AD-A03	SIFIED	ARMY CAPAC FEB 7	ENGINEE ITY STU 7 L L WES-MP	DIES OF DAGGETT	RWAYS E F WINFI F, R W	XPERIME ELD LOC MCCARLE	NT STAT	TION V	ICKSBUR	G MISS	F/G 1 RGINI	3/2 ETC (U)	
	1 OF 2												
			And		Tuille:					The second secon			
	Comparison of the second secon					Manufactura de Caraci Alexandro de Caraci Alex			1				
					Đ			E.		L.		Management	
U		Tailonta Tailonta Tailonta Tailonta	Restauro	-			-				interest I support		
				uutu	auffin						-		
				-		_						(and a	-







MISCELLANEOUS PAPER H-77-I

2

ADA 03738

FILE COPY

M. P. H-77-1

CAPACITY STUDIES OF WINFIELD LOCKS, KANA'/HA

大いない ちんちち あいていち

CAPACITY STUDIES OF WINFIELD LOCKS KANAWHA RIVER, WEST VIRGINIA

Ьу

Larry L. Daggett, Robert W. McCarley

Hydraulics Laboratory U. S. Army Engineer Waterways Experiment Station P. O. Box 631, Vicksburg, Miss. 39180

> February 1977 Interim Report



Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Engineer District, Huntington Huntington, W. Va. 25721

COPY AVAILABLE TO DDG DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

Destroy this report when no longer needed. Do not return it to the originator.

Unclassified SECURITY CLASSIFICATION OF THIS PAGE (When Deta Entered) READ INSTRUCTIONS BEFORE COMPLETING FORM REPORT DOCUMENTATION PAGE 2. GOVT ACCESSION NO. 3. RECIPIENT'S CATALOG NUMBER REPORT NUMBER Miscellaneous Paper H-77-1 COVERED 4. TITLE (and Subtitie) G Interim report. 0 Capacity Studies of Winfield Locks, Kanawha RT NUMBER PERFOR ORG. REF River, West Virginia . NUMBER(.) CONTRACT OR GRANT Larry L. Daggett Robert W. McCarley PERFORMING ORGANIZATION NAME AND ACORESS 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS U. S. Army Engineer Waterways Experiment Station Hydraulics Laboratory V P.O. Box 631, Vicksburg, MS 39180 1. CONTROLLING OFFICE NAME AND ADDRESS 077 Febr U. S. Army Engineer District, Huntington 13. NUMBER P. O. Box 2127 107 Hintington, WV 2572] 4. MONITORING AGENCY NAME & ADDRESS(II dillorent from: Controlling Office) 15. SECURITY CLASS. (of this report) Unclassified 15. DECLASSIFICATION/DOWNGRADING 6. DISTRIBUTION STATEMENT (of Lt. Report) Approved for public release; distribution unlimited P-H-77-1 18. SUPPLEMENTARY NOTES 9. KEY WORDS (Continue on reverse side if necessary and identify by block number) Computerized simulation Inland waterways Locks (waterways) Gallipolis Lock & Dam 20. ADSTRACT (Continue as reverse elde if necessary and identify by block number) The Winfield lockage facilities currently consist of two 360-ft x 56-ft chambers with a normal lift of 28 ft. With the increasing traffic on the Kanawha River, these facilities are no longer adequate to serve the towing industry using this portion of the inland waterway system. Excessive delays now occur at Winfield and if the predicted traffic growth materializes during the next 10 or 15 years without action being taken by the Corps to address the problem, transfers of traffic movements to other more costly modes of DD , JAN 73 1473 EDITION OF I NOV 65 IS ODSOLETE Unclassified SECURITY CLASSIFICATION OF THIS PAGE (Mien Date Entered) 038100

Inclassified ECURITY CLASSIFICATION OF THIS PAGE (When Date Entered)

Atransportation will result. Accordingly, studies were conducted to determine the capacity of the existing lockage facilities and to evaluate possible solutions for increasing this capacity through the use of alternative operating policies and rules that have been considered to be beneficial at other lock sites. Using the two simulation models, TOWGEN and WATSIM IV, the following four alternative operating policies were simulated to determine their respective effects on the capacity of Winfield and the delays to be expected should such policies be possible: --

a. First In-First Out (FIFO) Unrestricted.

b. FIFO Unrestricted with a 10 percent reduction in lockage component times;

(c. FIFO Ready-to-Serve;

d) 3 Up-3 Down, Unrestricted.

These operating policies are discussed in detail in the report. Input data for the models were collected through the Performance Monitoring System (PMS) of the Inland Navigation Systems Analysis (INSA) program. The report includes discussions of model calibration and the criteria employed to analyze the capacity of the lockage facility based on the best available projections of future tonnage levels. Numerous capacity curves were developed to show the relationship between increasing commodity tonnages, tow delays, and lock utilization.

eression or and some second and the second and the

Unclassificd SECURITY CLASS: FICATION OF THIS PAGE (When Dete Entered)

PREFACE

The study reported herein was performed by the U. S. Army Engineer Waterways Experiment Station (WES) for the U. S. Army Engineer District, Huntington. WES used computerized simulation models in conducting the investigation of the Winfield Locks' potential to serve future traffic levels. The Huntington District (ORHED-PE) provided essential prototype data and assistance in analyzing and reducing these data.

Completion of the planned Winfield Locks capacity studies was suspended as a result of a critical requirement to reanalyze the proposed replacement of the Gallipolis Locks. As a result, only the first objective of the Winfield studies is reported, i.e., the determination of capacity relative to the existing facilities and several alternative operating policies.

The investigation was conducted by Dr. L. L. Daggett and Mr. R. W. McCarley of the Mathematical Hydraulics Division (MHD), under the general supervision of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, and Mr. M. B. Boyd, Chief, MHD. The report was prepared by Mr. McCarley with technical guidance and input from Dr. Daggett. Special assistance and advice was provided by ORHED-PE during the course of the investigation. Acknowledgement is made to Messrs. Alan Elberfeld, Ron Mead, David Weekly and Ed Stone of the Huntington District for their cooperation and assistance at various times throughout the investigation.

Directors of WES during the conduct of this investigation and preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

weathers and the state of the	Page
PREFACE	1
PART I: INTRODUCTION	4
Background	4 5
Approach	6
PART II: THE WATSIM/TOWGEN MODEL	8
Brief Description of the Simulation Model: TOWGEN/WATSIM	8
Computer Facilities Used	12
PART III: ANALYSIS OF WINFIELD PROTOTYPE LOCKAGE DATA	13
General	13 13 13 15 21 25
PART IV: TOWGEN/WATSIM MODEL CALIBRATION	30
General	30 30 34 35
PART V: CAPACITY DETERMINATIONS OF THE EXISTING WINFIELD LOCKS	37
General Method of Determining Capacity Lock Operating Policies Studied	37 37 38 39 41 43

CONTENTS (continued)

Page

WINFIELD CAPACITY LEVELS FOR FOUR ALTERNATIVE PART VI: 46 General FIFO - Unrestricted with a 10 Percent Reduction REFERENCES . . APPENDIX C: REDUCED WATSIM DATA FOR FOUR ALTERNATIVE OPERATING POLICIES AT THE EXISTING WINFIELD LOCKS . . . C1 APPENDIX D: TONNAGE PROJECTION METHOD COMPARISON ANALYSIS DI APPENDIX E: DEFINITIONS . El

CAPACITY STUDIES OF WINFIELD LOCKS, KANAWHA RIVER WEST VIRGINIA

PART I: INTRODUCTION

Background

1. The Winfield lockage facilities, located near Winfield, WV, currently consist of two 360-ft x 56-ft chambers with a normal lift of 28 ft. Since many of the tows using these locks are much longer than the chambers, they necessarily must break into sections for lockage. In addition, the river configuration of many tows would probably be much wider than at present if the lock chambers were wide enough to accommodate them, as it is known that short, wide tows can more easily navigate tight bends as are found on the Kanawha River. Three- and four-cut lockages are not uncommon and the maximum number of cuts now reach as high as eight. The breaking and remaking of large tows within an undersized lock chamber inherently requires long processing times and often results in the excessive delay of tows waiting to be serviced. The results of such delays and the accompanying long waiting lines at the Winfield locks are the inefficient use of men and equipment, rapidly escalating costs for the shipper, less reliability in the receipt of commodities on time, and hence increased storage costs to the user as stockpiling is required. If the delays to movements become great enough, transfers of traffic movements to other more costly modes of transportation will result.

2. The traffic passing through the Winfield locks is predicted to grow dramatically during the next 15 years. Detailed commodity growth projection studies have been completed for 1980 and 1990, revealing 65% and 125% increases, respectively, over and above the tonnages reported in 1975. Such growth will undoubtedly tax the lockage capabilities of the current facilities at Winfield. With tonnage growth of this magnitude expected in the near future, the Winfield capacity studies reported

herein were initiated in March 1976 to estimate the associated increase in delays and the resulting costs to the towing industry and to develop information required for estimating the capacity of the present locks and the proposed replacement alternatives. These studies, though not complete at this writing, will provide essential knowledge required in planning for the proper expansion, of locking capabilities at Winfield.

Objectives

3. The first objective of the Winfield studies was to determine the capacity of the existing lockage facilities and to evaluate possible solutions for increasing this capacity through the use of alternative operating policies and rules that have been considered to be beneficial at other lock sites. The initial overall objectives of the work also included the evaluation of proposed alternative structural improvements if, as a result of the capacity studies, such improvements were considered necessary for the continued efficient operation of the locks. The final objective at the outset of these studies was to evaluate the effect of the current or any proposed replacement locks on the waterway system. The system-wide analysis was to allow for the determination of costs and benefits to the towing industry and their customers resulting from more efficient shipping and improved transit times throughout the waterway.

4. Completion of the planned Winfield capacity studies has been suspended as a result of a critical requirement to reanalyze the proposed replacement of the Gallipolis Locks. The decision was made during the last week of June 1976 to suspend work on the Winfield studies at a logical stopping point and to then redirect all resources to the more urgent Gallipolis study. As a result, only the first objective of the Winfield studies will be accomplished at this time, i.e., the determination of capacity relative to the existing facilities and several alternative operating policies, some of which would undoubtedly require major

improvements to the approaches and/or the availability of several switchboats to assist in the lockage operations.

Scope

5. Therefore, the scope of the study has been limited to analyzing the capacity of the existing Winfield locks. Tonnage projections representing a "most likely" growth in traffic were available for the years 1980 and 1990. Thus, only one set of tonnage projection data were used during the study. The characteristics (general configuration) of the tow fleet currently using Winfield were assumed to remain unchanged in the future, though it was recognized that larger tows from the Ohio River may someday use the Kanawha River. The original scope included an analysis of changes in the tow characteristics and makeup but had to be suspended at this time for the reasons given above.

6. The following four alternative operating policies were simulated to determine their respective effects on the capacity of Winfield and the delays to be expected should such policies be implemented:

a. First In-First Out (FIFO) Unrestricted

b. FIFO Unrestricted

with a 10% reduction in lockage component times

c. FIFO Ready-to-Serve

d. 3 Up-3 Down, Unrestricted

The above operating policies will be discussed in further detail later in the report.

Approach

7. Simulation modeling methodology was used to evaluate the locks at Winfield. This type of modeling has been used in the past to analyze the lock replacement and improvement projects being proposed for the Illinois Waterway, the Upper Mississippi and the proposed Red River waterway. Simulation modeling techniques were also applied in a detailed analysis of Locks and Dam 26, Mississippi River, and they are currently being used to analyze the effects of the replacement of existing locks on the Black Warrior River System.

8. The particular simulation model used in these studies was developed for the Corps of Engineers by Pennsylvania State University and extensively modified and expanded by the WES during the past several years. The model consists of two computer programs named TOWGEN (tow generator) and WATSIM (waterway simulator), which are described in detail in "A New Generalized Waterway Simulator: WATSIM IV."¹ A general discussion of the model is given later in this report. The most recent approach to using the simulation model for determining the capacity of a set of locks has been discussed in a recent paper entitled, "Determination of Lock Capabilities Using Simulation Modeling,"² presented at the First International Waterborne Transportation Conference in October 1975. The same model was slightly modified for use in this study to determine the capacity of the existing Winfield Locks and to evaluate any possible alternative lock operating policies.

9. In order to model the waterway traffic at Winfield, information had to be obtained regarding the traffic using the locks, the times required to process vessels, the commodities passing through the locks, and the types of lockages occurring. The data being collected as part of the Performance Monitoring System (PMS) were utilized as the source of the required information.

PART II: THE WATSIM/TOWGEN MODEL

Brief Description of the Simulation Model: TOWGEN/WATSIM

10. As mentioned in Paragraph 8, the simulation model used in this study consisted of two separate computer programs called TOWGEN and WATSIM. TOWGEN is a tow generation program that combined the commodity movement pattern and the tow equipment and flotilla description to develop a randomly generated list of simulated tows to be moved through the waterway system being tested. This tow list contains a description of the characteristics of each tow, the origin and destination of each movement, and the time of entry into the system. The tows are generated so that all the commodity movements required are started during the simulated time period. The tows are generated in such a manner as to assure that a balance of equipment exists throughout the system, i.e., that empty barges are moved to the locations where they are required for the mevement of goods.

11. Through the use of TOWGEN, the towing industry's requirements or demands for use of the waterway being analyzed may be developed for input to the waterway simulator, WATSIM. WATSIM reads the list of tows generated by TOWGEN and inserts the simulated tows at the appropriate time into the traffic flow on the waterway at its point of origin. WATSIM then moves each tow from its originating point to its destination in a series of steps covering each segment of the simulated waterway. As each tow is moved, statistics concerning the trip and the waterway facilities used are accumulated. These statistics provide a measure of the waterway's effectiveness in handling the traffic demands placed upon it and the time required to transit the waterway between various points. This transit time may then be interpreted into a cost of transport through the application of tow operating costs per unit of time. 12. The simulation process used by WATSIM is called event modeling. The various activities required to accomplish the task being modeled are represented by a series of events. Because the time to accomplish these events and, hence, the entire task is the critical parameter, each event is represented by WATSIM as a period of elapsed time. Because these times are stochastic and not deterministic, they are described by frequency distributions and functional representations. The modeling process thus involves the logical combination of the events required to move a tow from its origin to its destination, accounting for the interaction of the tows at commonly shared facilities.

13. Simulation modeling involves the use of simplified representations of the real-world activities involved in the modeled situation. The degree of simplification allowed in the description of any event depends upon the purpose of the simulation and significance of that event to the process being simulated. WATSIM has been primarily used in the past to evaluate lock replacement or expansion requirements and scheduling. Therefore, the modeling of these events is quite detailed and well developed.

WATSIM Modifications

14. Modifications were made to the WATSIM program (written in FORTRAN) to enable the printing of all model output required for capacity analysis on one table (Table 13, Composite Lock Statistics) and to more accurately compute the utilization of the lock chambers. The major modification involved the creation of a summary output subroutine that produces the desired statistics. All information now printed on Table 13 (see Figure 1) was formerly available in Tables 3A, 3D, 4, and 12. The new modification to the program allows the data required for capacity determination to be obtained from only one printed page rather than the four pages previously required, thus reducing the printing time for each run. These data may be placed on disc or tape files at the

central site in addition to being printed at a remote batch site. At the conclusion of each run, all output tables (1-13) are printed for the entire simulation period (one 30-day month for this study). The chamber utilization (percent of time chamber is used) by direction was included in the new Table 13. The revised method for computing utilization is considered more accurate and realistic than previously employed because now the model considers the actual length of time the chamber is used over the simulation period, rather than merely the tow processing time. No changes were made to the way the model processes tow movements during a simulation run. Actual program coding changes have been documented in a memorandum which can be obtained either from the Waterways Experiment Station (ATTN: WESHM) or the Huntington District (ATTN: ORHED-PE).

15. The data in Table 13 (Figure 1) are self-explanatory. The upper portion of Table 13 presents useful data for each chamber; the lower portion displays other important data by lock. The Run Identification Number ("0001M01WFU75" in Figure 1), which is explained in Appendix A, simulation time (47520 minutes in the figure), and the number of chambers and locks are shown as header information on each printed page. All output information contained in the printed table is also written to a file at the central computer site. This includes data for every intermediate output simulation time interval, as provided in the printouts. The file may then be accessed by post-WATSIM processing programs to provide data for various analyses. A short program to retrieve the data file on cards at the remote site at WES has also been written. It reads the data on the file, changes formats in some cases, then punches the data on cards so that the files at the central site can be purged for use by others. Each card contains the RUN ID Number, the time of data sample, the lock name, chamber designation (e.g., 1, 2), and a sequence number in addition to the various data items in Table 13.

0001+01+FUT5 47520 2 1

のないという

「「「「「「「」」」」」」

WINFLO CHMB ND. OF SINGLE LOCKAGES DN . UP TOTAL 121 222 4545 5657 117 30 30 00 00 00 NO. OF DOUBLE LOCKAGES UP TOTAL NO. OF TRIPLE LOCKAGES DN TOTAL NO. OF SETOVER LUCKAGES DN UP TUTAL ND. OF MULTI-TON LOCKAGES UP TOTAL NO. OF OPEN-PASS LOCKAGES UP TOTAL 0 84 91 175 341 400 741 TOTAL ND. OF LUCKAGES DN UP TOTAL TOTAL NO. OF BARGES DN UP . TOTAL TOTAL TOW PROCESSING TIME 9674 UP 11951 21625 22.98 28.26 51.25 TOTAL DN UP PERCENT UTILIZATION . TUTAL

	MINFLD
TOTAL NO. OF TOWS ON	170
UP	155
TOTAL	325
NO. OF FULTI-LUCKAGE TOWS DH	0
UP	0
TOTAL	0
NO. DE TONS DELAYED DN	6.2
	50
2021	50
	102
TOTAL NO. OF LUADED BARGES ON	317
UP	402
. TOTAL	719
TOTAL NO. OF EMPTY BARGES ON	341
UP	246
TOTAL	587
TOTAL TONNAGE ON	336000
up.	547280
TOTAL	881240
TATAL BELLY TINE FUTUL ON	3003200
TOTAL DELAT TIME (MIN) UN	3040
UP	2976
TOTAL	6022
AVG DELAY FOR TOWS DELAYED ON	. 59
AVG DELAY FOR TOWS PASSING ON	16

THE CURRENT SIMULATION TIME IS 47521

NUMBER OF MINDR ERRORS THUS FAR

TABLE NUMBER 13 COMPOSITE LOCK STATISTICS

۱. .

WINFLS

10

000

0

86

150 317

248

7349

7130

4479

17.86

16.95

34.81

CHMB

LENGTH

0

Figure 1: Composite Lock Statistics (Table 13)

Computer Facilities Used

16. The CDC 6600 computer facilities located at the U. S. Army Mobility Engineering Research and Development Center (MERDC), Ft. Belvoir, VA, were used to make all simulation runs. Access to this computer system was made through the COPE terminal located at the WES.

PART III: ANALYSIS OF WINFIELD PROTOTYPE LOCKAGE DATA

General

17. The July 1975 prototype data collected under the PMS program provided the primary source of input data required by the TOWGEN/WATSIM model. Lockage data for three additional months (May, Sept, and Dec) were used in formulating average statistics for comparison with the July data and for determining seasonal effects on lockage and traffic characteristics. In addition, December 1975 PMS data were used during the calibration phase of the study, as will be discussed in Part IV of this report. The over 300 tow lockages recorded during July 1975 were considered to be an adequate sample size, and based on comparisons with other available data, July proved to be representative of the other months.

Barge Type Determination

18. A number of different barge types and sizes pass through Winfield. A careful study of the barge types using Winfield, as reported for July, resulted in the list of predominant types shown in Figure 2. Since integrated barges vary in size, a rule for classifying them by barge type had to be established. Considering that one of the alternative replacement locks proposed for study is 800 ft in length, a barge size of 265 ft in length was selected as the breakpoint for barges classed in the IC260 and IC300 classes. Barges between 201 ft and 265 ft in length can be placed in an 800-ft lock in three-barge long sections. No particular problem was encountered in type classifying the IP240 and IP260 type barge passing through Winfield during July.

Bivariant Density Distribution of Tow Types

19. The next step in the data analysis was to prepare a bivariant density distribution of tows classified according to the 10 predominant

Barge Type	Description
R BULK	175' x 26' Open & Covered Hopper; Bulk Commodities
J BULK	195' x 35' Open & Covered Hopper; Bulk Commodities
IP 240	240' x 50' Integrated Petroleum Barges
IP 260	260: x 53' Integrated Petroleum Barges
J TANK	195' x 35' Tank Barges (Petroleum & Chemical)
S CHEM	200' x 50' Chemical Barges
IC 260	260' x 53' Integrated Chemical Barges
IC 300	300' x 52' Integrated Chemical Barges
CEM 278	278' x 50' Cement Barges
SGC 110	100' to 125' x 26' Sand, Gravel, Clay, and Rock Barges

「「「「「「「」」」」」

A STATE AND A STAT

Figure 2 - Predominant Winfield Barge Types (Approx. Dimensions Indicated) barge types. These distributions consist of a count of tow types by horsepower and number of barges. Table 1 is a representation of these counts in the format required by the model and shows the percent of tows in each horsepower/size class by barge type. A number of mixed barge tows were classified according to the dominant barge type and included in the counts. When no dominant barge type was present in a mixed barge tow, such tows could not be included in these counts. These distributions were checked against the 4-month average distributions and found to be similar.

Current Lockage Types at Winfield

20. For each barge type classification used in the simulation model and each tow size based on the number of barges in the tow, a standard tow dimension (length and width) and type of lockage that would normally be expected at the existing Winfield Locks was developed. This was largely a hand computation task based on the average barge size and towboat length and current flotilla configurations. It was observed in the prototype data that all tows consisting of barges larger than standard barges (175 ft x 26 ft) were configured one barge wide; thus, this configuration was used in computing flotilla dimensions and lockage types. The assumed tow sizes and lockage types for the existing Winfield locks are shown in Table 2. Note, however, that WATSIM at present models multi-cut lockages that require more than two cuts by randomly drawing processing times from a single distribution of time, i.e., no consideration is given to the size of the tow being processed. When the sampling period includes a representative sample of the lockages occurring at the locks, the proportion of times randomly drawn from the processing time distribution will be the same as the proportion of lockages having 3, 4, 5, etc. cuts. The effect of this is that, as the fleet characteristics change, the time distribution for the lockages being used must be adjusted to reflect the changing proportions of processing times of these

							·		•	4			
										S	7 .		
•										•.	El Can	•	
	5	witto st	54+1 A00								mr.	101:	
		PREOU	EVEY OISTR	IBUTION OF	EXPECTED 1	TON CHARAC	124137108					Jon Ston	
	3U	I NON			•							30,	~
10. 07 144653 14852	125	375	150	1250	14T HCRSEP(1750	2250	2750	3500	4500	•	10746	**	
3447 ND1		•						•					
			0000	0000	0000	0000	0000	••••	0000	6000	0000	•	
			200		0-0			000 			0000		
•• :		000	••••	000	0000	000	000	000			000.0		
ERCENT	0.0	1.0	0.94	10.0	15.0	2.0	18.0	3.0	0.0	0.0	100.0		
TON TTPL	~												
- ~ ~ • •			00000 Néngr	00000 NN007							• • • • • •		
1014L		24.0		1.0	23.0	•••	• • •	• •	0.4	• •	100.5		
3411 +01													
				••••	0000 N N	0000	• • • • •	0000	0000 000N	0000	22.00 2000 2000 2000 2000 2000 2000 200		
TOTAL	.0.0	•••	0.0	38.0	\$5.0	25.0	•••	•••	12.0	0.0	100.0		
3411 401	•												
		0000 0000		0000 0000		6000 6000			0.000	0000	0.0000		
1014L PENCENT	0.0	•••	0.0	•••	10.0	0.0	•••	•••		•••	100.0		
		4	ABLE 1	TOW SIZ	E-110RSEP	CWER DI	TRIBUTIC	T YE SNC	OW TYPE			•	
•						(sheet	1 of 2)						

												1.	then -											
		•									4	54	51	r /	11)	·								
												·		- 1	V	9/2	4	9/						
														··				4	4	L	0	0	2	
	22.00	100.0		00000 ••••••			•••••	100.0		••••	24.0	100.0		••	100.0		35.0				12.0	100.0		
		0.0		00000	• •	•		0.0		•••		¢.0		•••	0.0		•••					•.•		
		0.0		40000 00000	• • •			0.0		•••		•••		•••	0.0		•••				0.0	e.s	•	• • •
	 	. 0.0		00000 00000	• •		0000	•••		0.0	•••			•••	0.0						0.0	0.0		
	0000 0000	0.0			0.0		0000	0.9	•	000	•••	5.0		•••	. 0.0		00.00				0.0	0.0		
	0000 0000	0.0		•••••	•••	· · · · · · · · · · · · · · · · · · ·	• •	•••			0.0	. 0.0		•••	•••		•••				0.0	0.0	+ 2 of 2	•
	 	0.0		00000	• • •		0.000			e	5.0	10.0		•••	0.0		•••				0.0	0.0	1 iShea	
	0000 • • • •	. 16.0		C	••			12.0		•••	0.0	0.0		93.0	100.0		23.0	 				27.0	TAINLE	
		39,0		6.000 6.000	•••		0000 ••••	20.0		•••	10.01	33.0	·	•••	0.0		•••				12.0	30.0		
•				90600 90600	• • •					• • • •	•••	•••		•••	0"0		00.0				0.0	13.0	•	•
	•••••	0.0	• •	*****	•••			0.0		•••	0.0	0.0	•		0.0	1 10	0.0				•••	12.0		· · · · · · · · ·
Tou tre		1014L	ets als		1014L	101 111		PERCENT	10- 11			PEACENT	104 110		11201	411 NO1	-~				10	PLACENT .		•

						-					
LOCKAGE	T	PES	BY	T	DW .	SIZE	A	D	BARGE	TYPE	
EXISTIN	G	360	x	56	ft	LOC	KS	AT	WINF	IELD	

	T	ow Length	Tow Width	Pusher Length	
No. Ba	rges	Ft	Ft	Ft	Lockage Type* *
			TOWS WITH "R	BULK" BARGES	
			(Barge Size = 1	175 x 26 ft)	
		240		65	55
		240	20	65	1
		240	52	65	. 44
		415	52	65	2
		415	52	65	5
	•	290	52	03	2
(5	590	52	65	2
	7	785	52	. 85	3 .
	8	785	52	85	3 :
		990	52	115	3
10		990	52	115	3
	1.1.1.1.1.1				
		TC	WS WITH "J BUL	K" BARGES	
			Barge Size = 1	95 x 35 ft)	
		265	35	70	1
		460	35	70	2
		675	35	90	3 .
		690	35	110	4
		1105	35	1 30	5
				-	
			TOWS WITH "IP	240" BARGES	
			(Barge Size = 2	40 x 50 ft)	
	1	340	50	100	1
	2	580	50	100	2
192 - 가슴 프로그램 193	2	840	50	120	. 4
	4	1110	50	150	5
-					
			TOWE WITH HTD	ANT BARCES	
			IOWS WITH TP	200 BAROLS	
			(barge Size =	200 x 33 11)	
				05	1
1		355	55	95	1
2		630	53	110	3
3		905	53	125	4
4		1190	53	150	5

		Tow Length*	Tow Width	Pusher Length	
No.	Barges	Ft	Ft	Ft	Lockage Type*
				IN BADCEC	
		TOW	S WITH "J TAN	IN DARGES	
		(ba	rge 512e = 19	5 X 55 IL)	
	1	265	35	70	
	2	460	. 35	70	. 2
	3	675	35	90	ž
	4	890	35	110	
	5	1105	35	130	5
				1.	
		. 7	OWS WITH "S C	HEM" BARGES	•
		(B	arge Size = 2	200 x 52 ft)	
		205	52	05	,
	2	295	52	110	;
	2	770	52	150	
	3	010	52	140	4
	4	1140	52	140	5
	5	. 1140	52	140	
	0	1340	32	140	•
	· ·	TO	WE WITH UIC	260" BADCES	
	·.	(B	arge Size = 1	260 x 53 ft)	
	,	355	53	95	: 1
	2	630	53	110	. 3
	2	905	53	125	. 4
	3	1190	53	150	5
		1150		200	
		Tr	WS WITH VIC	300" BARCES	
		(Ba	rge Size = 3	00 x 52 ft3	
	1	390	52	90	2
	2	710	52	110	. 3
	3	1015	52	115	4
	4	1340	52	140	5
		TOP	VS WITH "CEM	278" BARGES 78 x 50 ft)	
		(6)	The 2176 - 7		
	1	370	50	92	2
	2	646	50	92	3

TABLE 2 (Continued)

No	Barges	Tow Length *	Tow Width Ft	Pusher Length Ft	Lockage Type**
NO.	Darges				
		•			
		TOW	S WITH "SGC 1	10" BARGES	
		(Ba:	rge Size = 11	0 x 26 ft)	
	1	170	26	60	55
	2	170	52	60	55
	3	280	52	/ 60	1
	4 .	280	52	60	1
	5	390	52	60	44
	6	390	52	60	2
	7	530	52	90	2
	8	530	52	90	2
	9	640	52	90	2
	10	640	52	90	2

TABLE 2 (Continued)

*Tow length includes pusher length.

**Lockage types indicate number of cuts for standard lockages, except "55" which indicates multiple tow lockages are possible and "44" which is a single setover type lockage. type lockages (e.g., triples, quadruples, etc.). In order to keep the Winfield Study costs down, the model was not modified to include separate processing time distributions for the larger tows using Winfield. The verification tests demonstrated that this did not significantly affect the results of the study, particularly since only the existing fleet characteristics were considered. When modeling the ready-to-serve locking procedure, all cuts of a tow are individually accounted for.

Detailed Barge and Commodity Data

21. The model requires additional statistics identifying the load characteristics of the 10 predominant barge types. These data were obtained by accumulating the number (count) and the tonnages of each commodity type moved by each of these barge types during the representative month of July 1975 (see Table 3). From the information in Table 3, the barge type used to transport each commodity group and the average load in tons involved were easily tabulated as shown in Table 4. Thus, the percent of each commodity type group carried by the various barge types was determined for use as input data in the simulation model. There was a variation in the distribution of barge types transporting some commodities during July as compared with the 4-month average. An adjustment was made to the July statistics as indicated in Table 4 to more closely represent the 4-month average. Commodity Group 6 was added to more accurately simulate the passage through the lock of the special cement barges using Winfield, particularly for projected conditions.

22. For purposes of model calibration, the directional movement of commodities during the month of July 1975 was determined. These data were obtained by tabulating the commodity type and tons by direction for each loaded tow. Tow data were then summarized as shown in Table 5.

		SWA				SMG				- SW4	
Barge	No.	Commodity	Tons Cargo	Barge Type	No. Barges	Commodity Code	Tons Cargo	Barge Type	No. Barges	Commodity Code	Tons Cargo
2.1.	0										
R BULK	127	10	112,650	J TANK	2	12	2,400	IC 300	-	30	1,455
R BULK	24	51	19,050	J TANK	4	22	5,000	IC 300	14	35	51,400
R BULK	156	52	128,000	J TANK	-4	26	1,200	IC 300	00	66	24,500
R BULK	30	60	22,000	J TANK	27	30	42.700	•	ł		
R BULK	2	95	500	J TANK	. 5	31	3,400		23		57, 355
R BULK	1	66	100	J TANK	-	33	1,200				
	340		282,300	J TANK	-	34	1,200	CEM 278	2	19	17,600
				J TANK	-	36	1,200				
J BULK	92	10	123,900	J TANK	8	38	10,400	1			
J BULK	4	42	4,200		1			SGC 110	70	. 52	23,250
J BULK	1	45	400		. 48		68,700	SGC 110	νJ	90	1,500
J BULK	-	46	1,200								
J BULK	12	52	14,400	S CHEM	16	30	31,600		75		24,550
J BULK	۳Ì	54	6,175	S CHEM	-1	38	5,000				
								GRAND			
	113		150,275		17		34,600	TOTAL	612		879,615
		•		IC 260	. 9	30	13,900				
IP 240	16	22	34,200	IC 260	s	31	14,000				
				IC 260	42	66	112,500				
IP 260	20	22	56,245	-	:						
IP 260	5	24	9,500		22		140,400				
IP 260	4	25	3, 890								
	1										
	27		69,635					_			

TABLE 3 WINFIELD LOCKS TRAFFIC DATA SUMMARY - JULY 1975

The second second

Commo	dity Tonnag	es	[Commodity	Percentages	by Barge 1	fype
	Barge			Barge		
Commodity	Туре	Tonnage	Commodity	Туре	Tonnage	<u>°;</u>
Group 1-Coa	1		Group 1	•		
10	R BULK	112.650	10	R BULK	112.650	18
10	J BULK	123,900	10	J BULK	123,900	52
		236,550			236,550	100
Group 2-Che	emicals		Group 2			
30	J TANK	60,100	30	J TANK	60,100	20
30	S CHEM	34,600	30	S CHEM	34,600	12
30	IC 260	27,900	30 & 99	IC 260	140,400	48
30	IC 300	32,855	30 699	IC 300	57,355	20
99	R BULK	100	99	R BULK	100	0
99	IC 260	112,500	99.	SGC 110	1.300	0
99	IC 300	24,500			293.855	100
99	SGC 110	1.300				
		293.855	Group 3			
		,	51 52860	R BULK	169.050	57
Group 3-Age	regates		52	J BULK	14,400	-
51	R BIILK	19.050	52	SGC 110	25,250	11
52	P BILK	128,000		500 110	206 700	100
52	I DULK	14,400			200,100	100
52	SCC 110	27 250	Crown A			
52	D DULY	23,230	20	TANK	18 02:	16+
60	K DULK	22,000	20	ID 240	24 772	10-
		200,700	20	IP 240	60 675	12
			20	IP 200	09,033	100
Group 4-Pet	troleum	10 001 *			112,435	100
20	J TANK	18,021-				`
20	IP 240	24,779	Group 5		10 150	
20	IP 260	69,635	40654	J BULK	10,419	. 84*
		112,435	62		0	0
			95	R BULK	1,995	16*
Group 5-Oth	her			·	12,475	100
40	J BULK	5,050*				
54	J BULK	5,429*	Group 6			
62		0	61	CEM 278	17,600	100
95	R BULK	1,996*				
		12,475	Average L	.oad: Per Ba	arge (Tons)	:
			R BULK	830	IP 260	2250
Group 6-Cer	ment	17 600	J. BULK	1340	S CHEM	2030
61	CEM 2/8	17,000	J TANK	1430.	IC 260	2650
			IP 240	2140	IC 300	2540
			C		CEM 278	2510
"Adjusted	to represen	t 4-month aver	age		SGC 110	330

TABLE 4 WINFIELD STUDY COMMODITY GROUPS

AT) I	-	Э

Directional Movement of Commodities at Winfield During July 1975

	T	onnage (tons	5)
Commodity	IJp	Down	Total
Group 1			
10	68,600	167,950	236,550
Group 2			
30	68.400	21 255	89 655
31	17,400	0	17 400
33		1 200	1 200
34	1 200	0	1 200
35	600	50 800	31 400
36	1 200	0,000	1 200
39	11,000	2 400	13,400
100	138 300	2,400	138,400
33	130,300	100	130,400
	238,100	55,755	293,855
Group 3			
51	19,050	0	19,050
52	165,650	C	165.650
60	22,000	0	22,000
	206.700	0	206.700
			,
Group 4			
21	2,400	0	2,400
22	90.480	4,965	95.445
.24	9,500	Ó	9.500
25	3.740	150	3,890
26	Ó	1,200	1,200
	106,120	6,315	112,435
Group E			
and	4 200	•	4 200
42	4,200	0	4,200
45	1 200	0	1 200
40	1,200	1 075	6 175
34	4,200	1,975	0,175
62	500	0	500
95			
	10,500	1,975	12,475
Group 6			
61	17,600	0	17,600

24.

Tow Processing Times at the Current Winfield Locks

23. The analysis of the July 1975 tow processing times at Winfield is summarized in Table 6. The average lockage component times and frequencies of occurrence are given for each chamber on separate pages. An explanation of the lockage components listed in Table 6 follows:

- a. Single lockages, Up and Down Each tow requiring only one standard lockage (filling or emptying of the lock chamber once) with no reconfiguration of the tow was placed into this category and separated by the tow's travel direction (up or down).
- b. Double, and Double Knockout, Setover and Jackknife Lockages, Up and Down - The vast majority of the lockage types falling into this category were double lockages, indicated in the PMS data base as a standard lockage requiring two cuts. There were a few double setover type lockages in July but no double knockouts or double jackknives.
- c. Triple and Over Standard, Knockout, Setover, and Jackknife Lockages, Up and Down - No triple or over knockout, setover, or jackknife lockages were recorded by Winfield personnel during July. Tows requiring three, four, or five standard lockages were placed in this group and their chambering times computed.
- d. Single Knockout, Setover, and Jackknife Lockages, Up and Down - These type lockages are also relatively rare at Winfield, but a few did occur so that a frequency distribution of chambering times could be developed.
- e. Fly and Exchange Entries, Up and Down The type of entry made by each tow is indicated in the PMS printout as a fly, exchange or turnback "approach." The fly and exchange type entries were grouped together since both are considered to be "long" entries, i.e., entries that involve transit of the approach channel.

f. Turnback Entries, Up and Down - Such entry types were grouped separately because of the shorter entry times normally involved. A turnback entry occurs when two vessels traveling in the same direction are locked sequentially, thus allowing the second tow to maneuver close to the lock entry gates while the first tow is being serviced. Thus, the second tow can normally position itself to make a turnback (or short) entry.

TABLE 6

ちとない

and the second state of th

FREQUENCY DISTRIBUTION OF LOCK COMPONENT TIMES Winfield Lock - Chamber 1 (July 1975 Data)

.

1										2											3											
								5		2											60				-							
				N				12		3											3											-
0.1			-	9				~		15											3				-							
NCE				9	-			10		8					-						12	-										_
RRE				9		S		2		9					24	-					14	-				-						-
CCU		-		25		11		6		17					10	11					14					00						
10				25		33		0		\$					28	13					14					8						
ο°) λ	-			16		9		22		80		14		14	14	21	33				8					17	0					-
ENC				9	-	17		5		6		14		14	14	33	8	18	34	50	ŝ					80	6			34	50	
EQU	50	75		4		22		S		12		43		43	2	13	6	18	33	25	10					6	18	20	75	33	25	_
FR	50	25		m		9	-	1		11		29		29	8	6	50	64	33	25	S				-	20	24	So	25	33	52	
<u></u>										240											18											-
	-						-	220		220					/				-		15					-						-
				98				200		210									. '		14											
				78				170		190											13											
(SE)				73				150		160											12	311	31.6	SLE	SLE							
INUT				68		83		140		140					33						1	ICVI	LCNI	ICAL	ICAI.							
E (M				63		58		130		130					28	28					10	NPPI	NPPI	APPI	Iddy	38						
TIM				58		53	-	120		120					23	23					6	NOT	NOT	NOT	NOT	28						
				53		48		110		110		40		40	15	13	18				\$					1.8	23					
				48		43		100		100		30		30	13	13	13	13	9	r.	2					13	18			9	3	
	16	13		43		38		90		90		25		25	8	s	S	80	4	2	0				_	v.	v.	16	1	4	5	
	13	10		28		33		80		80		20		20	M	3	2	3	M	-	S					2	~1	13	10	3	-	
WTD	15	12		60		49		136		132		26		26	22	15	x	9	4	2	10	1	;	1	;	11	9	15	12	4	2	
7			er,		er,	•	ut,	s, th	tt,	s, Down																						
ESCRIPTION			ut, Setov	s, Up	ut, Setov	s, Down	d, Knocko	c Lockage	d, Knocko	e Lockage:	over, §	dŋ	over, 6	Down	s, Up	s, Down					(spuno	hort	Suo					dn .	, Down			
COMPONENT DE	ckages, Up	ckages, Down	ouble Knocko	nife Lockage.	ouble Knocko	nife Lockage	Over Standard	, & Jackknift	Over Standar	. & Jackknif	nockout, Set	fe lockages,	lockout, Set	fe Lockages,	nange Entrie	hange Entrie	Entries, Up	Entrics, Down		-	(or Swingar	Lockages, Si	Lockages, L	SC	sou	Entry, Up	Entry, Down	Tow Lockages	Tow Lockages	Exits, Up	Exits, Down	
	Single Lot	Single Lot	Double, Do	& Jackkr	Double, Do	6 Jackkr	Triple & (Setover	Triple & (Setover	Single Ki	Jackknil	Single M	Jackkni	Fly & Excl	Fly & Excl	Turnback 1	Turrback I	Exit, Up	Exit, Down	Turnbacks	Open Pass	Open Pass	Break Time	Remake Tin	Multiple I	Multiple I	Multiple 1	Multiple 7	Multiple I	Multiple I	

TABLE 6 (Continued)

FREQUENCY DISTRIBUTION OF LOCK COMPONENT TIMES Winfield Lock - Chumber 2 (July 1975 Data)

ŀ															4											
				4											4											-
ω F			m	4	0								-		4			-								-
ENC		м	m	4	0									-	~					-						-
EN -		6	9	4	11				10					-	0											
0F 0C		6	9	1	0				10	14			9	-	~					10					9	
		6	24	12	16				16	œ			13	0	11			-		10		S			m	-
C I	16	22	31	12	19		+	14	24	23	30	8	13	4	9					10	s	c	16	8	2	-
no	6	22	15	27	5	:	1	14	19	35	20	16	9	13	10			-		30	16	61	26	16	9	-
FRI	19	17	9	:	M		<u>,</u>	43	10	16	30	6	31	52	8					30	6	19	37	5	Ē	
	21	6	0	=	0		2	29	S	4	20	67	31	23	12					20	6.7	50	21	67	5	
- 00					S. Dege										18						_					-
-					190										15											-
				250	170					-	-			-	14											-
			73	230	150								-	-	13	-										-
	1.1.1	88	68	06	30										12											-
UTES		83	53	50 1	20 1				33						11											-
(MIN		73	ŝ	1	1				8	8			1		0	AIL LE	VINLE	URLE	BLE						2	
빚		80	m						m	15			5	0	6	LIC/	LIC/	1017	LICI	8	1	-		-		
11	M 012	0	3	13	10			-	2	2			-	-	-	ddv	APP VPP	APP	APP	3 2	-	M.		-		
	1 N	3	4	12(6		-	4	ñ	-	-		-			NOT	NOT	NOT	NOT	1 18	=	51	2	Ξ	4	_
	16	58	43	110	80		2	30	13	13	13		m	5	1					13	¢	16	13	s	5	
1. 100	13 10	53	38	100	70	26	3	25	8	8	8		~	5	9					S	5	13	10	5	2	-
2.9%	10	48	33	06	50	00	2	20	2	3	2	3	-	-	S	10				n	~	10	2	CI	-	-
WTD	14	63	SC	129	116	26	2	26	20	16	11	S	m	2	10	;	:	:	:	15	S	14	11	41	m	-
COMPONENT DESCRIPTION	Single Lockages, Up Single Lockages, Down	Double, Double Knockout, Setover, & Jackknife Lockages, Up	Double, Double Knockout, Sctover, & Jackknife Lockages, Down	Triple & Over Standard, Knockout, Setover, & Jackknife Lockages, Up	Triple & Over Standard, Knockout, Setover, & Jackknife Lockages, nown	Single Knockout, Sctover, § Jackbrife Lockanos 110	Single knockout, Setover, &	Jackknife Lockages, Down	Fly & Exchange Entries, Up	Fly & Exchange Entries, Down	Thumback Entries, Up	Turnback Entrics, Down	Exit, Up	Exit, Down	Turnbacks (or Swingarounds)	Open Pass Lockages, Short	Open Pass Lockages, Long	Break Times	Remake Times	Multiple Entry, Up	Multiple Entry, Down	Multiple Tow Lockages, Up	Multiple Tow Lockages, Down	Multiple Exits, Up	Multiple Exits, Down	

Exits, Up and Down - The exit times of single lockage tows g. only were compiled since the WATSIM defined exit times cf tows requiring other lockage types could not be computed using the PMS data. The PMS exit times for these other lockage types include the time for reconfiguring the tow for transit in the river. This is considered to be a valid approach since almost all normal exit times are relatively short, regardless of tow size or horsepower.

- <u>h</u>. Turnback Times required to fill or to empty the lock and their frequencies of occurrence were recorded for each chamber.
- i. Open-Pass Lockages, and Tow Break and Remake These lockage components are not applicable at this time to the Winfield capacity study.
- j. Multiple Entries, Up and Down This involves the entry time required by two or more relatively small tows which are to be processed in a single lock operation. Due to the lack of data, turnback entry times were used to approximate multiple tow entry times. This approach should have no effect on the model results since multiple tow lockages occur very infrequently at Winfield.
- k. Multiple Tow Lockages, Up and Down Again, since no data were available, standard single lockage times and distributions were employed for modeling purposes in lieu of actual multiple tow lockage times.
- 1. Multiple Exits, Up and Down Single lockage tow exit times were used for this data element also.

24. The lockage component times, computed using the PMS data were placed in groups according to their magnitude, the average of each time group computed, and a frequency distribution developed. From these data, the frequency of occurrence was computed on a percentage basis as shown in Table 6. The only deviation from the July 1975 prototype data concern a small number of recorded entry times that seemed to be excessively long. These long entry times were eliminated as unrepresentative samples and the occurrence frequencies of the longest entry times shown in Table 6 were increased. Subsequent tests of the effects of these modifications indicated that they had very little effect on the simulation run results. Concern was expressed to the Huntington District about these observed long times required for both fly and exchange approaches and turnback approaches, some of which were nearly an hour in length. The Huntington District investigated this and verified that such long entries do occur. Reasons for such long approaches include:

- a. The presence of one sharp bend in the downstream approach with a narrow channel, about 300 ft wide.
- b. The extensive maneuvering required by a tow entering from the downstream approach.
- c. The low horsepower of some of the towboats.
- d. Under certain conditions of current and wind, maneuvering is excessively difficult.
- e. Short river guard walls at the locks.

PART IV: TOWGEN/WATSIM MODEL CALIBRATION

General

25. This part of the report discusses the results of efforts to calibrate the simulation model to insure that it will reasonably reproduce selected historical prototype statistics. Tabular comparisons of the significant Winfield prototype data and the calibrated WATSIM output are shown in Tables 7, 8, and 9.

26. The statistical lockage data used for verification are summarized for both chambers as a single facility in Table 7 and for each chamber in Table 8. As shown in Table 7, prototype data used for verification covers the following three different periods:

a. July 1975.

b. Four-month average for May, July, Sep, and Dec 1975.

c. December 1975.

July 1975 data only were used for verification by chamber (Table 8).

27. The simulation runs were made for a typical 30-day month and then the results were adjusted for comparison with the two 31-day months (July and Dec). Cement was broken out as a separate commodity in the model so that the proper mix of the various types of barges could be more accurately reproduced by the model. As mentioned earlier entry times were revised slightly to eliminate the few entry times considered to be exceptionally high; however, this had essentially no effect on the simulation run results.

Adjustments to Input Data During Model Calibration Runs

28. Only a minimal number of simulation runs were required to calibrate the model. Before each separate run, the input data were adjusted as deemed necessary after careful study of the latest run. In general, the following significant adjustments to the input data
TABLE 7

WINFIELD LOCKS AND DAM SIMULATION MODEL VERIFICATION

Comparison of Total Results for Locks

scription Tows s & Larger rs Barges ation Ktons elay of Tows yed	Verifica- tion Run 31 Days 31 Days 537 14% 33% 51% 51% 51% 51% 51% 51% 51% 51% 51% 53% 53% 53% 53% 53% 53% 53% 53% 53% 53	July 75 323 13% 35% 52% 22% 684 (49%) 42.5% 879 879	Differ- ence +4 +1 -1 -1 +1 +1 +1	4-Month Average ** 328 11% 35% 51% 51% 2% 749 646 (46%) 911	Differ- ence +3 +3 -2 -2 -2 -2 -2 -2 -2 -2 -3 -3 -3 -3 -3 -3 -3 -3 	Verifica- tion Run 31 Days* Dec 75 Input# 286 16 29 53 53 2 498 (47%) 789 789 789	Dec 75 297 35% 51% 23% 625 625 797 *	Differ encer + + + + + + + + + + + + + + + + + + +
	17 2.63 4.15	18 2.72 4.35		2.78		18 2.76 3.73	2.68	

*Adjusted from 30-day month values provided by simulation run. **May, July, Sep, Dec 1975 (multiple tow lockages amounting to 1% of all lockages not included above). #Dec 75 0-D matrix only; other input data based on July prototype duta.

VERIFICATION
MODEL
SIMULATION
MVD
UNN
LOCKS
WINFIELD

Comparison of Results by Chamber

	Verifica- tion Run 31 Days		Differ-
Description	Jul 75 Input	Jul 75	80
Chamber 1			
Total Tows	176	172	+2
Singles	113	53	9+
Doubles	213	29%	89 -
Triples & larger	67%	64%	+3
Setovers	2\$	28	•
Total Barges	721	798	
Utilization	:61	51%	
Chamber 2			
Total Tows	, 161	151	2+
Singles	19%	23%	4-
Doubles	45%	. 37%	6+
Triples & larger	33%	38%	-S
Setovers	2%	2%	0
Total Barges	679	606	+12
Utilization	33%	34%	

Adjusted from 30-day month values provided by simulation run.

TABLE 9

100

WINFIELD LOCKS AND DAM SIMULATION MODEL VERIFICATION

Comparisons of Results Using 1975 Total Annual Tonnages

......

	tion Run 1 Drve	4-Month	Differ-
Description	Total 1975 Input#	Average**	200 C
Total Tows	336	328	+2
Singles	e.so	11%	-3
Joubles	343	35%	1-
Triples & larger	56%	51%	+2
Setovers	2%	2%	0
Loaded Barres	742	749	
Empty Barges	607 (45%)	646 (46%)	7
Utilization	42.5%	:	
Fotal Ktons	912	911	0
Ave. Delay of Tows Delayed	59	:	
Ave. Delay of Tows Passing	15	:	
Ktons/tow	2.71	2.78	
Jarges/tow	4.02	4.25	

*Adjusted from 30-day month values provided by simulation model. •*May, July, Sep, Dec 1975 (multiple lockages amounting to 1% of all lockages included above). #Total 1975 tonnages by commodity were based on the lockmaster's records. Di

tional movements were based on 1974 percentages. Cement was broken out of the commodity grouping "Other" in the same proportion as estimated for 1980 (Reference: ORNED-PE letter dated 12 May 1976, subject: Capacity Studles of Winfield Lock and Dam, Kanawha River). Annual tonnages were reduced internally by the model through input data (tonnage divisions) to represent equally distributed monthly averages. Direcwere made to calibrate the model:

- a. The horsepower vs number of barges per tow frequency distribution (often referred to as tow codes) was revised slightly to permit the model to more closely reproduce the actual mix of the several different lockage types, i.e., singles, doubles, etc. This change was based on the observation that there was a large number of tows with mixed barge types that required double lockages. As these tows are not modeled directly, the size distributions of the regular and jumbo hopper barges were adjusted to represent these tows in the vessel mix. This brought the ratio of lockage types into close agreement with observations.
- b. Dedicated equipment percentages for several of the barge types were adjusted in order to reproduce the correct ratio of empty-to-loaded barges passing the locks. There appears to be a large number of independent operators, and small towing companies operating on the Kanawha. Therefore, even though commodities using the same or similar barge equipment move in both directions, most of these movements involve empty backhauls. Interlining of equipment does not appear to occur frequently.
- C. Chamber penalty times for selected lockage types were varied in several runs so that the use of the two chambers by various size tows could be more closely represented. This is influenced by the heavy use of Chamber 2 for recreational craft lockages and by the program logic used in selecting chambers. WATSIM assumes the second chamber to be less used than the first chamber because usually that chamber is smaller. At Winfield, both chambers are the same size.

Summary of Calibration Results

29. A review of Tables 7, 8, and 9 indicates that the final calibration run results and corresponding prototype data compare exceptionally well with one another in almost every case. A primary measure of good modeling results is the reproduction of the number of observed tows, tonnage, ratios of lockage types, and ratio of empty to loaded barges. As indicated by Table 7, the total number of tows passing through the lock during the sampling period is reproduced within 4 percent by the model. The tonnage passing the lock is reproduced within 1 percent using calibration input data (lockage component times, flotilla makeup, tonnages, etc.) and the July tonnage O-D matrix, and comparing the results with the actual July prototype data; within 3 percent using calibration input data and July tonnages and comparing the results with the 4-month average; and within 1 percent using the actual December tonnage O-D matrix together with calibration input data and comparing the results with December prototype data. The ratio of the four lockage types analyzed and the ratios of empty to loaded barges (percent empties) also compare favorably in each of the three cases shown on Table 7.

30. Table 8 shows the comparison of simulation model results and July prototype data by chamber. The model automatically assigns each approaching tow to one of the two chambers by considering the expected time for completion of lockage, accounting for vessels in queue and chamber penalty times, if any, as primary criteria for chamber selection. Since the model internally controls the assignment of tows to the chambers, the differences between the model's output and corresponding July data are not considered to be too great especially considering that Chamber 2 is used heavily for locking recreational craft which are not reproduced in WATSIM. It should be observed that the model correctly simulates the observed tendency for large tows to favor the use of Chamber 1. All comparative data are within 10 percent of one another except the total barges processed by Chamber 2, which deviates by only 12 percent from the actual count.

Seasonality of Commodity Movements

いるいでもないると

31. Since historical monthly tonnage data were available for 1970 through 1975, the effect of seasonal movement variations on lock utilization was investigated. A review and analysis of these monthly tonnage levels revealed that slight seasonal variations exist for only one commodity group: stone, sand, and gravel. However, peak movements for all commodities appeared during all months over the 6-year period of

record irrespective of the season. Using the 4-month averages for verification purposes, a test run of the model was made using 1975 total annual tonnages in the 0-D matrix, dividing the movements equally over the 12-month period for each of the six commodity groups. This, in essence, assumes no seasonal variation since total annual tonnages for each commodity are divided by 12.0 to get a monthly average for the year. A comparison of model results and the 4-month averages is shown in Table 9. The close reproduction of prototype data using 1975 total tonnages as input data further strengthens the accuracy and validity of the WATSIM model. Due to the seasonality of the aggregate movements, greater delays would probably be experienced at Winfield at some times during each year than at other times; however, the only apparent effect is due to the increased tonnage passing during that period, not the mix of vessels. This can easily be accounted for in determining annual delay values for projected periods, as will be explained in Part V.

いいないというないないないのである

PART V: CAPACITY DETERMINATIONS OF THE EXISTING WINFIELD LOCKS

General Method of Determining Capacity

32. Two primary approaches were used to analyze the capacity of existing lock facilities at Winfield: increases in delay times and lock utilization as functions of increased commodity tonnages. Both methods should yield similar results since the delays increase rapidly as lock utilization approaches 100 percent. Delay times reflect the economic costs to shippers and are indicative of both economic and physical capacity constraints. Lock utilization values are more indicative of the approach to physical capacity. Such studies give a good indication of the current lock's capability to handle the projected traffic levels. For each alternative lock operating policy, the analysis involved plotting the experimentally determined values, determining the range of experimental sample values, fitting functions, and plotting curves to these data points using the least squares method. These plots are included in Part VI of this report. Further statements of general applicability to the capacity studies of Winfield are contained in the remaining sections of Part V.

Lock Operating Policies Studied

33. The following four operating policies were analyzed separately to determine the positive impact of these potentially less expensive alternative interim solutions:

- a. First In, First Out (FIFO), Unrestricted This simply means that the tows are serviced in the order of their arrival and that no restriction is placed on their barge configuration (tow makeup) or size as they approach the lock, i.e., no remake or reconfiguration of the barges is required until after the lockage process begins.
- FIFO, Unrestricted with a 10 Percent Reduction in Lockage Component Times - All lockage component times were arbitrarily reduced by 10 percent to determine the effects of improving the overall efficiency of locking operations regardless of the methods employed.

- C. FIFO Ready-to-Serve This operating policy prohibits the break and remake of tows within or in the vicinity of a lock chamber. Each separate cut of a large tow is assumed to lock immediately following one another and is considered to be independently powered. This operating policy would require several switchboats at the lock at all times to assist in the locking operations and, therefore, may not be practical. Further discussion of the Ready-to-Serve policy is included in Reference 2.
- d. 3 Up-3 Down Three upbound tows are locked consecutively followed by three downbound tows, or vise versa. If the queue in the pool from which tows are being locked empties prior to reaching the maximum of three vessels, tows from the other pool are then selected. For this policy, it is assumed that the last two tows in sequence will approach the lock and, therefore, their entry will be of the turnback (or short) entry type.

Reduction and Analysis of WATSIM Output

34. As discussed in Appendix B, the WATSIM program prints for each 3-day sample period the cumulative delays, commodity tonnage, and tows processed from the beginning of the simulation to that period. A total of 10 sample interval printouts are thus obtained from a single WATSIM run. The sample intervals chosen for analysis of the existing Winfield locks were five 3-day periods. The delays, tonnages, etc., were then increased by a magnitude of 10 to obtain monthly values (assuming a 30-day month). Appendix B discusses the rationale for choosing the 3-day intervals and compares a number of other possible intervals that could have been selected. Appendix B also includes a table of the five sample time intervals used in this study.

35. The data taken directly from Table 13 of the WATSIM printouts are tabulated as shown for each alternative operating policy in Appendix C. For each year included in the study, the number of tows, monthly delay, and monthly tonnage were computed for the sample intervals. Monthly delays and tonnages were simply multiplied by 12 to obtain the annual delays and tonnages shown in Appendix C. In addition, the percent utilization during each sample interval was recorded. The monthly delays and tonnages were plotted initially and then consideration of the effects of monthly variations in the commodity movements were accounted for by plotting annual delay and tonnage curves, as described in Paragraph 37. The unadjusted annual delays and tonnages shown in Appendix C were used to generate the tonnage vs utilization and delay vs utilization plots.

Projected Tonnage Levels

36. The 1975 and future year tonnage levels used in the simulation runs are shown in Table 10. The "Notes" below the table explain the source of these tonnages. Since projected tonnages for 1980 and 1990 only were available, a simple scheme for increasing tonnages in steps was used in order to simulate infinite queuing conditions at the existing locks. Tonnages for each commodity were increased by reducing the "divisors" in the TOWGEN deck before each run. This procedure is explained in more detail in Appendix D. The years beyond 1990 (1993, 1998, etc.) in Table 10 relate to the tonnages obtained by using the divisors 11.0, 10.0, etc., and the trend of total tonnage increase between the years 1980 and 1990. This in effect assumed that all commodities would grow at the same rate and the proportionate distribution of the commodity tonnages would remain constant. The relationship between 1993 and the divisor of 11.0 is shown in Table D1. A trend projection method could also have been used with slightly more effort involved in changing the cards before each TOWGEN run. However, it was felt that in view of the variations in the sample delays and the high projected utilization of the lock in 1990, very little difference would be recognized in the WATSIM output (tonnages, delays, etc.), regardless of which projection method was used for years in the distant future. In addition, Huntington District had expressed concern about the validity of projected tonnages beyond 1990 and considered that

					Year				
					1993	1998	2002	2009	2017
Commodity	1975	1980	1985	1990	11.0*	10.0*	9.0*	8.0*	7.0*
Coal	3,783	7,252	8,439	9,626	10,501	11,551	12,839	14,439	16,502
Up	265	609	949	1,288					
Down	3,518	6,643	7,490	8,338					
Chemicals	3,392	6,732	8,455	10,177	11,102	12,212	13,569	15,266	17,446
Up	3,087	6,032	7,620	9,208					
Down	305	700	835	969					
Aggregates	1,655	1,952	1,927	1,903	2,075	2,283	2,537	2,855	3,262
Up	1,638	1,946	1,922	1,899			1.5		
Down	17	6	5	4					
Petroleum	1,111	1,166	1,371	1,576	1,719	1,891	2,101	2,364	2,702
Up	1,078	1,143	1,347	1,551					
Down	33	23	24	25			-		
Other	639	691	865	1,035	1,132	1,245	1,384	1,557	1,779
Up	537	599	751	903		1.0			
Down	102	92	114	135					
Cement	160	173	171	168	183	202	224	252	288
Up	160	173	171	168					
Down	0	0	0	0					
All Com.	10,740	17,966	21,228	24,488	26,712	29,384	32,708	36,733	41,979
Up	6,765	10,502	12,760	15,017					
Down	3,975	7,464	8,468	9,471					
	•								

TABLE 10 PROJECTED ANNUAL TONNAGE LEVELS FOR WINFIELD LOCKS AND DAM (K TONS)

*Divisor

Notes: 1975 tonnages are based on lockmasters' records; 1980 and 1990 projections were determined by the Huntington District (ORHED-PE), 1985 tonnages are linear in interpolation of the growth rate between 1980 and 1990; 1995 and beyond tonnages were artificially produced by using TOWGEN 'Tonnage Divisors" of 11.0, 10.0, 9.0, 8.0 and 7.0. The years 1993, 1998, 2002, 2009, and 2017, respectively, were assigned to these tonnage levels based on linear extrapolations of the projected 1980 and 1990 tonnages. resource studies should be initiated prior to accepting any projected tonnage levels for time periods beyond that year. Since these tonnage levels were being used only for establishing the locks' capacity, the more straightforward approach was selected. A comparison of the tonnages obtained from both methods is given in Appendix D also.

Procedures Used to Develop the Lock Capacity Curves

37. Based on output from the simulation model, a monthly delay versus monthly tonnage plot was made for each of the four alternative operating policies tested (see Part VI). These plots show the rate that monthly delays are expected to increase as tonnages moving through Winfield grow in future years. The extremely high delays are indicated at the top of each figure, where appropriate, to indicate the magnitude of the values that could not be plotted. From these monthly plots and the historical data on monthly variations in commodity movements, a plot of adjusted annual delays versus annual tonnages was developed. This plot is shown later in the report but the method used to produce it will be explained here, since all four alternative lock operating policies are involved. To a degree, the adjusted annual plots developed in this manner take into consideration the effects of the slight seasonal variations in the traffic passing through Winfield.

38. The monthly movement of commodities for a 6-year period (1970-1975) was available from the lockmaster's records. Table 11 shows these monthly tonnage levels in terms of average percentages of the total annual movements during this period. Actual 1975 monthly tonnages are also shown together with projected monthly levels for future years, based on the historical monthly averages. With these tonnage values, the delays shown for each alternative lock operating policy were obtained from the appropriate monthly delay versus monthly tonnage plot. The total annual delays and tonnages shown in Table 11 were then plotted for each operating policy as four separate curves in

	Per muler	Multi matrix Multi matrix<	¹ arrente mucht precenten hand en 1974 1975 commedity wonnent. ² rmanied be Macingen Dirtreic (1986-141). Reinsted be wird 14.0, erspectively, an commedity formare divident in 78035 for the years 1993, 1994, 2002. 2199, and 2017. Directed be wird 14.0, 10.0, 6.4, 2.4, 2.4, 2.4, 2.4, 2.4, 2.4, 2.4, 2	
--	-----------	--	---	--

a single figure. For the exceptionally high tonnage levels that occurred after the monthly delay versus tonnage curves became vertical, the value ">3000" was used in order to obtain the totals in Table 11. Some of the high projected tonnages would undoubtedly have resulted in total delays much longer than 3000 hours; however, the exact figures for these delays could not be obtained from the curves. Therefore, these adjusted annual delay values are only illustrative of the delays that might be incurred. In reality, the full tonnage levels for those months could not have been serviced and the traffic would have been diverted or would have been delayed until a month with less tonnage.

39. As indicated in Table 11, tonnages were increased until "infinite queuing" occurred in the simulation model. This means that the traffic waiting to be serviced reached the preset limit of 30 tows. This value, though set arbitrarily, was chosen for two reasons. First, 30 tows waiting to be serviced on each side of the lock is considered an "impossible" situation from a practical standpoint, especially since the average interarrival time (time between tows arriving at the locks) at that traffic level is much less than the average service time. Secondly, as in the prototype, the queues are not static, but build and diminish. With a more reasonable preset queue limit (say 15 tows), a slight increase in the number of tows in queue might cause premature termination of a simulation run, i.e., infinite queuing would occur due to an unusual series of tow arrivals. To avoid such occurrences and to allow very high lock utilization values and tow delays, a large number, e.g., 30 for these runs, was selected.

Interpretation of the Capacity Curves

40. The delay versus tonnage curves become asymtotic as tonnage levels increase. That is, at some point on the delay versus tonnage curve, a slight increase in tonnage will cause an extremely large increase

in total delay. When this occurs, an unstable condition in the relationship between delay and tonnage develops, producing a band of uncertainty in the capacity. A least squares regression of an exponential function was attempted for all test cases; however, the exponential function diverges in the area of instability due to the fact that it is an ever increasing function and has no asymtotic value.

41. The region where the delay versus tonnage level approaches an asymtotic value of tonnage defines the physical limitation of tonnage or capacity that can be serviced under the given operating conditions (service times, lock operating policy, fleet characteristics and commodity mix at given tonnage levels). Practical tonnage capacity levels would fall below this region due primarily to three reasons:

- At such high lock utilization levels, the total delay of tows is very sensitive to the specific tow arrival pattern.
- b. Small changes in particular queuing characteristics can cause dramatic increases in the delay costs incurred by the towing industry.
- c. No allowance is made in the simulation procedure for maintenance and accident downtime nor for utilization of the locks for recreational craft and work boats.

42. A study of lock utilization as a function of tonnage and/or delay is another way to determine the capacity of a lock. The tonnage versus utilization is linear in most cases and once a specific value of utilization is chosen to represent a capacity level of usage, a specific level of tonnage associated with that utilization can readily be obtained for use in an economic evaluation of both structural and nonstructural alternative lock improvements. The delay versus utilization curve is provided so that a corresponding total delay time to be expected for a particular utilization can also be determined.

43. With the tonnage versus utilization and delay versus utilization plots, some of the other variables of lock operation can be considered by adjusting utilization and obtaining a revised capacity level. This becomes necessary because the simulation model does not account for all factors involved in the capacity of a lockage facility. For example, the simulation model used for this study considers only the tows with one or more barges. It has no direct means of introducing work boats, towboats without barges, pleasure craft or other relatively small, but often numerous, boats into the simulation process. The utilization curves provide a means of subtracting the percentage of lock utilization attributed to these other users. Another factor, downtime due to mechanical failures, maintenance, or accidents can also be easily compensated for by using these types of capacity definitions.

PART VI: WINFIELD CAPACITY LEVELS FOR FOUR ALTERNATIVE OPERATING POLICIES

General

44. Figure 3 lists the simulation run sets made for each of the four alternative operating policies tested. Numerous additional runs were initially planned for the study but had to be suspended to concentrate efforts on the Gallipolis study. Only a "Most Likely" tonnage projection set was used in the capacity tests even though plans also called for considering an alternate (either high or low) projection set. As shown in Figure 3, only the existing Winfield lockage facilities were simulated. The other lock system alternatives to be studied at a later date include:

- a. Dual 800- x 110-ft chambers at the current site.
- b. Dual 800- x 110-ft chambers at a selected site upstream from the current site.
- c. Dual 800- x 110-ft chambers located in a channel cut through a bend near the present dam.
- d. Either dual 1200- x 110-ft chambers or dual 600- x 110-ft chambers, depending upon the results of previous simulation runs (site to be selected).
- e. A single chamber lock either 1200- x 110-ft or 600- x 110-ft, whichever is selected, so that phased construction of the dual chambers can be considered.

Three fleet characteristic sets were planned since simulation results are sensitive to the types and sizes of the flotillas using the locks. This effect is primarily caused by the type of lockages (singles, doubles, setovers, etc.) required to process the various sized flotillas. The three proposed fleet characteristics included the currently observed tow makeups passing the Winfield Locks, the currently observed tow makeups passing the Gallipolis Locks on the Ohio River, and a set of fleet characteristics that make optimum use of the proposed lock sizes. The use of the Ohio River fleet characteristics would allow evaluation of the impact resulting from a shift of tow makeups toward the sizes operating on the Ohio. The traffic on the Kanawha River will most likely

Run Number	Description*
1M01WFU75	FIFO-Unrestricted (FU), Year 1975
2M01WFU80	FU, Year 1980
3M01WFU90	FU, Year 1990
4M01WFU93	FU, Year 1993 (Tonnage divisor = 11.0 ea. commodity)
5M01WFU98	FU, Year 1998 (Tonnage divisor = 10.0 ea. commodity)
6M01WFU75	FU, Year 1975, 10% reduction in all lockage times**
7M01WFU80	FU, Year 1980, 10% reduction in all lockage times**
8M01WFU90	FU, Year 1990, 10% reduction in all lockage times**
9M01WFU93	FU, Year 1993 (Tonnage divisor = 11.0 ea. commodity), 10% reduction in all lockage times**
10M01WFU98	FU, Year 1998 (Tonnage divisor = 10.0 ea. commodity), 10% reduction in all lockage times**
11M01WFU02	FU, Year 2002 (Tonnage divisor = 9.0 ea. commodity) 10% reduction in all lockage times**
12M01WFR75	First In First Out-Ready to Serve (FR), Year 1975
13M01WFR80	FR, Year 1980
14M01WFR90	FR, Year 1990

* All runs were made using a most likely tonnage projection set, current Winfield L&D fleet characteristics, and the existing Winfield lockage facilities.

** Includes all components of the lockage procedure, i.e., entry, chambering, and exit.

Figure 3. Simulation model runs for the Winfield L&D Capacity Study (Single Lock Configuration)

Run Number	Description*
15M01WFR93	FR, Year 1993 (Tonnage divisor = 11.0 ea. commodity)
16M01WFR98	FR, Year 1998 (Tonnage divisor = 10.0 ea. commodity)
17M01WFR02	FR, Year 2002 (Tonnage divisor = 9.0 ea. commodity)
18M01WFR09	FR, Year 2009 (Tonnage divisor = 8.0 ea. commodity)
19M01WFR17	FR, Year 2017 (Tonnage divisor = 7.0 ea. commodity)
20M01W3U75	3 Up-3 Down, Unrestricted (3U), Year 1975
21M01W3U80	3U, Year 1980
22M01W3U90	3U, Year 1990
23M01W3U85	3U, Year 1985

Figure 3 (Cont.)

be tending towards these characteristics. The optimum sized tow set would demonstrate what efficiencies could be obtained if the towing industry could make up its tows in that manner. To date simulation runs include only the current Kanawha River fleet characteristics.

FIFO - Unrestricted Operating Policy

45. The capacity curves for this operating policy are shown in Figures 4, 5, and 6. Figure 4 defines the minimum and maximum limits of the region of instability of the locks to be 1.88 and 2.39 million tons per month, respectively. The legend in Figure 4 includes utilization increases with increasing traffic.

FIFO - Unrestricted with a 10 Percent Reduction in Lockage Component Times

46. The lockage component time distributions obtained from an analysis of the July 1975 prototype data and used in the FIFO - Unrestricted runs discussed above were reduced by 10 percent to model the effect of more efficient locking operations, by whatever means this might be accomplished. This resulted in a capacity increase of less than 10 percent in both the minimum and maximum limits of the region of instability 2.00 and 2.55 million tons per month, respectively, as shown in Figure 7. Figures 8 and 9 are the accompanying tonnage versus utilization and delay versus utilization plots for use in determining tonnages and delays associated with selected levels of lock utilization.

FIFO - Ready-to-Serve Operating Policy

47. As expected, dramatic increases in the capacity of the locks could be attained if the FIFO - Ready-to-Serve operating policy is practical. Figures 10, 11, and 12 graphically summarize the results of







and the state of the











ころでは、「いい」というというというないである











3.24 million tons per month would be possible with this policy. However, the feasibility of adopting such a rule at Winfield is questionable. The relatively small existing lock chambers coupled with the exceptionally high percentages of tows requiring three or more cuts discourages the use of a ready-to-serve operating policy at Winfield. A number of switchboats or helper boats would be permanently required at the locks to assist in the locking operations. The cost of such operations in terms of both equipment and manpower may make this alternative economically infeasible. It may be possible to have the industry assist each other if insurance and other obstacles to such assistance could be rendered. In any case, mooring and reflecting areas in the vicinity of the locks would be required.

3 Up-3 Down Operating Policy

48. The results of the 3U3D simulation runs are shown in Figures 13, 14, and 15. Due to unforeseen miner problems with the simulation model, a complete run to include all five sample time intervals for each tonnage level tested could be made only for the year 1975, as shown in Table C4. Table C4 also shows the reduced number of intervals produced for the other years. The limited sample data obtained from the model runs are considered to be accurate; however, a few additional data points would have been helpful in plotting the curves shown in Figures 13 and 15. Time did not permit a revision of the program and the computer runs required to obtain the desired additional data points. The curves were approximated using the available data and are considered to be reasonably representative of the delays to be expected under the 3U3D operating policy.

49. As indicated by Figure 13, the 3U3D operating policy would actually result in increased delays, as compared to the current FIFO-Unrestricted Policy at Winfield. This is because the small reduction in service times as the result of a lock turnback plus tow short entry, in lieu of an exit plus a long entry, is not enough to compensate for the

longer total waiting times inherent in the 3U3D operating policy. The longer waiting times are imposed on tows that arrived at the lock sooner than the tows being locked ahead of them. The tests of the 3U3D rule thus demonstrate that it is not a potential alternative operating policy for Winfield.

PART VII: CONCLUSIONS

50. Figure 16 graphically compares the annual tonnages and adjusted annual delays for each of the four alternative lock operating policies tested. These curves were constructed as described in Paragraphs 37-39 to take into consideration the small monthly variation in commodity movements at Winfield. Table 12 presents a tabular comparison and test summary for the four operating policies. If practical, the Ready-To-Serve policy would result in the most efficient use of the lock chambers themselves. However, due to the frequent need of several switchboats to assist large tows and the prevailing approach conditions at Winfield. the practicality of such a policy is questionable. Feasibility studies would be required before the Ready-to-Serve policy could be seriously considered as a potential means of increasing the locks' capacity. The 3U3D policy proved to be worse than FIFO mainly because of the present exceptionally long "short" entry times at the lock. (A "short" entry is usually possible when two or more tows traveling in the same direction are locked sequentially. The entering tow is permitted to tie to the guide wall only a short distance from the gates of the lock.) A number of factors such as the approach conditions, horsepower of towboats, tow lengths, type of cargo, river currents, and winds, among others, adversely influence entry times at Winfield, thus dictating that additional study would also be required for this alternative before it could be seriously considered as a potential operating policy. The FIFO, Unrestricted Policy with a 10 percent reduction in lockage component times would result in about a 6.4 percent and 6.7 percent increase in the minimum and maximum capacities, respectively, as compared with the FIFO, unrestricted policy using present lockage component times.

51. Although the physical capacity of the Winfield locks may not be reached in the near future, the economic capacity may have already been reached. Based on anticipated demands, traffic on the Kanawha River is expected to increase dramatically by 1980. However, this



projection is not readily apparent from a study of historical data of the tonnages. Since 1967, the total annual tonnages passing through the locks have remained relatively constant, between about 10 and 12 million tons per year. This may mean that the towing industry is not willing to accept additional delays and, therefore, will not expand their waterborne operations to meet the anticipated requirements. In essence, then, the long transit times now being experienced by large tows at this small chamber lockage facility may be a limiting factor that is just as important as the waiting times.
TABLE 12

COMPARISON OF THE FOUR OPERATING POLICIES TESTED

Omerating Policy	Cumu Util 1975	lative ization 1980 /	Lock (%) 1990	Min. Limits (Million	Max. Limits Tons/Mo)	Annual Tonnage 95% Utilization (Million Tons/Yr)
						•
FIFO, Unrestricted	43.09	68.18	94.18	1.88	2.39	24.49
FIFO, Unrestricted (10% reduction in						
Times)	38.36	62.25	85.81	2.00	2.55	26.23
FIFO, Ready-To-Serve	30.10	47.56	65.52	2.79	3.24	34.78
3 Up-3 Down, Unrestricted	43.20	68.89	97.92	1.76	2.22	22.87

REFERENCES

- Daggett, L. L., Ankeny, T. D., and Eiland, J. A., <u>A New Generalized</u> <u>Waterway Simulator: WATSIM IV</u>, U. S. Army Engineer Waterways <u>Experiment Station</u>, to be published.
- Daggett, L. L. and Ankeny, T. D., "Determination of Lock Capacities Using Simulation Modeling," Miscellaneous Paper H-75-9, December 1975, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

APPENDIX A

FILE IDENTIFICATION CODES

APPENDIX A FILE IDENTIFICATION CODES

The data generated by each WATSIM run was stored in permanent files under separate file names. Each file name has been coded to include: (a) Run number, (b) Commodity projection set number, (c) Lock system alternative, (d) Fleet characteristics, (e) Operating policy, and (f) Tonnage year. Each file name was coded as follows:

aaaabccdeeff

where

- aaaa = Run number. Run numbers will be sequentially assigned and listed in a master run registration table which will contain all pertinent information on each computer run.
 - b = Commodity projection set code:
 - M for the most likely projection set
 - H for high projection set } whichever is selected for testing L for low projection set
 - cc = Lock system alternative
 - 01 for the existing system of locks
 - 02 for dual 800'x110' locks at the current site
 - 03 for dual 800'x110' locks at a new upstream site in the existing channel
 - 04 for dual 800'x110' locks in a cutoff
 - 05 for dual 1200'x110' locks or 600'x110', as necessary
 - 06 for a single chamber lock of the size selected
 - 07 for existing locks at Winfield and Gallipolis
 - 08 for recommended replacement at Winfield and existing locks at Gallipolis
 - 09 for replacement at Gallipolis and existing locks at Winfield
 - 10 for proposed replacements at both Winfield and Gallipolis

d = Fleet characteristics

W for the current 1975 fleet characteristics at Winfield

G for currently observed tow makeups at Gallipolis shifting

F for future fleet characteristics that may make optimum use of the proposed lock sizes by 1990

ee = Operating policy code

FU for first in-first out (FIFO), unrestricted

FR for FIFO, ready to serve

1U for 1 up-1 down (flip-flop), unrestricted

3U for 3 up-3 down, unrestricted

ff = Tonnage year

- 75 for 1975
- 80 for 1980
- 90 for 1990
- 00 for 2000
- 10 for 2010
- 20 for 2020
- 30 for 2030
- 40 for 2040

APPENDIX B

SAMPLING PERIOD SENSITIVITY ANALYSIS

APPENDIX B Sampling Period Sensitivity Analysis

1. The variation in monthly delays obtained from a given WATSIM run has been the subject of some concern. The procedure used to obtain monthly delays associated with a particular tonnage level and year is quite simple. The WATSIM program outputs delays in minutes and commodity movements in tons, together with a number of other pertinent data elements, for 10 separate 3-day periods (4,320 minutes) during a typical 30-day month. To get average monthly delays, any sampling period (or interval) length can be chosen and the associated delays increased linearly to approximate the delays during a 30-day month.

2. The decision was made to use five independent three-day sample periods in the Winfield Capacity Study to obtain monthly delays for each WATSIM run. The delays encountered during each period were simply multiplied by 10 and then divided by 60 to arrive at monthly totals in hours. The selected sample time periods are shown below:

Interval Beginning	Interval Ending
(Minutes from Run Initiation)	(Minutes from Run Initiation)
8640	12960
17280	21600
25920	30240
34560	38880
43200	47520

As shown above, there is no sample time interval overlap, e.g., the period from 8640 minutes to 12960 minutes is an entirely different period of simulation time than the period from 17280 minutes to 21600 minutes. An example of two overlapping time periods would be the intervals say from 8640 minutes to 21600 minutes and from 17280 minutes to 30240 minutes. Both sampling periods are 6 days in length but each includes delays associated with the other; i.e., the samples are not independent.

B1

3. In addition to avoiding actual time overlaps in the sampled period, the choice of the intervals shown in the table above was also an attempt to avoid, to the extent possible, the often excessive delays associated with tows arriving during one 3-day period and not completing lockage until the next period. It is desirable to have independent sample periods. The simulation model does not add the statistics of any lockage to the lock's statistics until the lockage is completed. Thus when queue buildup during any one period occurs, the delay caused to tows arriving during this period but locking during the following period is added to the statistics for the following period. That is, there is some autocorrelation between sampling periods. In order to minimize this effect, a 3-day interval occurs between each of the above selected sample periods. For example, the 3-day period between 12960 minutes and 17280 minutes would be such an interval.

4. Unfortunately, however, even though the above rationale and logic were instrumental in choosing the five time intervals used, the variation in the computed monthly delay times was still significant, especially for future high tonnage years. As a result, a Sampling Period Sensitivity Analysis was performed for one high-level lock utilization run: the run using estimated 1993 tonnage levels with first in-first out (FIFO), unrestricted* operating policies. This run was partitioned into 6 different sample time interval sets for comparison of the monthly delay times obtained from each (see Table B1). Table B2 shows the variation in monthly delays for each sample interval within each set. For example, in Sample Set No. 1 monthly delays range from a low of 1,791 hours to a high of 13,256 hours. Sample Set No. 4 has the least variation between intervals. As shown in Table B2, the extreme high delays tend to occur during the last sample inverval, indicating the effects of major differences in the times between arrival of each

B2

^{* &}quot;Unrestricted" infers that tows may approach the lock chamber in the same configurations used between locks. That is, tows are not required to configure for the most efficient utilization of the lockage facilities. This is the operating policy used at Winfield today.

tow (interarrival times) and the service times. During high lock utilization, tows arrive much too often to be serviced without long delays. The queues continue to build under these conditions as lock operations are simulated over a period of time. Toward the end of the simulation period (1 month in this case), queues and delay times have increased to the point where tonnage throughput increases vary little, if any, along with the extremely high rate of increase in delays.

5. The results of the Sampling Period Sensitivity Analysis indicated that large variatons in monthly delay times will usually occur during periods of high lock utilization, regardless of the sample interval selected. The sample intervals of three-days length used in the Winfield analysis are, therefore, considered to be of an adequate length.

6. It is believed that a major part of the variation observed in the sampled data for the Winfield Locks is due to the wide range in the number of cuts required for lockage and hence the wide range of lockage times required to service various tows. Thus, in any one sampling period the tonnage levels may not vary much but the number of tows serviced may vary significantly. Any tows present would incur large delay times if several tows requiring many cuts were serviced during the sampling period, while the delays incurred during another sampling period could be quite short if only singles and doubled were serviced during that period. All this could occur while the tonnage processed during these sampling periods would not vary by a large amount.

TABLE B1

Sampling Period Sensitivity Analysis Formulation of Sample Interval Sets Tested

The six time period sets are given below in schematic form. Each interval is bracketed and numbered, and the multiplier used to adjust each associated delay to a 30-day month is shown in Note C.

Sample Interval Set No. 1

	(8640
1	\$12960
	617280
2	21600
	2 5920
3	30240
	J 34560
4	38880
	(43200
	47520

Note: A. Four 8640- minute intervals

- B. 8640 minutes = 6 days = 0.2 month
- C. Delays during each 6-day period times 5 = monthly delays

Sample Interval Set No. 2

	C 8640
1	12960
	17280
	21600
2	(25920
	30240
	34560
3	(38880
	\$ 43200
	47520

- Note: A. Three 12960-minute intervals
 - B. 12960 minutes = 9 days = 0.30 month
 - C. Delays during each 9-day period times 3.33 = monthly delays

TABLE B1 (continued)

Sample Interval Set No. 3



Sample Interval Set No. 4

1

2

3

1

8640 1296 17280

21600=

25920

30240

34560

38880 43200 47520

В.	17280	minutes	=	12	days	=	0.40	month
c.	Delays times	s during $2.5 = m$	e:	ach thly	12-da dela	ay ay:	perio s	bd

Note: A. Two 17280-minute intervals

- Note: A. Three 30240-minute intervals
 - B. 30240 minutes = 21 day = 0.70 month
 - C. Delays during each 21-day period times 1.43 = monthly delays

Sample Interval Set No. 5

r	8640
1	12960
1	17280
	21600
	25920
1	30240
(34560
	38880
1	43200
1	47520

Sample Interval Set No. 6

	8640
. (12960
1.	- 17280
2	21600
2	25920
7	30240
3	\$134560
	4 38880
4	5 43200
	47520

- Note: A. One 38880-minute interval
 - B. 38880 minutes = 27 days = 0.90 month
 - C. Delays during each 27-day period times 1.11 = monthly delays

- Note: A. Four 12960 minute intervals
 - B. 12960 minutes = 9 days = 0.30 month
 - C. Delays during each 9-day period times 3.33 = monthly delays

TABLE B2

Sampling Period Sensitivity Analysis Delays and Associated Tonnages for Each Sample Interval Set (1993 FIFO - Unrestricted Run)

Sample Interval	Year	Monthly Delay	Monthly Tonnage
Set No.	(Sample Interval)	(hrs)	(K COIIS)
	1005		
1	1993		0.001
	(1)	3,038	2,094
	(2)	1,791	1,844
	(3)	3,672	2,013
	(4)	13,256	2,278
2	1993		
	(1)	2,620	2,135
	(2)	3.041	1.828
	(3)	15,157	2,134
7	1007		
3	1995	2 414	1 060
	(1)	2,414	2,106
	(2)	12,725	2,100
4	1993		
	(1)	3,920	2,049
	(2)	5,723	2,019
	(3)	8,072	2,050
5	1993		
5	(1)	6,877	2,014
,	1007		
0	1993	0 (00	2 175
	(1)	2,620	2,135
	(2)	1,846	1,898
	(3)	5,913	2,148
	(4)	15,157	2,134

APPENDIX C

REDUCED WATSIM DATA FOR FOUR ALTERNATIVE OPERATING POLICIES AT THE EXISTING WINFIELD LOCKS

TABLE CI

WINFIELD LED CAPACITY TESTS

Present 360'x56' Dual Chamber Locks Most Likely Traffic Level 1975 Tow Characteristics Operating Policy: FIFO Unrestricted

Y		No. of Tows Per Month	Monthly	Monthly Tonnage	Annual Delav	Annual Tonnare	Perce	nt Utilizat	ion
(Sampl	e No.)	(Main & Aux)	(hrs)	(K tons)	(hrs)	(K tons)	Cham. A	Cham. B	Lock
		•							
1975	Ξ	360	111	006	1,328	10,799	55.24	34.10	44.67
	(2)	270	70	695	840	8,339	51.21	30.90	41.06
	(3)	380	147	1,017	1,760	12,203	53.54	34.95	44.25
	(4)	400	303	1,412	3,638	16,938	53.51	36.23	44.87
	(2)	320	57	774	678	9,290	51.25	34.81	43.09
1980	(1)	510	495	1,356	5,934	16,273	80.75	70.51	75.63
	(2)	490	482	1,559	5,780	18,707	81.24	70.09	75.67
	(3)	480	254	1,116	3,012	13,388	78.40	63.95	71.18
	(4)	510	315	1,406	3,774	16,868	77.43	60.31	68.87
	(2)	530	513	1,132	6,152	13,585	75.90	60.45	68.18
1000	~~~	740	3.590	1.848	43,076	22,172	16.30	97.99	96.95
DEET		750	6,890	2,372	82,684	28,459	97.85	98.29	98.07
	(2)	760	5,139	2,103	61,672	25,240	97.54	96.78	97.16
		650	3,225	1,851	38,700	21,976	95.27	93.40	94.34
	(2)	660	2,845	2,190	34,144	26,276	95.25	93.11	94.18
19931	. (1)	750	3.496	2.120	41,952	25,440	96.47	91.43	93.95
	(2)	780	1,793	2,223	21,518	26,680	97.27	91.88	94.58
	(3)	069	1,963	2,012	23,556	24,142	97.43	90.96	94.20
	(4)	820	10,413	2,427	124,958	29,118	98.03	93.06	95.55
	(2)	200	19,006	1,854	228,076	22,242	97.74	94.16	95.95
19982	(1)	740	18,252	2,153	219,022	25.837	99.42	100 00	17 00
	(2)	Infinite Que	suing at time	16,970 minu	tes				****

¹Estimated using 1990 projections and divisors of 11.0 in 'TONGG'N for each commodity. ²Estimated using 1990 projections and divisors of 10.0 in TOWCHN for each commodity. TABLE C2

この あいかい あいち あいち してい

WINFIELD LGD CAPACITY TESTS Present 360'x56' Dual Chamber Locks Most Likely Traffic Level .1975 Tow Characteristics fo Unrestricted w/10% Reduction in Lockage Component Times

		Operating Pol	icy: FIFO	Unrestricted	w/10% Reduct	tion in Lockag	e Component	Times	
Yes	ł	No. of Tows Per Month	Monthly Delay	Monthly Tonnage	· Annual Delay	Annual Tonnage	Percei	nt Utilizat	ion
(Sample	c .vo.)	(Main & Aux)	(hrs)	(K tons)	(lırs)	(K tons)	Cham. A	Cham. B	Lock
1975	(1)	360	62	006	744	10,799	48.74	29.16	38.95
	(2)	270	40	695	480	8,339	45.45	25.44	35.45
	50	370	92	1,017	1,106	12,203	46.73	32.94	39.84
	(4)	400	141	1,412	1,696	16,938	46.39	33.36	39.88
	20	320	37	774	438	9,290	44.42	32.29	38.36
1980	(1)	520	303	1,398	3,634	16,771	75.37	60.31	67.84
	(2)	480	313	1,559	3,756	18,707	75.48	61.05	68.27
	(3)	480	284	1,116	3,410	13,388	72.11	56.76	64.44
	(4)	500	257	1,385	. 3,078	16,625	70.66	54.87	62.77
	(2)	550	440	1,215	5,274	14,581	69.31	55.19	62.25
1990	(1)	062	2,610	1,950	31,322	23,394	92.37	85.29	88.83
	(2)	810	1,334	2,311	16,002	27,731	94.63	90.94	. 92.79
	(3)	730	2,425	2,003	29,098	24,037	93.16	87.52	90.34
	(4)	590	578	1,651	6,910	19,817	89.81	83.51	86.66
	(2)	710	1,359	2,174	16,312	26,090	88.82	82.80	85.81
1993*	(1)	850	1,586	. 2,309	19,034	27,712	93.10	90.96	92.03
	(2)	270	1,362	2,210	16,340	26,519	89.00	84.10	86.55
	(3)	069	1,064	2,012	12,772	24,142	88.31	82.66	85.49
	(+)	830	5,689	2,571	68,272	30,852	90.87	86.62	88.75
	(2)	200	4,463	2,089	53,558	25,063	92.51	88.94	90.73
1998	Ξ	860	10,979	2,437	131,750	29,245	99.76	98.85	99.31
	[2]	890	13,138	2,356	157,652	28,272	99.37	99.29	99.33
	(3)	760	2,285	2,018	27,424	24,210	98.05	97.37	17.70
	E	830	8,713	2,548	104,556	30,578	98.01	97.14	97.58
	(2)	810	7,127	1,993	85,524	23,910	98.06	97.42	97.74
2002*	(1)	840	17,097	2,161	205,162	25,934	60.66	29.57	99.33
	(2)	860	21,963	1,997	263,560	23,960	99.46	100.001	99.73
	(3)	Infinite que	uing at 29,	82/ minutes.					

*Tonnage levels in TOWGEN for these years were estimated by using 1990 projections and commodity tonnage divisors of 11.0, 10.0, and 9.0 for 1993, 1998, and 2002, respectively.

TABLE C3

WINFIELD L&D CAPACITY TESTS Present 360'x56' Dual Chamber Locks Most Likely Traffic Level 1975 Tow Charucteristics Operating Policy: FIFO Ready-To-Serve

;		No. of Tows	Monthly	Monthly	Annual	Annua1			
Yca Yea	1	Per Month	Delay	Tonnage	Uctay	Tonnage	Cham A	Cham R	Inck
ardure	1.00	TYPY & IITPUI	(6711)	Tenn N	(ctil)	(CIINT V)	C.I.C.I.	Citant. P	
1975	Ξ	360	27	005	322	10,799	38.08	22.53	30.31
	(2)	270	20	695	240	8,339	36.85	19.64	28.25
	(3)	360	42	915	508	10,985	37.94	23.39	30.67
	(4)	400	69	1,412	832	16,938	38.00	24.26	51.13
	(2)	320	25	774	298	9,290	36.79	23.40	30.10
1980	(1)	520	. 106	1,398	1,274	16,771	60.75	44.62	52.69
	(2)	520	194	1,659	2,326	19,902	58.28	47.46	52.87
	(3)	. 450	111	1,116	1,328	13,388	56.94	42.48	49.71
	(4)	490	80	956	1,385	16,625	56.52	39.85	48.19
	(2)	550	204	1,215	2,444	14,581	55.89	39.23	47.56
1990	(1)	770	413	1,976	4,954	23,708	72.24	62.52	67.38
	(2)	800	525	2,278	6,304	27,332	77.09	64.15	70.62
	(3)	680	330	1,927	3,962	23,118	75.01	61.26	68.14
	(1)	540	44	1,595	522	19,139	72.74	59.59	66.17
	(2)	700	345	2,158	4,146	25,891	71.92	60.12	65.52
1993	(1)	850	327	2,309	3,920	27,712	74.48	61.19	67.84
	(2)	770	682	2,210	8,178	26,519	73.37	60.07	66.72
	(3)	069	568	2,012	6,810	24,142	71.92	59.01	65.47
	(4)	1,000	1,427	2,954	17,122	35,448	75.95	63.23	69.59
	(2)	910	530	2,237	6,354	27,440	76.68	64.46	70.57
1998	(1)	760	532	2,137	6,392	25,640	81.44	74.94	78.19
	(2)	. 029	224	1,670	2,692	20,035	83.14	70.97	77.06
	(3)	780	320	2,011	3, 842	24,136	80.72	69.06	74.89
	(4)	890	1,014	2,813	12,168	33,757	81.79	70.01	75.90
	(2)	. 780	. 332	1,938	3,958	23,252	81.34	70.07	75.71

C3

(Continued)	
3	
TABLE	

Yea	H	No. of Tows Per Month	Monthly Delay	Month1y Tonnage	Annual Delay	Annual Tonnage	Percer	nt Utilizat	ion
(Samp]	c No.)	(Main & Aux)	(hrs)	(K tons)	(hrs)	(X tons)	Cham. A	Cham. B	Lock
2002	(1)	930	766	2,669	9,194	32,028	90.32	78.57	84.45
	(2)	830	654	1,845	7,842	22,136	87.21	76.80	82.01
	(3)	960	1,569	2,538	16,824	30,451	86.41	76.85	81.63
	(4)	010	956	2,278	11,474	27,338	87.99	12.62	83.85
	(2)	062	600	2,373	7,200	28,475	87.78	78.10	82.94
2009	(1)	1,070	5,807	3,253	69,682	39,034	98.68	96.72	97.70
	(2)	1,080	3,421	2,803	41,046	33,640	95.42	90.36	92.89
	(3)	1,080	2,526	3,052	30,310	36,988	95,55	50.73	93.14
	(4)	1,160	4,250	3,029	51,004	36,346	95.36	91.25	93.31
	(2)	1,070	16,463	3,244	197,558	38,928	96.16	92.97	94.57
2017	3	1,120	20,724	2,912	248,686	34,944	99.85	99.75	99.80
	(7)	Intinite que	uing at lime	I / JUS mimutes	•				

C4

TABLE C4

and the state

いいたないの日日の

WINFIELD LED CAPACITY TESTS

Present 360'x56' Dual Chamber Locks Most Likely Traffic Level 1975 Tow Characteristics Operating Policy: 3 up-3 down, Unrestricted

Year (Sample	r No.)	No. of Tows Per Month (Main & Aux)	Monthly Delay (hrs)	Monthly Tonnage (K tons)	Annual Delay (hrs)	Annual Tonnage (K tons)	Percel Cham. A	nt Utilizat Cham. B	i on Lock
1975	33	360 270	331 42	006 006	3,576	10,799 8,332	56.59 52.09	33.43 29.01	45.01
	S (4 3	380 400 320	525 212 65	1,412	6,294 2,540 774	10,985 16,938 9,290	54.87 53.95 52.33	33.57 35.76 34.06	44.22 44.86 43.20
1980	5555	510 520 480 490	650 517 276 952	1,356 1,639 1,116 1,491	7,802 6,208 3,312 11,420	16,273 19,664 13,388 17,897	79.73 78.63 76.01 75.16	70.37 71.41 64.79 62.61	75.05 75.02 70.40 68.89
1985	(1)	680	945	1,810	11,540	21,720	87.89	88,10	88.00
1990	333	710 710 Infinite	11,407 18,460 Queuing occur	1,959 1,995 s at Time 2	136, 384 221, 590 8, 737 minutes.	2 5,503 2 3,936	97.34 99.33	92.43 96.50	94.89

C5

APPENDIX D

18 8 S.

TONNAGE PROJECTION METHOD COMPARISON ANALYSIS

APPENDIX D Tonnage Projection Method Comparison Analysis

1. Only historical commodity tonnage data for 1975 and projected tonnages for 1980 and 1990 were available for use in the Winfield Lock capacity studies. Although high lock utilization percentages occur for the 1990 tonnages using two of the alternative lock operating procedures, the 1990 tonnages are not great enough to cause infinite queuing. Thus, a decision was made to increase tonnage levels beyond the year 1990 by keeping the relative distribution of commodities constant at any given tonnage level with the ratio being the same as the projected 1990 distribution. To accomplish this, tonnage divisors of 11.0, 10.0, 9.0, 8.0, and 7.0, respectively, were used in TOWGEN for producing more tows per month for input to WATSIM.

2. The tonnage divisors in TOWGEN work in the following manner to create more tonnage passing through the lock, and thus more tows. Annual tonnages by commodity and direction are input to TOWGEN. If the projected tonnages for a given year, say 1990, are available, these are input directly to TOWGEN together with a divisor of 12.0 for each commodity. This in effect divides the resulting tow list by 12 and outputs a list of tows to be processed by the lock during a typical month. A tonnage divisor less than 12.0 for each commodity produces more tonnage by dividing the input tonnages by a smaller number. For example, annual tonnage level of 25,000 tons for a given commodity would be equivalent to 25,000 \div 12 or 2083 tons per month; whereas, dividing 25,000 tons by 11 would be 2273 tons per month. The tonnage divisor feature is usually used to compute monthly tonnages that are not equally distributed throughout the year.

3. The purpose of this appendix is to briefly compare the tonnage divisor method of projecting tonnages with a linear trend procedure based on expected increases and decreases in the six commodity groups

D1

between 1980 and 1990. Table D1 shows a comparison of tonnage projections by commodity for these two methods. The following is a column by column description of Table D1:

- a. Column 1 The six commodity groupings in the Winfield Capacity Study.
- b. Columns 2 and 3 Projected tonnage levels for the years 1980 and 1990 as provided by the Huntington District (ORHED-PE).
- c. Column 4 Increases and decreases in tonnages by commodity type during the period 1980 to 1990.
- d. Column 5 Linear change in tonnages by year for the 10-year period, i.e., each tonnage in Column 4 divided by 10.
- e. Column 6 The percent each commodity either increases or decreases during each year of the decade is derived by simply dividing the tonnage change for each commodity group as shown in Column 5 by the total change shown at the bottom of Column 5.
- f. Column 7 These are the tonnages obtained by using the tonnage divisor 11.0. The 1990 commodity tonnages are each divided by 11.0 and then multiplied by 12.0 to obtain an increased annual tonnage for each commodity.
- g. Column 8 This column simply shows the increase in total tonnage between 1990 and the level obtained by using a divisor of 11.0.
- h. Column 9 This is the number of years growth represented by the tonnage increase shown in Column 8. The 3.4 years is related to the 1980 to 1990 trend of total expected tonnage increase by dividing the tonnage in Column 8 by the average growth during this decade.
- i. Column 10 The 3.4 years equivalent growth is multiplied by the tonnages for each commodity group in Column 5 to determine commodity increases and decreases for this period based on the 1980 to 1990 trend.
- j. Column 11 The year 1993.4 is truncated to be 1993. Linear tonnage changes during this period based on the 1980 to 1990 trend are added to the 1990 levels to obtain the 1993 tonnages for comparison with Column 7.
- k. Column 12 This shows the differences in the tonnages obtained by using the two projection techniques.

4. Using trend increases, 246,000 more tons of chemicals would have been used as input to TOWGEN and 189,000 and 69,000 less tons of aggregates and coal, respectively. These are the major differences in the two projection methods. While differences in tonnages provided by the two techniques described above might be considered significant, considering the lock utilization and delay times obtained from a test WATSIM run, there did not appear to be any significant effect on the determination of the locks' capacity. Based on the results of this analysis, it was not considered necessary or fruitful to make additional WATSIM runs to determine delays associated with other projected tonnage levels beyond 1990. The subject of tonnage projections is discussed further in the main text of this report. TABLE DI

A CARLES AND A CARD AND A CARD

Tonnage Projection Method Sensitivity Analysis

							-		Tonnage		Diff in
							Total	Co1 8	Changes	1993	Projection
			Difference	Linear		Projected	Col 7	+	1990 to	Tonnages	Methods
	Prof	ected	Co1 3	Tonnage		Tonnage	Minus	Col 5	1993	Co1 3	Col 7
	Tonn	ages	Minus	Change/yr	% Change	Using	Total	Total	Col 5 x	+	Minus
	(K)	(suo)	Co1 2	(Diff + 10)	Each	Divisor=11.0	Col 3	(years)	3.4	Col 10	Col 11
Commodity	1980	1990	(K Tons)	(K Tons)	Commodity	(K Tons)	(K Tns)		(K Tons)	(K Tons)	(K Tons)
Ξ	(2)	(3)	(4)	(2)	(9)	(2)	(8)	(6)	(10)	(11)	(12)
Coa 1	7252	9626	2374	237.4	36.4	10,501	•	•	807.2	10433	68
Chemicals	6732	10177	3445	344.5	52.82	11,102	•		1171.3	11348	-246
Aggregates	1952	1903	-49	-4.9	-0.75	2,075		•	-16.7	1886	189
Petroleum	1166	1576	410	41.0	6.29	1,719	•		139.4	1715	4
Other	169	1038	347	34.7	5.32	1,132	·		118.0	1156	-24
Cement	173	168	-5	-0.5	-0.05	185	•	••	-1.7	166	17
TOTAL.	17966	24488	. 6522	652.2	100.0%	26,712	2,224	3.4*	2217.5	26705	+7

*Thus equating to 1990 + 3.4 years = 1993.4 and truncated to the whole year 1993.

APPENDIX E

DEFINITIONS

APPENDIX E Definitions

Specialized terms used in this report are defined below:

- 1. <u>Chambering</u>: The filling or emptying of the lock chamber with one or more vessels in the chamber.
- 2. <u>Chambering time</u>: The time period beginning when the bow of the vessel being served crosses the sill upon entry to the lock chamber and ending when the stern of the power unit, or towboat, crosses the opposite sill upon exiting the chamber. For multi-cut lockages and jackknife, knockout and setover lockages, this time includes the time required to break the tow upon entry to the lock, remake the tow upon exiting and for processing all intermediate cuts of multi-cut lockage, including the turnback times.
- 3. <u>Cut</u>: That portion of a tow that can be contained within the lock chamber for chambering.
- 4. <u>Dedicated equipment</u>: The exclusive use of a towboat and particularly the barges to transport only one type of commodity. The greater the percentage of dedicated equipment, the greater the number of empty backhaul barges.
- 5. <u>Double lockage</u>: The lockage of a tow larger than the lock via two distinct lockages.
- 6. Double knockout, double setover, or double jackknife lockage: One cut of a double lockage must either be a knockout, setover, or jackknife type lockage in order to permit the passage of the tow in only two lockages. (See definitions of knockout, setover, and jackknife lockages below.)

E1

- 7. <u>Downstream approach</u>: The reach of river immediately downstream from the lockage facility and dam leading to the lock chamber entrance.
- Exit time: The period in minutes beginning when the stern of the exiting towboat crosses the sill on exit and ending when the tow passes the defined approach point or the next entering tow, whichever occurs first.
- 9. First In, First Out (FIFO), Unrestricted Operating Policy: The tows are serviced in the order of their arrival and no restriction is placed on the barge configuration (tow makeup) or size as they approach the lock, i.e., no remake or reconfiguration of the barges is required prior to beginning the lockage process.
- 10. First In, First Out (FIFO) Ready-to-Serve Operating Policy: Same as the FIFO Unrestricted Policy except it prohibits the breaking or remaking of tows in the vicinity of or within a lock chamber.
- 11. <u>Fleet characteristics</u>: The general makeup of tows in a particular river reach as pertains to boat horsepower, number of barges, barge types and sizes, flotilla configuration, etc.
- 12. <u>Fly entry</u>: A fly entry occurs when the lock is idle when an inbound vessel arrives at the lock and is the period of time beginning when the vessel passes the approach point and ending when the vessel's bow crosses the sill upon entering the lock chamber.
- 13. Integrated barge: A single unit of barges made up of two or more barges which are usually left connected together to form the integrated barge. A wide variety of barge sizes exists for the barges and this manner. Most integrated barges are tank barges and are a dedicated manner.





- 14. Jackknife lockage: The tow is rearranged, e.g., from two barges wide to three, by breaking the face couplings on at least two barges and the side couplings on at least one barge.
- Jumbo barge: A regular long jumbo barge either 195 or 200 ft long and 35 ft wide.
- Knockout lockage: The towboat alone is separated from its barges to be "set over" for service.
- 17. Lockage: The passage of a vessel through the lock facility.
- Lockage component: One of the sequences of events involved in the locking process. These include various types of tow entries, chamberings, and exits.
- Lockage types: Lockage types include straight singles, doubles, triples, etc., along with setovers, jackknifes, knockouts, multivessel lockages, and others.
- 20. Mixed barge tows: A tow consisting of more than one barge type.
- Multi-cut lockage: A lockage requiring two or more straight cuts,
 e.g., double, triple, quadruple, etc.
- 22. <u>Multiple entry</u>: The entry of two or more relatively small tows to be locked together in a single lockage.
- 23. <u>Multiple exit</u>: The exit of two or more relatively small tows following their being locked together in a single lockage.
- 24. <u>Multiple tow lockage</u>: More than one vessel or tow is served in a single chambering.

E3

- 25. <u>Open-pass lockage</u>: The vessel transverses the lock with no lock hardware operation.
- 26. <u>Performance Monitoring System (PMS)</u>: A system developed by the U. S. Army Corps of Engineers to measure the service which the inland waterways provide to the navigation industry. It has been implemented at Corps inland navigation facilities within the U. S. and provides planners and operations' personnel with data and complete programs needed for analysis of the operation of the inland and intracoastal navigation systems.
- 27. Queue: A group of one or more tows waiting to be serviced by the lock.
- 28. Regular barge: A small regular barge 175 ft long and 26 ft wide.
- 29. <u>Setover lockage</u>: The towboat and one or more of its barges are separated from the remaining barges to be "set over" for service.
- 30. Single lockage: The tow is not broken up for lockage.
- 31. <u>Turnback</u>: The filling or emptying of the lock chamber required to service the next cut of a multi-cut lockage tow or another tow traveling in the same direction.
- 32. <u>Turnback entry</u>: An entry following a lock turnback during which no vessel was served and in which the vessel to be locked had arrived prior to the exit of the previous vessel being locked.
- 33. <u>Tow processing time</u>: The total time in minutes required for a tow to be served by a lock. This time begins when the tow is signaled to enter the lock and ends upon completion of the exit.

34. <u>Three up-three down operating policy</u>: Three vessels traveling in the same direction are locked sequentially, followed by the sequential lockage of three vessels traveling in the opposite direction or until all vessels in a queue are served, whichever occurs first.

35. Upstream approach: The reach of the river immediately upstream from the lockage facility and dam leading to the lock chamber entrance.

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Daggett, Larry L Capacity studies of Winfield Locks, Kanawha River, West Virginia, by Larry L. Daggett Landj Robert W. McCarley. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1977. 1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Miscellaneous paper H-77-1) Prepared for U. S. Army Engineer District, Huntington, Huntington, W. Va. Includes bibliography. Computerized simulation. 2. Inland waterways.
 Locks (Waterways). 4. Gallipolis Lock & Dam. I. McCarley, Robert Winton, joint author. II. U. S. Army Engineer District, Huntington. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper H-77-1) TA7.W34m no.H-77-1