56	07-24-80	1400	63	07-24-80	1400	78
07-24-80	1430	98	07-24-80	1430	66	07-24-80	1430	71
07-24-80	1500	59	07-24-80	1500	60	07-24-80	1500	71
07-24-80	1530	66	07-24-80	1530	56	07-24-80	1530	68
07-24-80	1600	96	07-24-80	1600	58	07-24-80	1600	67
07-24-80	1630	26	07-24-80	1630	55	07-24-80	1630	64
07-24-80	1700	60	07-24-80	1700	56	07-24-80	1700	64

Site: Hadley's Landing
River mile 13.2
Trip no. 3

Station A			Station B			Station C		
Date	Time	Suspended sediment Conc.(ppm)	Date	Time	Suspended sediment Conc.(ppm)	Date	Time	Suspended sediment Cono.(ppm)
09-23-80	1430	230	09-23-80	1200	331	09-23-80	1700	425
09-23-80	1700	262	09-23-80	1430	307	09-24-80	0930	340
09-24-80	0930	211	09-23-80	1700	385	09-24-80	1000	347
09-24-80	1000	204	09-24-80	0930	287	09-24-80	1030	350
09-24-80	1030	190	09-24-80	1000	264	09-24-80	1100	201
09-24-80	1100	191	09-24-80	1030	246	09-24-80	1130	303
09-24-80	1130	197	09-24-80	1100	249	09-24-80	1200	328
09-24-80	1200	196	09-24-80	1130	267	09-24-80	1300	302
09-24-80	1300	178	09-24-80	1200	257	09-24-80	1530	344
09-24-80	1530	163	09-24-80	1300	260	09-24-80	1600	341
09-24-80	1600	179	09-24-80	1530	249	09-25-80	1000	373
09-25-80	1000	200	09-24-80	1600	286	09-25-80	1700	405
09-25-80	1702	181	09-25-80	1000	298	09-25-80	1730	351
09-25-80	1740	184	09-25-80	1700	291	09-26-80	0830	394
09-26-80	0830	207	09-25-80	1730	247	09-26-80	0900	325
09-26-80	0900	205	09-26-80	0830	276	09-26-80	0930	308
09-26-80	0930	191	09-26-80	0900	234			
			09-26-80	0930	252			

Site: Riprap Landing
River mile 265.1
Trip no. 4

Station A Date	Station A Time	Station A Suspended sediment Conc.(ppm)	Station B Date	Station B Time	Station B Suspended sediment Conc.(ppm)	Station C Date	Station C Time	Station C Suspended sediment Conc.(ppm)
04-08-81	1400	124	04-08-81	1400	118B	04-08-81	1445	117T
04-08-81	1415	124	04-08-81	1400	116T	04-08-81	1445	126P
04-08-81	1505	122	04-08-81	1500	114T	04-08-81	1445	122B
04-08-81	1517	120	04-08-81	1500	120B	04-08-81	1520	135P
04-08-81	1611	119	04-09-81	1540	108T	04-08-81	1520	123B
04-08-81	1621	121	04-10-81	0815	116T	04-08-81	152,0	119T
04-09-81	1530	110	04-10-81	1100	118T	04-08-81	1600	121B
04-09-81	1530	115	04-10-81	1400	116T	04-08-81	1615	117T
04-10-81	1100	135	04-10-81	1500	113T	04-08-81	1619	116P
04-10-81	1400	124	04-10-81	1700	119T	04-08-81	1633	122B
04-10-81	1500	128				04-08-81	1635	118T
04-10-81	1700	53				04-08-81	1639	124P
04-10-81	1710	126				04-09-81	1539	107T
						04-09-81	1539	116P
						04-09-81	1539	113B
						04-10-81	0811	112B
						04-10-81	0811	99P
						04-10-81	0811	108T
						04-10-81	1107	104B
						04-10-81	1108	140T
						04-10-81	1109	108P
						04-10-81	1409	213B
						04-10-81	1411	109T
						04-10-81	1414	111P
						04-10-81	1438	107B
						04-10-81	1440	108T
						04-10-81	1441	106P
						04-10-81	1500	108B
						04-10-81	1501	111T
						04-10-81	1502	115P
						04-10-81	1655	112B
						04-10-81	1657	117T
						04-10-81	1658	133P

NOTE: The letter B,T,or P follows some suspended sediment concentrations.
B indicates a depth-integrated sample of the bottom half of the water column
T indicates a depth-integrated sample of the top half of the water column
P indicates a point-integrated sample at a specific depth
All others are depth-integrated samples of the entire water column

Site: Mosier Landing
River mile 260.2
Trip no. 5

Station A

Date	Time	Suspended sediment Conc.(ppm)
05-20-81	1250	286
05-20-81	1540	288
05-20-81	1630	450
05-20-81	1730	1256
05-20-81	1830	360
05-21-81	1400	302
05-22-81	1430	392
05-22-81	1530	364
05-22-81	1630	398

Station B

Date	Time	Suspended sediment Conc.(ppm)
05-20-81	1245	414B
05-20-81	1246	448T
05-20-81	1530	487B
05-20-81	1530	477T
05-20-81	1530	477P
05-20-81	1630	467P
05-20-81	1630	461B
05-20-81	1630	427T
05-20-81	1730	476T
05-20-81	1730	485B
05-20-81	1730	516P
05-20-81	1830	457B
05-20-81	1830	515P
05-20-81	1830	482T
05-21-81	1400	346P
05-21-81	1400	368P
05-21-81	1400	340T
05-21-81	1400	350B
05-21-81	1400	342P
05-21-81	1400	359P
05-21-81	1400	349P
05-21-81	1400	343P
05-21-81	1500	352T
05-21-81	1500	340P
05-21-81	1500	342B
05-22-81	0900	482P
05-22-81	0900	382
05-22-81	1200	363
05-22-81	1200	335
05-22-81	1430	368P
05-22-81	1430	374P
05-22-81	1430	352B
05-22-81	1430	38OP
05-22-81	1430	367P
05-22-81	1430	363P
05-22-81	1430	370P
05-22-81	1430	367P
05-22-81	1430	369T
05-22-81	1630	382T
05-22-81	1630	375P
05-22-81	1630	375B

Station C

Date	Time	Suspended sediment Conc.(ppm)
05-20-81	1230	627B
05-20-81	1230	647T
05-20-81	1230	656P
05-20-81	1530	627T
05-20-81	1530	527P
05-20-81	1530	572B
05-20-81	1630	635T
05-20-81	1630	539B
05-20-81	1630	567P
05-20-81	1730	586B
05-20-81	1730	611T
05-20-81	1730	605P
05-20-81	1830	578B
05-20-81	1830	576T
05-20-81	1830	579P
05-21-81	1400	496
05-21-81	1415	467P
05-21-81	1417	483P
05-21-81	1420	466P
05-21-81	1421	494P
05-21-81	1422	489P
05-21-81	1425	479P
05-21-81	1430	504P
05-21-81	1500	409P
05-21-81	1500	516
05-22-81	0900	510T
05-22-81	1200	426T
05-22-81	1430	460T
05-22-81	1530	434T
05-22-81	1630	409T

APPENDIX D

WATER VELOCITIES DURING TOW PASSAGE EVENTS

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 1
Date: 04-08-81

Starting time: 0947
Tow name: Atlas
No. of barges: 9
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 3.9 mph

Station A		Station B		Station C	
Total depth: 2.15 m		Total depth: 8.40 m		Total depth: 10.30 m	
Sampling depth: 2.04 m		Sampling depth: 7.95 m		Sampling depth: 9.73 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
3:00	1.79	10:30	1.86	10:00	2.01
3:30	2.16	11:00	2.45	10:30	1.93
4:30	1.64	11:30	2.23	11:00	1.86
5:00	1.64	12:00	2.23	11:30	1.79
5:30	1.71	12:30	2.23	12:00	2.16
6:00	1.93	13:00	2.45	12:30	2.16
6:30	1.79	13:30	2.16	13:00	1.86
7:00	1.71	14:00	2.16	13:30	1.64
7:30	1.86	14:30	2.38	14:00	1.86
8:00	1.64	15:00	2.08	14:30	1.56
8:30	2.16	15:30	2.45	15:00	1.86
9:00	1.93	16:00	2.45	26:00	2.23
9:30	2.01	16:30	2.30	27:30	2.42
10:00	2.16	17:00	2.30	30:30	2.12
10:30	1.86	17:30	2.38	35:00	2.07
11:00	2.16	18:00	2.45	40:00	2.23
11:30	1.79	18:30	2.52	45:00	2.12
12:00	2.16	19:00	2.23		
12:30	2.08	19:30	2.08		
13:00	1.93	20:00	2.52		
13:30	1.34	20:30	2.89		
14:00	1.82	21:00	2.45		
16:00	1.79	21:30	2.60		
18:00	2.03	31:00	2.37		
20:00	1.94	36:00	2.32		
22:00	2.07	41:00	2.47		
24:00	2.03	46:00	2.78		
26:00	2.17				
28:00	1.98				
30:00	1.86				
35:00	1.94				
40:00	1.94				
45:00	1.79				
50:00	2.03				

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 2
Date: 04-08-81

Starting time: 1044
Tow name: Prairie Dawn
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 7.0 mph

Station A Total depth: 2.15 m Sampling depth: 1.80 m		Station B Total depth: 8.00 m Sampling depth: 6.40 m		Station C Total depth: 10.40 m Sampling depth: 8.33 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
-2:30	2.16	9:00	2.52	12:26	2.52
-1:00	2.01	9:30	2.97	12:56	2.82
-0:30	2.52	10:00	2.67	13:26	2.75
0:00	2.23	10:30	2.97	13:56	2.75
0:30	2.23	11:00	2.89	14:26	2.60
1:00	2.16	11:30	2.75	14:56	2.45
1:30	2.16	12:00	2.67	15:26	2.60
2:00	2.08	12:30	2.82	15:56	2.75
2:30	1.49	13:00	2.67	16:26	2.75
3:00	2.08	13:30	2.67	16:56	2.75
3:30	2.23	14:00	2.52	17:26	2.67
4:00	1.86	14:30	2.89	17:56	2.52
4:30	2.08	15:00	2.89	18:26	2.67
5:00	2.16	15:30	2.60	18:56	2.67
5:30	2.01	16:00	2.75	19:26	2.67
6:00	2.01	16:30	2.82	19:56	2.60
6:30	2.16	17:00	2.89	20:26	2.60
7:00	2.08	17:30	2.89	20:56	2.60
7:30	2.01	18:00	2.82	21:26	2.52
8:00	2.23	18:30	2.82	21:56	2.45
8:30	2.01	19:00	2.67	22:26	2.75
9:00	2.23	21:00	2.89	22:56	2.67
9:30	2.23	23:00	2.75	23:26	2.45
12:00	2.07	25:00	2.89	23:56	2.75
14:00	1.98	27:00	2.75	28:00	2.47
16:00	2.07	29:00	2.97	32:30	2.78
18:00	2.27	31:00	2.85	36:00	2.47
20:00	2.32	33:00	2.73	40:00	2.59
22:00	2.23	35:00	2.73	45:00	2.84
24:00	1.98	50:00	2.78	50:00	2.59
26:00	2.07	55:00	2.67	55:00	2.73
28:00	2.07	60:00	2.84,	60:00	2.59
30:00	2.03	70:00	2.73	70:00	2.84
35:00	2.12	80:00	.2.78	80:00	2.47
40:00	2.23	90:00	2.67		
45:00	2.12				
50:00	2.07				
55:00	1.98				

(Continued)

Station A		Station B		Station C	
Total depth: 2.15 m		Total depth: 8.00 m		Total depth: 10.40 m	
Sampling depth: 1.80 m		Sampling depth: 6.40 m		Sampling depth: 8.33 m	
Time (min:3ec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
60:00	2.03				
70:00	2.17				
80:00	2.27				
90:00	2.17				

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 3
Date: 04-09-81

Starting time: 0823
Tow name: Lillian Clark
No. of barges: 16
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 7.9 mph

Station A
Total depth: 1.83 m
Sampling depth: 1.10 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
10:30	2.23
11:00	2.23
11:30	2.30
12:00	2.52
12:30	2.30
13:00	2.45
13:30	2.60
14:00	2.60
14:30	2.67
15:00	2.23
15:30	2.60
16:00	2.30
16:30	2.60
18:00	2.38
18:30	2.38
19:00	2.67
19:30	2.60
20:00	2.52
20:30	2.52
21:00	2.38
21:30	2.60
22:00	2.65
24:00	2.65
26:00	2.59
28:00	2.37
30:00	2.65
32:00	2.47
35:00	2.53
40:00	2.42
45:00	2.23
50:00	2.47
55:00	2.59
60:00	2.53
70:00	2.65
80:00	2.53
90:00	2.47

Station B
Total depth: 7.91 m
Sampling depth: 4.75 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
6:30	3.34
7:00	3.11
7:30	3.41
8:00	3.34
8:30	3.19
9:00	3.34
9:30	2.97
10:00	2.89
10:30	2.60
11:00	2.52
11:30	2.75
12:00	2.60
12:30	2.75
13:00	2.16
20:00	3.46
22:00	3.34
24:00	3.10
26:00	3.10
28:00	3.03
30:00	3.46
35:00	3.25
40:00	3.25
45:00	3.10
50:00	2.84
55:00	3.18
60:00	3.18
70:00	3.10
80:00	3.25
90:00	3.34

Station C
Total depth: 10.50 m
Sampling depth: 6.30 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
12:30	3.19
13:00	3.41
13:30	3.26
14:00	2.97
14:30	2.89
15:00	2.82
15:30	3.26
16:00	3.04
16:30	2.97
17:00	2.60
17:30	2.97
18:00	3.26
18:30	2.82
19:00	3.19
20:00	2.89
20:30	3.26
21:00	3.26
21:30	3.11
22:00	3.11
22:30	3.19
23:00	3.19
30:30	3.03
34:00	3.25
40:00	3.25
50:30	2.84
53:00	3.25
55:00	3.03
63:00	3.18
72:00	3.10
81:00	2.97
91:10	2.90

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 4
Date: 04-09-81

Starting time: 1005
Tow name: Arthur E. Snider
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.1 mph

Station A
Total depth: 4.44 m
Sampling depth: 0.89 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
4:30	2.82
5:00	2.60
5:30	2.38
6:00	2.45
6:30	2.60
7:00	2.67
7:30	2.67
8:00	2.67
8:30	2.89
9:00	2.67
9:30	2.89
10:00	2.67
10:30	2.82
11:00	2.67
11:30	2.52
12:00	2.82
12:30	2.67
13:00	2.60
13:30	2.60
14:00	2.75
14:30	2.60
16:00	2.84
18:00	2.84
20:00	2.59
22:00	2.71
24:00	2.65
26:00	2.78
28:00	2.71
40:00	2.59
45:00	2.71
50:00	2.71
55:00	2.71
60:55	2.59
70:00	2.78

Station B
Total depth: 8.00 m
Sampling depth: 1.60 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
9:00	3.34
9:30	3.48
10:00	3.41
10:30	3.70
11:00	3.70
11:30	3.78
12:00	3.56
12:30	3.70
13:00	3.41
13:30	3.56
14:00	3.48
14:30	3.41
15:00	3.48
15:30	3.41
16:00	3.56
16:30	3.48
17:00	3.41
17:30	3.48
18:00	3.56
18:30	3.41
19:00	3.63
20:00	3.51
22:00	3.51
24:00	3.51
26:00	3.54
28:00	3.46
30:00	3.38
35:00	3.54
40:00	3.54
45:00	3.46
50:00	3.46
55:00	3.54
60:00	3.54

Station C
Total depth: 10.50 m
Sampling depth: 2.10 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
12:00	3.41
12:30	3.93
13:00	3.93
14:30	3.63
15:30	3.56
16:00	3.63
17:00	3.78
17:30	3.70
18:00	3.48
18:30	3.70
19:00	3.85
19:30	3.78
20:00	3.93
20:30	3.85
21:00	3.56
21:30	3.85
22:00	3.63
22:30	3.70
24:00	3.56
26:00	3.63
28:00	3.56
31:00	3.63
35:00	3.70
41:00	3.78
45:00	3.70
50:30	3.78
56:00	3.70
62:00	3.70

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 5
Date: 04-09-81

Starting time: 1129
Tow name: Rose Marie Walden
No. of barges: 9
Draft: 8 ft
Traffic direction: Downstream
Tow speed: ----

Station A
Total depth: 4.44 m
Sampling depth: 4.22 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
-3:30	1.71
-3:00	1.56
-2:30	1.79
-2:00	1.79
-1:30	1.71
-1:00	1.71
-0:30	1.56
0:00	1.79
0:30	1.49
1:00	1.64
1:30	1.71
2:00	1.71
2:30	1.71
3:00	1.64
3:30	1.71
4:00	1.64
4:30	1.64
5:00	1.49
5:30	1.49
6:00	1.71
6:30	1.71
7:00	1.71
7:30	1.71
8:00	1.56
8:30	1.71
9:00	1.71
9:30	1.79
10:00	1.56
12:00	1.75
14:00	1.63
16:00	1.82
18:00	1.79
20:00	1.63
22:00	1.75
24:00	1.63
26:00	1.79
28:00	1.86
30:00	1.56

Station B
Total depth: 8.30 m
Sampling depth: 7.89 m

Time (min:see elapsed)	Water Velocity (ft/sec)
16:00	2.23
16:30	1.93
17:00	1.79
17:30	1.71
18:00	2.23
18:30	2.30
19:00	1.64
19:30	1.79
20:00	1.93
20:30	2.08
21:00	1.71
21:30	2.23
22:00	1.56
22:30	2.30
23:00	2.75
23:30	2.30
24:00	1.86
24:30	2.01
25:00	2.08
25:30	2.30
26:00	2.16
28:00	2.10
30:00	2.06
35:00	2.14
40:00	1.92
45:00	2.10
50:00	2.03
55:00	2.10
60:00	2.14
70:00	2.19
80:00	2.14

Station C
Total depth: 9.92 m
Sampling depth: 9.42 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
8:30	2.45
9:00	1.56
9:30	1.93
10:00	2.16
10:30	2.30
11:00	2.60
11:30	2.67
12:00	2.67
12:30	2.16
13:00	2.23
13:30	2.08
14:00	2.97
14:30	2.30
15:00	2.38
15:30	2.23
16:00	2.30
16:30	2.16
17:00	2.30
17:30	2.52
18:00	2.23
18:30	2.60
20:30	2.23
25:30	2.42
29:00	2.17
35:00	2.37
40:00	2.42
45:00	2.32
50:00	2.32
55:00	2.32
60:00	2.12
70:00	2.65
79:00	2.10

(Continued)

Station A		Station B		Station C	
Total depth: 4.44 m		Total depth: 8.30 m		Total depth: 9.92 m	
Sampling depth: 4.22 m		Sampling depth: 7.89 m		Sampling depth: 9.42 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	. Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
35:00	1.68				
40:00	1.46				
45:00	1.75				
50:00	1.82				
55:00	1.68				
60:00	1.75				
70:00	1.63				
80:00	1.75				
90:00	1.63				

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 6
Date: 04-09-81

Starting time: 1300
Tow name: White Dawn
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.7 mph

Station A
Total depth: 4.44 m
Sampling depth: 3.66 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
2:00	2.01
2:30	1.93
3:00	1.79
3:30	1.86
4:00	2.16
4:30	2.16
5:00	2.16
5:30	1.56
6:00	1.86
6:30	1.86
7:00	1.79
7:30	1.93
8:00	2.01
8:30	1.93
9:00	1.71
9:30	1.86
10:00	2.16
12:00	1.86
14:00	1.98
16:00	1.98
18:00	1.82
20:00	1.98
22:00	1.86
24:00	1.90
26:00	1.86
28:00	1.94
30:00	1.63
35:00	1.98
40:00	1.90
50:00	1.98
55:00	1.94
60:00	2.07
70:00	1.98
80:00	2.07
90:00	1.86

Station B
Total depth: 8.45 m
Sampling depth: 6.77 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
8:30	3.04
9:00	3.04
9:30	3.04
10:00	2.97
10:30	2.97
11:00	3.34
11:30	2.97
12:00	2.82
12:30	2.89
13:00	2.75
13:30	3.11
14:00	3.26
14:30	2.45
15:00	2.89
15:30	2.89
16:00	2.89
16:30	2.38
17:00	2.89
17:30	2.75
18:00	3.19
18:30	3.11
19:00	3.04
19:30	2.97
20:00	3.19
20:30	2.67
21:00	2.97
24:00	2.78
26:00	3.25
28:00	3.03
30:00	3.03
35:00	2.78
40:00	3.03
45:00	2.97
50:00	2.84
55:00	2.67
60:00	3.10

Station C
Total depth: 10.03 m
Sampling depth: 8.00 m

Time (min:3ec elapsed)	Water Velocity (ft/sec)
10:00	2.89
10:30	2.82
11:00	2.60
11:30	2.97
12:00	2.67
12:30	2.97
13:00	2.45
13:30	3.11
14:00	3.11
14:30	2.67
15:00	2.82
15:30	2.60
16:00	2.82
16:30	2.60
17:00	2.82
17:30	2.75
18:00	2.82
18:30	2.45
19:00	2.23
19:30	2.82
20:00	2.89
24:00	2.78
28:00	2.78
35:00	2.97
41:00	2.65
47:30	2.84
50:30	2.65
55:00	2.65
60:00	2.97
70:00	2.37

(Continued)

Station A		Station B		Station C	
Total depth: 4.44 m		Total depth: 8.45 m		Total depth: 10.03 m	
Sampling depth: 3.66 m		Sampling depth: 6.77 m		Sampling depth: 8.00 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
		70:00	2.67		
		80:00	2.97		
		90:00	2.67		

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 7
Date: 04-09-81

Starting time: 1602
Tow name: Robin Mott
No. of barges: 14
Draft: 2 ft
Traffic direction: Upstream
Tow speed: ----

Station A
Total depth: 4.12 m
Sampling depth: 2.47 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
-2:30	2.52
-2:00	2.52
-1:30	2.23
-1:00	2.23
-0:30	2.38
0:00	2.23
0:30	2.52
1:00	2.45
1:30	2.60
2:00	2.38
2:30	2.67
3:00	2.30
3:30	2.23
4:00	2.30
4:30	2.16
5:00	2.16
5:30	2.38
6:00	2.23
6:30	2.45
7:00	2.23
7:30	2.30
8:00	2.08
8:30	2.23
9:00	2.01
9:30	2.23
10:00	1.93
12:00	2.53
14:00	2.12
16:00	2.06

Station B
Total depth: 8.20 m
Sampling depth: 1.86 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
6:30	3.63
7:00	3.63
7:30	3.63
8:00	3.48
8:30	3.41
9:00	3.48
9:30	3.34
10:00	3.48

Sampling depth: 4.91 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
12:30	3.26
13:00	3.19
13:30	3.41
14:00	3.15
15:00	2.97
15:30	3.11
16:00	3.19

Station C
Total depth: 10.55 m
Sampling depth: 6.96 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
11:00	2.75
11:30	2.89
12:30	3.11
13:30	3.19
14:00	3.00
15:00	2.97

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 8
Date: 04-09-81

Starting time: 1623
Tow name: Hawkeye
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.1 mph

Station A
Total depth: 4.12 m
Sampling depth: 2.47 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
23:00	2.01
23:30	1.93
24:00	2.30
24:30	2.38
25:00	2.16
25:30	2.16
26:00	2.38
26:30	2.16
27:00	2.45
27:30	2.30
28:00	2.38
28:30	2.23
29:00	1.93
29:30	2.08
30:00	2.16
30:30	2.01
31:00	2.23
31:30	2.23
32:00	2.23
32:30	2.16
33:00	2.16
33:30	1.86
34:00	2.30
34:30	2.01
35:00	2.30
35:30	2.08
36:00	2.16
36:30	2.08
39:00	2.23
41:00	2.23
43:00	2.42
45:00	2.23
47:00	2.07
49:00	2.14
51:00	2.17
56:00	2.06
61:00	2.37
66:00	2.03

Station B
Total depth: 7.90 m
Sampling depth: 4.74 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
29:00	3.56
29:30	3.19
30:00	3.11
30:30	3.19
31:00	3.11
31:30	3.26
32:00	3.19
32:30	3.19
33:00	3.19
33:30	3.26
34:30	3.41
35:00	2.97
35:30	3.04
36:00	3.11
36:30	3.41
37:00	3.41
37:30	3.11
38:00	2.97
38:30	3.04
39:00	3.34
39:30	3.56
40:00	3.04
40:30	2.97
41:00	3.04
41:30	3.04
44:00	3.38
46:00	3.25
48:00	3.03
50:00	2.97
55:00	3.18
60:00	3.03
69:00	3.31
70:00	3.25
75:00	3.38
80:00	2.97
90:00	3.34

Station C
Total depth: 10.55 m
Sampling depth: 6.96 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
29:30	2.89
30:00	3.04
30:30	3.04
31:30	3.26
32:00	2.82
32:30	3.04
33:00	3.34
33:30	2.82
34:00	3.11
34:30	2.97
35:30	3.19
36:00	3.04
36:30	3.04
37:00	2.82
37:30	3.11
38:00	3.11
38:30	2.82
42:30	2.90
46:30	2.97
52:00	3.10
57:30	2.78
63:00	2.71
68:00	3.10
72:00	3.34
77:30	3.03
83:00	2.97

(Continued)

Station A Total depth: 4.12 m Sampling depth: 2.47 m		Station B Total depth: 7.90 m Sampling depth: 4.74 m		Station C Total depth: 10.55 m Sampling depth: 6.96 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
71:00	2.37				
76:00	2.37				
81:00	2.12				

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 9
Date: 04-10-81

Starting time: 0825
Tow name: Conti Afton(W)
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 5.9 mph

Starting time: 0825
Tow name: Gordon Jones(E)
No. of barges: 13
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 5.0 mph

Station A
Total depth: 3.93 m
Sampling depth: 0.79 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
8:30	2.67
9:00	2.67
9:30	2.75
10:00	2.89
10:30	2.75
11:00	2.52
11:30	.2.67
12:00	2.38
12:30	2.67
13:00	2.67
13:30	2.60
14:00	2.82
14:30	2.67
15:00	2.67
15:30	2.82
16:00	2.67
16:30	2.67
17:00	2.75
17:30	2.75
18:00	2.45
18:30	2.82
19:00	2.67
20:00	2.73
22:00	2.71
24:00	2.47
26:00	2.71
28:00	2.42
30:00	2.71
35:00	2.71
40:00	2.84
45:00	2.53

Station B
Total depth: 9.30 m
Sampling depth: 1.86 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
21:30	3.70
22:00	3.63
22:30	3.48
23:00	3.56
23:30	3.56
24:00	3.41
24:30	3.48
25:00	3.48
25:30	3.93
26:00	3.70
26:30	3.41
27:00	3.26
27:30	3.70
28:00	3.63
28:30	3.70
29:00	3.70
29:30	3.70
30:00	3.48
35:00	3.79
40:00	3.79
45:00	3.70
50:00	3.70
55:00	3.34
60:00	3.62
70:00	3.62
80:00	3.25
90:00	3.70

Station C
Total depth: 9.11 m
Sampling depth: 1.82 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
12:00	3.85
12:30	4.07
13:00	3.85
13:30	4.00
14:00	4.07
14:30	3.78
15:00	3.78
15:30	3.93
16:00	3.93
16:30	3.85
17:00	4.07
17:30	3.85
18:00	3.93
18:30	3.93
19:00	3.78
19:30	3.78
20:00	3.85
20:30	3.70
21:00	3.85
21:30	3.78
22:00	3.78
22:30	3.78
25:00	3.70
29:00	3.87
35:00	3.78
40:00	3.87
45:00	3.95
50:00	3.78
55:00	3.70
60:00	3.78
70:00	3.87

(Continued)

Station A		Station B		Station C	
Total depth: 3.93 m		Total depth: 9.30 m		Total depth: 9.11 m	
Sampling depth: 0.79 m		Sampling depth: 1.86 m		Sampling depth: 1.82 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
50:00	2.84			80:00	3.78
55:00	2.78			90:00	3.70
60:00	2.71				
70:00	2.84				
80:00	2.78				
90:00	2.78				

Site: Riprap Landing
River mile 265.1
Trip no. 4
Event no: 10
Date: 04-10-81

Starting time: 1118
Tow name: Mr. Joey
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.0 mph

Station A Total depth: 4.63 m Sampling depth: 4.40 m		Station B Total depth: 8.80 m Sampling depth: 7.98 m		Station C Total depth: 10.80 m Sampling depth: 10.26 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
0:30	1.42	5:30	2.30	8:00	2.01
1:00	1.56	6:00	2.45	8:30	2.30
1:30	1.71	6:30	2.67	9:00	2.52
2:00	1.86	7:00	2.60	9:30	2.01
2:30	1.86	7:30	2.97	10:00	2.38
3:00	1.71	8:00	2.45	10:30	2.45
3:30	1.56	8:30	2.38	11:00	2.16
4:00	1.64	9:00	2.08	11:30	2.16
4:30	1.79	9:30	2.60	12:00	2.60
5:00	1.71	10:00	2.23	12:30	2.82
5:30	1.71	10:30	2.30	14:00	2.23
6:00	1.71	11:00	2.60	14:30	2.01
6:30	1.79	11:30	2.52	15:00	2.67
7:00	2.01	12:00	2.30	15:30	2.38
7:30	1.93	12:30	2.52	16:00	2.01
8:00	1.86	13:00	2.67	16:30	2.38
8:30	2.01	13:30	2.97	17:00	2.23
9:00	1.93	14:00	2.45	17:30	2.23
9:30	1.93	14:30	2.30	18:00	2.08
10:00	1.93	15:00	2.45	18:30	1.93
12:00	2.17	18:00	2.78	19:00	2.01
14:00	2.17	20:00	2.59	21:30	2.65
16:00	2.12	22:00	2.71	24:00	2.23
18:00	1.96	24:00	2.65	27:00	2.23
20:00	1.98	26:00	2.47	30:30	2.37
22:00	2.03	28:00	2.78	45:30	2.23
24:00	2.07	30:00	2.71	49:00	2.23
26:00	2.07	35:00	2.53	52:30	2.32
28:00	1.94	40:00	2.59	61:00	2.27
30:00	1.98	45:00	2.78	70:00	2.23
35:00	2.03	50:00	2.37	80:00	2.47
40:00	2.03	55:00	2.42	90:00	2.23
45:00	2.12	60:00	3.10		
50:00	1.98	70:00	2.65		
55:00	1.86	80:00	2.37		
60:00	1.90	90:00	2.47		

(Continued)

Station A		Station B		Station C	
Total depth: 4.63 m		Total depth: 8.80 m		Total depth: 10.80 m	
Sampling depth: 4.40 m		Sampling depth: 7.98 m		Sampling depth: 10.26 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
70:00	1.98				
80:00	2.07				
90:00	2.03				

Site: Hosier Landing
River mile 260.2
Trip no. 5
Event no: 1
Date: 05-20-81

Starting time: 1258
Tow name: Colonel George Lambert
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.9 mph

Station A
Total depth: 3.96 m
Sampling depth: 3.75 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
3:00	1.05
3:30	1.12
4:00	1.20
4:30	1.34
5:00	1.20
5:30	1.20
6:00	1.12
6:30	0.97
7:00	1.05
7:30	0.83
8:00	0.68
8:30	0.61
9:00	0.53
9:30	0.46
10:00	0.24
10:30	0.75
11:00	0.97
11:30	1.12
12:00	1.12
12:30	1.12
13:00	1.05
13:30	1.05
14:00	0.90
14:30	1.05
15:00	1.20
15:30	1.12
16:00	1.20
16:30	1.12
17:00	1.49
17:30	1.20
20:00	0.96

Station B
Total depth: 10.29 m
Sampling depth: 9.78 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
9:00	2.38
9:30	2.52
10:00	2.45
10:30	2.67
11:00	2.23
11:30	2.16
12:00	2.30
12:30	2.30
13:00	2.60
13:30	2.38
14:00	2.67
14:30	2.52
15:00	2.60
15:30	2.67
16:00	2.38
16:30	2.30
17:00	2.38
17:30	2.16
18:00	2.16
18:30	1.86
19:00	1.79
20:00	2.65

Station C
Total depth: 10.76 m
Sampling depth: 10.23 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
8:30	1.71
9:00	2.01
9:30	1.93
10:00	1.71
10:30	2.30
11:00	2.45
11:30	2.38
12:00	2.60
12:30	2.67
13:00	2.67
13:30	2.89
14:00	2.82
14:30	2.30
15:00	2.30
15:30	1.93
16:00	2.23
16:30	2.97
17:00	2.30
17:30	2.16
18:00	2.52
18:30	2.38

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 2
Date: 05-20-81

Starting time: 1325
Tow name: Joanne
No. of barges: 4
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 10.0 mph

Station A Total depth: 3.96 m Sampling depth: 3.14 m		Station B Total depth: 9.30 m Sampling depth: 7.44 m		Station C Total depth: 9.75 m Sampling depth: 8.00 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
0:30	1.56	9:00	2.82	8:00	2.67
2:00	1.34	9:30	2.45	8:30	2.82
2:30	1.20	10:00	2.23	9:00	3.34
3:30	0.68	10:30	2.52	9:30	3.04
4:00	0.68	11:00	2.16	10:00	2.75
4:30	0.68	11:30	2.52	10:30	2.52
5:00	0.90	12:00	2.52	11:00	2.23
5:30	1.34	12:30	2.60	11:30	2.45
6:00	1.05	13:00	2.60	12:00	3.04
6:30	0.24	13:30	2.52	12:30	2.89
7:00	0.16	14:00	2.45	13:00	2.60
10:30	1.42	14:30	2.45	13:30	2.89
11:00	1.27	15:00	2.97	14:00	2.82
11:30	1.27	15:30	2.89	14:30	2.38
14:00	0.96	16:00	2.82	15:00	2.82
16:00	1.02	16:30	2.52	15:30	2.08
18:00	1.52	17:00	2.89	16:00	2.82
20:00	1.32	17:30	2.67	16:30	2.82
22:00	1.02	18:00	2.01	17:00	2.16
24:00	0.57	18:30	2.38	17:30	2.67
28:00	1.20	19:00	2.60	18:00	2.60
30:00	1.46	20:00	2.59	18:30	2.60
35:00	1.27	22:00	2.78	19:00	3.11
45:00	0.78	24:00	2.53	22:00	2.42
50:00	0.83	26:00	2.32	26:30	2.53
55:00	1.22	28:00	2.53	35:00	2.59
60:00	0.96	30:00	2.47	40:00	2.59
70:00	0.94	35:00	2.42	45:00	3.03
80:00	0.96	40:00	2.47	50:00	1.75
90:00	1.29	45:00	2.12		
		50:00	2.65		
		55:00	2.17		

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 3
Date: 05-21-81

Starting time: 0850
Tow name: Sally Barton
No. of barges: 9
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 5.8 mph

Starting time: 0854
Tow name: Kathy Ellen
No. of barges:. 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.5 mph

Starting time: 0908
Tow name: Marvin E. Norman
No. of barges: 9
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 0.9 mph

Station A Total depth: 2.22 m Sampling depth: 1.33 m		Station B Total depth: 9.72 m Sampling depth: 5.83 m		Station C Total depth: 9.85 m Sampling depth: 5.91 m	
Time (rain:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
6:00	1.09	29:00	3.04	29:00	3.26
7:00	0.90	29:30	3.19	29:30	3.19
7:30	0.79	30:00	3.56	30:00	3.34
8:30	0.83	30:30	3.19	30:30	3.34
9:00	1.05	31:00	0.02	31:00	3.70
9:30	0.97	31:30	2.60	31:30	3.93
10:00	1.12	32:00	2.89	32:00	3.70
10:30	1.20	32:30	2.67	32:30	3.63
11:00	0.97	33:00	3.34	33:00	3.70
11:30	1.05	33:30	3.63	33:30	3.70
12:00	0.90	34:00	3.26	34:00	3.56
12:30	0.97	34:30	3.48	34:30	3.41
13:00	1.20	35:00	3.34	35:00	3.70
13:30	0.90	35:30	3.26	35:30	2.23
14:00	0.79	36:00	3.04	36:00	3.26
15:00	0.75	37:30	3.26	36:30	3.26
15:30	0.46	38:00	3.04	37:00	3.34
16:00	0.38	38:30	3.26	37:30	3.56
16:30	0.38	39:00	3.41	39:00	3.26
17:00	0.53	39:30	3.56	39:30	3.34
17:30	0.61	40:00	3.03	40:00	3.34
18:00	0.61	42:00	3.46	43:00	3.37
19:00	0.83	44:00	3.03	45:00	3.10
19:30	1.05	46:00	3.18	47:00	3.54
20:00	0.97	48:00	3.89	51:03	3.46
21:00	0.94	53:00	2.78	62:00	3.46
22:00	0.90	58:00	3.10	73:30	3.46
22:30	1.05	63:00	3.25	78:05	3.62
23:00	1.05	68:00	3.46	83:00	3.70
24:00	0.83	73:00	2.97	87:30	3.70
24:30	0.94	78:00	3.25	94:00	3.70

(Continued)

Station A
Total depth: 2.22 m
Sampling depth: 1.33 m

Time (rain:sec elapsed)	Water Velocity (ft/sec)
25:30	0.90
26:00	0.75
26:30	0.97
27:00	0.75
27:30	0.90
32:30	1.22
34:20	1.20
36:00	1.32
38:00	1.22
40:00	1.04
53:00	0.74
58:00	0.82
63:00	1.04
73:00	1.07
78:00	1.24
88:00	1.12
99:15	0.72
108:00	0.77

Station B
Total depth: 9.72 m
Sampling depth: 5.83 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
88:00	3.38
98:00	2.84
108:00	2.84

Station C
Total depth: 9.85 m
Sampling depth: 5.91 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
98:30	3.62
107:00	3.03

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 4
Date: 05-21-81

Starting time: 1055
Tow name: Frederick B. Wells
No. of barges: 12
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 8.9 mph

Station A
Total depth: 3.58 m
Sampling depth: 0.72 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
9:00	0.75
9:30	0.53
10:00	0.46
10:30	0.46
11:00	0.46
11:30	0.75
12:00	0.97
12:30	1.20
13:00	1.71
13:30	1.56
14:00	1.34
14:30	1.27
15:00	1.34
15:30	1.20
16:00	1.12
16:30	1.27
17:00	1.20
17:30	1.27
18:00	1.42
18:30	1.49
19:00	1.34
19:30	1.34
20:00	1.56
20:30	1.42
21:00	1.34
23:00	1.56
26:00	1.05
28:00	1.72
30:00	1.63
35:00	1.60
40:00	1.75
45:00	1.86
50:00	1.43
55:00	1.63
60:00	1.75
70:00	1.43
80:00	1.46
90:00	1.34

Station B
Total depth: 9.72 m
Sampling depth: 1.96 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
8:00	3.78
8:30	3.78
9:00	3.85
9:30	3.63
10:00	3.56
10:30	3.93
11:00	3.56
11:30	3.78
12:00	3.56
12:30	3.63
13:00	3.26
13:30	3.78
14:00	3.70
14:30	3.70
15:00	3.48
15:30	3.26
16:00	3.34
16:30	3.34
17:00	3.48
17:30	3.70
18:00	3.93
18:30	3.41
19:00	3.70
21:00	3.34
23:00	3.54
25:00	3.62
27:00	3.79
29:00	3.46
35:00	3.54
50:00	3.79
55:00	3.54
60:00	3.70
70:00	3.79
80:00	3.54
90:00	4.33

Station C
Total depth: 9.94 m
Sampling depth: 1.99 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
8:30	3.48
9:00	3.70
10:00	3.67
10:30	3.56
13:30	3.78
14:00	3.63
14:30	3.48
17:00	3.19
17:30	3.56
18:30	3.45
19:00	3.85
22:00	3.95
24:00	4.04
27:00	3.70
30:00	3.54
31:00	3.70
36:00	3.62
41:00	3.95
45:00	3.70
50:00	3.54
57:00	3.62
61:00	3.46
70:00	3.79
80:00	3.54
90:00	3.79

Site: Mosier Landing
River mile 260,2
Trip no. 5
Event no: 5
Date: 05-21-81

Starting time: 1511
Tow name: Sierra Dawn
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 3.2 mph

Station A
Total depth: 3.26 m
Sampling depth: 2.95 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
-15:30	0.90
-15:00	0.53
-14:30	0.75
-14:00	0.90
-13:30	0.68
-13:00	0.83
-12:30	0.90
-12:00	0.90
-11:30	0.90
-11:00	0.97
-10:30	1.12
-10:00	1.12
-9:30	1.20
-9:00	1.12
-8:30	1.12
-8:00	1.12
-7:30	1.05
-7:00	1.05
-6:30	1.34
-6:00	1.34
-5:30	0.97
-5:00	1.05
-4:30	0.83
-3:30	0.90
-3:00	1.05
-2:30	1.12
-2:00	0.97
-1:30	1.49
-1:00	0.83
-0:30	0.68
0:00	0.97
0:30	1.27
1:30	1.49
2:00	1.12
2:30	1.20
3:00	1.20
3:30	0.90
4:00	0.97

(Continued)

Station A

Total depth: 3.26 m

Sampling depth: 2.95 m

Time (min:3ec elapsed)	Water Velocity (ft/sec)
4:30	1.12
5:00	0.90
5:30	1.05
6:00	0.90
6:30	0.83
7:00	0.90
7:30	0.90
8:00	0.68
8:30	1.05
9:00	0.46
9:30	0.31
10:30	0.83
11:00	0.68
11:30	0.61
12:00	0.75
13:00	1.05
13:30	0.90
20:00	0.90
22:00	0.79
24:00	0.54
26:00	0.54
28:00	0.44
30:00	1.29
32:00	1.04
34:00	1.02
36:00	0.52

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 6
Date: 05-21-81

Starting time: 1555
Tow name: Atlas
No. of barges: 6
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 7.7 mph

Station A
Total depth: 3.26 m
Sampling depth: 2.95 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
-1:30	0.31
-1:00	0.49
0:00	0.83
0:30	0.83
1:00	1.27
1:30	1.20
2:00	1.20
2:30	0.97
3:00	1.12
3:30	1.05
4:00	1.34
4:30	1.27
5:00	1.12
5:30	1.27
6:00	1.05
6:30	0.97
7:00	0.75
8:00	1.20
8:30	1.27
9:00	1.20
9:30	1.05
10:00	0.90
10:30	0.83
11:00	0.68
11:30	0.53
12:00	0.38
12:30	0.24
13:00	0.24
13:30	0.31
14:00	0.68
14:30	0.57
15:30	0.68
16:00	0.75
18:00	1.07
20:00	0.90
22:00	1.09
24:00	1.22
26:00	0.74

Station B
Total depth: 6.73 m
Sampling depth: 6.40 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
7:00	1.42
7:30	1.27
8:00	1.27
8:30	1.49
9:00	1.12
9:30	1.05
10:00	1.49
10:30	1.56
11:00	1.42
11:30	1.20
12:00	1.12
12:30	1.20
13:00	0.97
13:30	1.42
14:00	1.56
14:30	1.64
15:00	1.42
15:30	1.64
16:00	1.56
16:30	1.20
17:00	1.27
19:00	1.40
21:00	1.32
23:00	1.29
25:00	1.27
27:00	1.34
29:00	1.24
34:00	1.12
39:00	0.90
44:00	0.83
49:00	1.12
54:00	0.82
59:00	0.96
69:00	0.96
79:00	0.82
89:00	1.22

Station C
Total depth: 7.40 m
Sampling depth: 7.04 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
6:30	2.23
7:00	2.23
7:30	2.97
8:00	2.23
8:30	2.60
9:00	2.23
9:30	2.60
10:00	2.23
10:30	2.23
11:00	2.23
11:30	2.23
12:00	2.60
12:30	2.23
13:00	2.23
13:30	2.23
14:00	2.60
14:30	2.97
15:00	2.60
15:30	2.60
16:00	2.60
16:30	2.23
17:00	2.60
22:00	2.65
24:00	2.59
28:30	2.47
30:00	2.78
38:00	2.78
46:30	2.65
50:00	2.65
55:00	2.53
60:30	2.97
70:30	2.42
80:00	2.97
90:00	2.71

(Continued)

Station A		Station B		Station C	
Total depth: 3.26 m		Total depth: 6.73 m		Total depth: 7.40 m	
Sampling depth: 2.95 m		Sampling depth: 6.40 m		Sampling depth: 7.04 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
28:00	0.37				
30:00	0.70				
35:00	1.09				
40:00	0.94				
45:00	0.79				
50:00	0.79				
55:00	0.71				
60:00	1.20				
70:00	0.78				
80:00	0.96				
90:00	0.88				

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 7
Date: 05-22-81

Starting time: 0915
Tow name: New Dawn
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.2 mph

Station A		Station B		Station C	
Total depth: 3.80 m		Total depth: 7.10 m		Total depth: 8.50 m	
Sampling depth: 2.30 m		Sampling depth: 5.68 m		Sampling depth: 7.00 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
18:00	1.93	11:00	2.30	8:00	2.60
18:30	1.79	11:30	2.16	8:30	2.75
19:00	1.79	12:00	2.01	9:00	2.60
19:30	1.79	12:30	1.71	9:30	2.97
20:00	1.79	13:00	2.30	10:00	2.60
20:30	2.01	13:30	2.23	10:30	2.60
21:00	1.86	14:00	2.23	11:00	2.82
21:30	1.93	14:30	2.38	11:30	2.52
22:00	2.08	15:00	2.45	12:00	2.30
22:30	1.93	15:30	2.45	12:30	2.60
23:00	2.01	16:00	2.30	13:00	2.52
23:30	2.01	16:30	2.38	13:30	2.60
24:00	1.71	17:00	2.23	14:00	2.30
25:30	1.79	17:30	2.67	14:30	2.45
26:00	1.86	18:00	2.38	15:00	2.67
26:30	1.79	18:30	2.38	15:30	2.60
27:00	1.86	19:00	2.38	16:00	2.52
27:30	1.86	19:30	2.60	16:30	2.45
28:00	1.79	20:00	2.60	17:00	2.75
28:30	2.01	20:30	2.01	17:30	2.60
29:00	1.93	21:00	2.23	18:00	2.38
29:30	1.86	22:00	2.59	18:30	2.60
		24:00	1.94	19:00	2.23
		26:00	2.03	19:30	2.52
		28:00	2.37	20:00	2.30
		30:00	2.42	20:30	2.60
		32:00	2.19	21:00	2.60
		34:00	2.23	21:30	2.45
		36:00	2.07	22:00	2.30
				26:00	2.27
				28:00	2.27
				30:00	2.37
				35:00	2.47

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 8
Date: 05-22-81

Starting time: 1215
Tow name: Nohab Express
No. of barges: 3
Draft: 9 ft
Traffic direction: Upstream
Tow speed: 6.7 mph

Station A
Total depth: 4.58 m
Sampling depth: 0.92 m

Time (min:3ec elapsed)	Water Velocity (ft/sec)
6:30	2.23
7:00	2.38
7:30	2.38
8:00	2.01
8:30	2.45
9:00	2.45
9:30	2.45
10:00	2.67
10:30	2.67
11:00	2.45
11:30	2.38
12:00	2.38
12:30	2.52
13:00	2.45
14:30	2.23
15:00	2.45
15:30	2.23
16:30	2.38
18:00	2.23
20:00	2.07
22:00	2.07
24:00	2.07
26:00	1.86
28:00	1.43
30:00	2.12
40:00	2.03
45:00	2.17
50:00	1.72
55:00	2.23
60:00	2.23
70:00	2.07
80:00	2.27
90:00	2.41

Station B
Total depth: 8.54 m
Sampling depth: 5.12 m

Time (min:3ec elapsed)	Water Velocity (ft/sec)
10:30	3.11
11:00	3.11
11:30	3.11
12:00	2.97
12:30	2.75
13:00	2.97
13:30	2.97
14:00	2.60
14:30	2.67
15:00	2.89
15:30	2.89
16:00	2.67
16:30	2.60
17:00	2.45
17:30	2.67
18:00	2.89
18:30	2.97
19:00	3.19
19:30	2.60
20:00	3.11
20:30	2.97
22:00	2.53
24:00	2.59
26:00	3.03
28:00	2.97
30:00	3.03
35:00	2.65
40:00	2.78
45:00	2.84
50:00	2.84
55:00	2.78
60:00	2.59
70:00	2.84
80:00	2.90
90:00	3.03

Station C
Total depth: 6.89 m
Sampling depth: 4.14 m

Time (min:sec elapsed)	Water Velocity (ft/sec)
9:00	2.97
9:30	2.60
10:00	2.97
10:30	2.97
11:00	3.34
11:30	2.97
12:00	2.60
12:30	2.97
13:00	2.97
13:30	3.34
14:00	3.34
14:30	2.97
15:00	2.97
15:30	3.34
16:00	2.97
16:30	2.97
17:00	2.97
17:30	2.97
18:00	2.97
18:30	2.97
19:00	2.97
23:06	3.34
24:00	3.18
26:00	2.90
28:00	3.25
30:00	3.25
35:00	3.34
40:00	3.31
45:00	3.10
50:00	3.38
55:00	3.34
60:00	3.03
70:00	3.10
80:00	3.10
90:00	3.18

Site: Mosier Landing
River mile 260.2
Trip no. 5
Event no: 9
Date: 05-22-81

Starting time: 1730
Tow name: White Knight
No. of barges: 15
Draft: 9 ft
Traffic direction: Downstream
Tow speed: 9.1 mph

Starting time: 1741
Tow name: Colonel George Lambert
No. of barges: 15
Draft: 2 ft
Traffic direction: Upstream
Tow speed: 6.3 mph

Station A		Station B		Station C	
Total depth: 3.18 m		Total depth: 8.62 m		Total depth: 7.25 m	
Sampling depth: 1.91 m		Sampling depth: 1.72 m		Sampling depth: 1.46 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
1:00	1.49	20:30	3.11	20:30	2.60
1:30	1.56	21:00	3.11	21:00	2.60
2:00	1.93	21:30	3.19	21:30	2.60
2:30	1.93	22:30	3.34	22:00	2.97
3:00	2.01	23:00	3.34	22:30	2.60
3:30	2.01	23:30	3.26	23:00	2.97
4:00	1.86	24:00	3.26	23:30	3.34
4:30	2.01	24:30	3.48	24:00	2.60
5:00	1.86	25:00	3.26	24:30	2.97
5:30	1.86	25:30	3.48	25:00	3.34
6:00	1.93	26:00	3.19	25:30	2.97
6:30	1.93	26:30	3.11	26:00	2.60
7:00	1.64	27:00	3.48	26:30	2.97
7:30	1.86	27:30	3.56	27:00	2.60
8:00	2.08	28:00	2.97	27:30	2.97
8:30	2.04	28:30	3.19	28:00	3.34
9:30	1.93	29:00	3.26	28:30	2.97
10:00	2.08	29:30	3.04	29:00	3.34
10:30	2.01	30:00	3.11	29:30	3.34
11:30	1.97	46:00	3.18	30:00	2.97
12:30	2.08	56:00	3.03	32:00	3.38
13:00	1.71	61:00	3.03	34:00	3.38
13:30	1.64			36:00	3.46
14:00	1.79			38:00	3.54
14:30	2.01			40:00	3.62
15:00	1.79			42:00	3.18
15:30	1.64			44:00	3.24
16:30	1.56			46:00	3.38
17:00	1.86			50:00	3.79
17:30	2.08			54:00	3.54
18:00	2.23			58:00	3.54

(Continued)

Station A Total depth: 3.18 m Sampling depth: 1.91 m		Station B Total depth: 8.62 m Sampling depth: 1.72 m		Station C Total depth: 7.25 m Sampling depth: 1.46 m	
Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)	Time (min:sec elapsed)	Water Velocity (ft/sec)
18:30	2.16				
19:00	2.08				
19:30	1.71				
20:00	1.86				
20:30	1.93				
21:00	1.93				
21:30	1.86				
22:00	1.94				
24:00	1.94				
26:00	1.86				
28:00	1.90				
30:00	1.98				
32:00	2.23				
34:00	1.86				
36:00	1.98				
38:00	2.03				
40:00	2.03				
42:00	1.90				
47:00	1.98				
52:00	1.98				
57:00	1.82				
62:00	1.94				

APPENDIX E

BACKGROUND WATER VELOCITY DATA

Site: Riprap Landing
River mile 265.1
Trip no. 4

Station	Total depth(m)	Sampling depth(m)	Date	Time	Water velocity (ft/sec)
A	3.73	2.98	04-08-81	1410	1.56
A	3.73	2.24	04-08-81	1412	2.07
A	3.73	1.49	04-08-81	1413	2.37
A	3.73	0.75	04-08-81	1414	2.65
A	2.97	2.40	04-08-81	1508	1.56
A	2.97	1.80	04-08-81	1510	1.56
A	2.97	1.20	04-08-81	1513	1.90
A	2.97	0.60	04-08-81	1515	2.53
A	4.21	3.37	04-08-81	1613	2.19
A	4.21	2.53	04-08-81	1616	2.32
A	4.21	1.68	04-08-81	1618	2.53
A	4.21	0.84	04-08-81	1620	2.59
B	8.36	7.53	04-08-81	1410	2.65
B	8.36	6.30	04-08-81	1411	3.10
B	8.36	5.47	04-08-81	1411	3.38
B	8.36	4.64	04-08-81	1412	3.34
B	8.36	3.81	04-08-81	1412	3.34
B	8.36	2.98	04-08-81	1413	3.34
B	8.36	2.15	04-08-81	1414	3.46
B	8.36	1.32	04-08-81	1415	3.62
B	8.36	0.49	04-08-81	1416	3.46
B	8.60	7.74	04-08-81	1510	2.71
B	8.60	6.88	04-08-81	1511	2.59
B	8.60	6.00	04-08-81	1513	2.90
B	8.60	5.14	04-08-81	1515	3.18
B	8.60	4.28	04-08-81	1517	3.10
B	8.60	3.42	04-08-81	1519	3.46
B	8.60	2.56	04-08-81	1521	3.25
B	8.60	1.70	04-08-81	1523	3.54
B	8.60	0.84	04-08-81	1525	3.38
C	10.02	9.50	04-08-81	1500	1.68
C	10.02	9.00	04-08-81	1500	2.47
C	10.02	8.00	04-08-81	1500	2.71
C	10.02	7.00	04-08-81	1500	2.97
C	10.02	6.00	04-08-81	1500	2.97
C	10.02	5.00	04-08-81	1500	3.18
C	10.02	4.00	04-08-81	1500	3.38
C	10.02	3.00	04-08-81	1500	3.34
C	10.02	2.00	04-08-81	1500	3.38
C	10.02	1.00	04-08-81	1500	3.54
C	10.20	9.69	04-08-81	1607	2.03
C	10.20	9.18	04-08-81	1607	2.67
C	10.20	8.16	04-08-81	1607	2.47
C	10.20	7.14	04-08-81	1607	2.78
C	10.20	6.12	04-08-81	1607	3.03

(Continued)

Station	Total depth(m)	Sampling depth(m)	Date	Time	Water velocity (ft/sec)
C	10.20	5.10	04-08-81	1607	3.18
C	10.20	4.08	04-08-81	1607	3.34
C	10.20	3.06	04-08-81	1607	3.25
C	10.20	2.04	04-08-81	1607	3.70
C	10.20	1.02	04-08-81	1607	3.54
A	4.12	3.30	04-09-81	1545	2.34
A	4.12	2.47	04-09-81	1545	2.28
A	4.12	1.65	04-09-81	1545	.2.78
A	4.12	0.82	04-09-81	1545	2.67
B	8.10	7.30	04-09-81	1545	2.73
B	8.10	6.50	04-09-81	1545	3.34
B	8.10	5.70	04-09-81	1545	2.90
B	8.10	4.90	04-09-81	1545	2.97
B	8.10	4.10	04-09-81	1545	3.10
B	8.10	2.50	04-09-81	1545	3.46
B	8.10	0.90	04-09-81	1545	3.54
C	10.50	10.00	04-09-81	1545	1.86
C	10.50	9.50	04-09-81	1545	2.32
C	10.50	8.40	04-09-81	1545	2.65
C	10.50	7.40	04-09-81	1545	3.10
C	10.50	6.30	04-09-81	1545	2.97
C	10.50	5.30	04-09-81	1545	3.34
C	10.50	4.20	04-09-81	1545	3.54
C	10.50	3.20	04-09-81	1545	3.63
C	10.50	2.10	04-09-81	1545	3.62
C	10.50	1.10	04-09-81	1545	3.54
A	4.60	3.68	04-10-81	1100	2.23
A	4.60	2.70	04-10-81	1100	2.51
A	4.60	1.84	04-10-81	1100	2.78
A	5.13	4.11	04-10-81	1400	2.53
A	5.13	3.07	04-10-81	1400	2.59
A	5.13	2.04	04-10-81	1400	2.71
A	5.13	1.01	04-10-81	1400	2.90
A	4.00	3.20	04-10-81	1500	1.72
A	4.00	2.40	04-10-81	1500	2.37
A	4.00	1.60	04-10-81	1500	2.23
A	4.00	0.80	04-10-81	1500	2.78
A	4.11	3.29	04-10-81	1700	1.90
A	4.11	2.47	04-10-81	1700	2.12
A	4.11	1.65	04-10-81	1700	2.71
A	4.11	0.82	04-10-81	1700	2.84
B	8.44	7.60	04-10-81	1106	2.27
B	8.44	6.76	04-10-81	1106	2.47
B	8.44	5.92	04-10-81	1106	3.18
B	8.44	5.08	04-10-81	1106	3.62
B	9.60	8.64	04-10-81	1420	2.37
B	9.60	7.68	04-10-81	1420	2.23

(Continued)

Station	Total depth(m)	Sampling depth(m)	Date	Time	Water velocity (ft/sec)
B	9.60	6.72	04-10-81	1420	2.65
B	9.60	5.76	04-10-81	1420	3.18
B	9.60	4.80	04-10-81	1420	3.34
3	9.60	3.84	04-10-81	1420	3.25
B	9.60	2.88	04-10-81	1420	3.46
B	9.60	1.92	04-10-81	1420	3.54
B	9.60	0.96	04-10-81	1420	3.79
C	10.90	2.18	04-10-81	1105	3.89
C	10.90	4.36	04-10-81	1105	3.54
C	10.90	6.44	04-10-81	1105	3.34
C	10.90	8.72	04-10-81	1105	2.65
C	10.90	10.35	04-10-81	1105	2.47
C	10.63	10.12	04-10-81	1410	2.07
C	10.63	9.63	04-10-81	1410	2.47
C	10.63	8.63	04-10-81	14,10	2.47
C	10.63	7.53	04-10-81	1410	3.10
C	10.63	6.53	04-10-81	1410	3.03
C	10.63	5.43	04-10-81	1410	3.34
C	10.63	4.43	04-10-81	1410	3.54
C	10.63	3.33	04-10-81	1410	3.79
C	10.63	2.33	04-10-81	1410	3.79
C	10.63	1.23	04-10-81	1410	3.79
C	10.80	10.26	04-10-81	1505	2.53
C	10.80	8.64	04-10-81	1505	2.84
C	10.80	6.48	04-10-81	1505	3.56
C	10.80	4.32	04-10-81	1505	3.63
C	10.80	2.16	04-10-81	1505	3.87
C	10.80	10.26	04-10-81	1700	1.79
C	10.80	8.64	04-10-81	1700	2.59
C	10.80	6.48	04-10-81	1700	3.34
C	10.80	4.32	04-10-81	1700	3.62
C	10.80	2.16	04-10-81	1700	3.70

Site: Mosier Landing
River mile 260.2
Trip no. 5

Station	Total depth(m)	Sampling depth(m)	Date	Time	Water velocity (ft/sec)
A	4.11	3.30	05-20-81	1540	0.96
A	4.11	2.47	05-20-81	1540	0.87
A	4.11	1.65	05-20-81	1540	0.88
A	4.11	0.82	05-20-81	1540	1.43
A	2.65	2.12	05-20-81	1630	0.83
A	2.65	1.59	05-20-81	1630	0.88
A	2.65	1.06	05-20-81	1630	0.94
A	2.65	0.53	05-20-81	1630	0.98
A	2.46	1.97	05-20-81	1730	1.04
A	2.46	1.48	05-20-81	1730	1.00
A	2.46	0.99	05-20-81	1730	1.20
A	2.46	0.49	05-20-81	1730	1.16
A	2.13	1.70	05-21-81	1400	0.96
A	2.13	1.28	05-21-81	1400	0.55
A	2.13	0.85	05-21-81	1400	0.37
A	2.13	0.43	05-21-81	1400	0.45
A	4.10	3.28	05-22-81	1430	1.82
A	4.10	2.46	05-22-81	1430	1.90
A	4.10	1.64	05-22-81	1430	2.07
A	4.10	0.82	05-22-81	1430	2.23
A	3.46	2.77	05-22-81	1630	1.49
A	3.46	2.08	05-22-81	1630	1.60
A	3.46	1.38	05-22-81	1630	1.72
A	3.46	0.69	05-22-81	1630	2.03
B	9.65	1.93	05-21-81	1406	3.62
B	9.65	3.86	05-21-81	1406	3.38
B	9.65	5.79	05-21-81	1406	3.10
B	9.65	7.72	05-21-81	1406	3.03
B	9.65	8.69	05-21-81	1406	2.53
B	9.65	9.17	05-21-81	1406	2.59
B	8.54	8.11	05-22-81	1430	2.17
B	8.54	7.68	05-22-81	1430	2.59
B	8.54	6.83	05-22-81	1430	2.59
B	8.54	5.97	05-22-81	1430	2.53
B	8.54	5.12	05-22-81	1430	2.90
B	8.54	3.41	05-22-81	1430	2.71
B	8.54	1.71	05-22-81	1430	3.18
B	8.44	8.01	05-22-81	1630	2.07
B	8.44	7.62	05-22-81	1630	2.42
B	8.44	6.73	05-22-81	1630	3.10
B	8.44	5.05	05-22-81	1630	3.03
B	8.44	3.38	05-22-81	1630	3.10
B	8.44	1.67	05-22-81	1630	3.25
C	9.60	9.12	05-20-81	1230	0.95
C	9.60	8.64	05-20-81	1230	3.16

(Continued)

Station	Total depth(m)	Sampling depth(m)	Date	Time	Water velocity (ft/sec)
C	7.30	7.00	05-21-81	1400	2.65
C	7.30	6.60	05-21-81	1400	2.85
C	7.30	5.90	05-21-81	1400	3.24
C	7.30	4.40	05-21-81	1400	3.03
C	7.30	2.90	05-21-81	1400	3.95
C	7.30	1.50	05-21-81	1420	3.79

APPENDIX F

BACKGROUND PERCENT VOLATILES

Appendix F. Background Percent Volatiles

Date	Time	Station	% volatile
4/8/81	1505	A	11.53
4/8/81	1611	A	11.56
4/9/81	1530	A	12.12
4/10/81	1500	A	11.35
4/10/81	1700	A	18.31
4/9/81	1540	B	13.31
4/10/81	1400	B	6.18
4/10/81	1500	B	10.62
4/10/81	1700	B	11.67
4/8/81	1600	C	12.30
4/8/81	1619	C	12.10
4/8/81	1635	C	11.70
4/9/81	1539	C	12.70
4/9/81	1539	C	12.92
4/10/81	0811	C	11.22
4/10/81	0811	C	12.78
4/10/81	1107	C	14.00
4/10/81	1409	C	9.47
4/10/81	1414	C	10.76
4/10/81	1440	C	12.30
4/10/81	1500	C	11.40
4/10/81	1655	C	12.03
5/20/81	1245	B	10.48
5/20/81	1530	B	9.02
5/20/81	1730	B	8.87
5/20/81	1830	B	8.87
5/21/81	1400	B	10.35
5/21/81	1400	B	10.04
5/21/81	1500	B	9.66
5/22/81	1200	B	9.91
5/22/81	1430	B	9.34
5/22/81	1430	B	9.21
5/22/81	1630	B	9.60
5/20/81	1230	C	8.37
5/20/81	1530	C	9.08
5/20/81	1630	C	8.31
5/20/81	1730	C	8.57
5/20/81	1830	C	8.45
5/21/81	1417	C	9.06
5/21/81	1425	C	9.16
5/21/81	1500	C	9.20