SECTION 5 - LOCK CAPACITY AND DELAY FUNCTION ESTIMATION

OVERVIEW

As traffic levels increase on a waterway, the increased traffic creates delays at bottlenecks on the system. Generally, these bottlenecks or constraints occur at navigation locks. Quantifying the relationship between tonnage moving through a lock and the delay at the lock is essential to the economic analysis of the value of the navigation system.

In this study, the simulation approach was used to establish the delay-tonnage relationship of lock operations for all system locks. Simulation was considered more appropriate, than other methods, due mainly to the fact that simulation analysis would be more adept at measuring the relative efficiencies of chamber packing with different size chambers. The following is a discussion of the simulation approach.

SIMULATION APPROACH

MODEL STRUCTURE

The Sim model that was used in this analysis was developed specifically for this study by Dr. Mike Racer from the University of Memphis under contract with the New Orleans District. (It should be noted that Dr. Racer developed a similar model for the New Orleans district for the "MRGO - New Lock and Connecting Channels Feasibility Study." completed in 1997.) It is written in SIMSCRIPT, a language developed specifically as an aid to simulation analyses. SIMSCRIPT is an event-based language. That is, the program monitors the system being modeled, and identifies the occurrence of the next event. Simulation time is automatically advanced to that next time.

Model Entities

SIMSCRIPT uses 'entities' to model the character of the system. In the current environment, these entities are:
-Vessel types
-Segments
-Locks

The vessel type entity specifies the attributes of the vessel including, arrival rates, physical characteristics, and breakout strategy. A vessel is created as a temporary entity, simulated only for as long as it is impacting on the lock system.

A segment in the system identifies a portion of the region. Segments are distinguished by location and function. For example, for Bayou Sorrel lock, the system is modeled as five segments:
- the northbound arrival queue
- the northbound staging area
- the lock
- the southbound staging area
- the southbound arrival queue.

A lock is a special type of segment. Because additional information must be specified for a lock segment, the decision was made to create an additional dual entity, carrying all of the lock-specific information.

Model Components

With these entities in mind, a SIMSCRIPT program is written to identify the activity within the system. A typical program consists of three types of components - a preamble, events, and routines.

a. Preamble. The preamble is the core of the simulation, providing the global definitions for each entity class, each event, each routine, and all global variables and arrays.

b. Events. This program consists of five events - Q.ARRIVAL, SEG.ARRIVAL, LOCK. EXIT, NEW. DAY, and NEW. SEASON. These form the core of the simulation, driving the activity of the system.

Q.ARRIVAL simulates the arrival of a vessel to one of the system queues. At this point, the vessel is created, any relevant breakouts (tow cuts) are created and light boats (assist vessels) employed. If the vessel is a priority one, it is placed early in the queue. If the arrival is a fly arrival, the vessel moves immediately to the appropriate staging area- a calculation of travel time is made to determine the time of arrival of the vessel and an event SEG.ARRIVAL is scheduled. The time of the next arrival of a vessel of this type is determined, based on probabilistic methods.

SEG.ARRIVAL simulates the arrival of a vessel to an intermediate segment of the system. If the segment is a lock, a call is made to LOCK.ARRIVAL, a routine that will be described later. Otherwise, time of traversal to the next segment is calculated and another SEG.ARRIVAL is scheduled. If the next segment is a lock, a call is made to LOCK.FILLER, also described later. The departure of a vessel from a segment triggers a second SEG.ARRIVAL for a vessel to fill the vacancy to be created in the current segment.

A LOCK.EXIT simulates the departure of a vessel, or set of vessels, from the lock. Calculations are made to determine the time at which the lock will be available for subsequent service, routine LOCK.MASTER is called, and a SEG.ARRIVAL is scheduled for all vessels leaving the lock. If the lock departure represents the departure of the vessels from the system, routine SYST.EXIT is called instead.

Events NEW. DAY and NEW. SEASON are time monitoring events. NEW. DAY simply flags the start of a new day. NEW. SEASON flags the start of a new season, and initiates the usage of a new season-dependent chambering time.

c. Routines. In addition to the core events, the simulation package also consists of seven routines - MAIN, COLL.STATS, LOCK.ARRIVAL, LOCK. FILLER, LOCK .MASTER, RD.DATA, and SYST.EXIT. These routines, unlike the events, provide support for the events, performing much of the functionality of the system.

MAIN is the driver routine. A call is made to RD.DATA to input the data, and the first set of arrival events are created. In addition, initializations of the day and season are accomplished through

MAIN. Simulation is initiated in this routine.

COLL.STATS is the statistics output routine. A call is made to COLL.STATS at the end of every season and at the completion of the iteration.

LOCK.ARRIVAL performs two functions when a SEG.ARRIVAL is identified as a lock arrival. First, usage statistics are tabulated. Second, a service time is calculated, to determine the time of the LOCK.EXIT.

LOCK.FILLER is called from SEG.ARRIVAL to determine a packing for the next usage of the chamber. Vessels are selected from the appropriate waiting queue, in priority order. LOCK.FILLER attempts to pack the chamber as fully as is practical.

LOCK.MASTER is responsible for determining assignments to the lock. Once LOCK.MASTER has determined which vessel(s) the lock will serve next, a SEG.ARRIVAL is scheduled.

RD.DATA is the data input routine.

SYST.EXIT controls the departure of a set of vessels from the system under study. All light boats are returned to their home base, traversing back through the lock.

MODEL INPUTS

The Sim model requires, detailed timing information on all aspects of traffic transiting the system such as the duration of the lockage itself, which is comprised of several operational components. In addition, the model requires traffic data by different tow size classes in order to accurately estimate the performance and volume of system throughput. The following paragraphs will describe the inputs that were used and how they were developed.

Lockage Times

A lockage is comprised of a series of events that are required to transfer a vessel or tow through a lock in a single direction. Timing information for each of these events was calculated using 1991 - 1994 LPMS data and a 50 - year period of record for relevant stage data in order to capture the impact of water levels on lock operations. The following is a brief description of each lockage event.

Approach time: The difference between the time the lock is ready to serve the incoming vessel and the time when the bow of the inbound vessel is abreast of the lock gates and it is in a position parallel to the guide wall to enter the lock chamber. The three possible types of approaches are:

1. Fly Approach: The lock has been idle and the inbound vessel directly enters the chamber.

2. Exchange Approach: The vessel inbound to the chamber passes a vessel outbound from the chamber.

3. Turnback Approach: The proceeding event is a lockage in which no tows were served.

Entry Time: Time from bow over sill to end of entry. Usually the end of entry takes place when the tow or the entering cut is secured within the lock and the gates are clear.

Chambering time: The time required to completely fill or empty the lock chamber.

Exit Time: The time from start of exit to end of lockage. This is the difference between the time when the gates are fully open, and when the indication to proceed is given, and the time when the lock has completed serving a vessel or cut and can be dedicated to another vessel or cut. As with the approach time there are three types of exit.

1. Fly Exit: The lock will be idle following the departure of the outgoing vessel.

2. Exchange Exit: The vessel outbound from the chamber passes a vessel inbound to the chamber.

3. Turnback Exit: The vessel to be served next is going in the same direction as the outbound vessel and the lock must be turned back with no vessels in the chamber.

Added time for Multivessel Lockages: A multivessel lockage occurs when more than one commercial vessel or tow is served in a single lockage cycle. As a result, the additional time it takes to process the additional vessels must be taken into account.

For the most part, 1991 – 1994 Lock Performance Monitoring System (LPMS) lock data was used in the production of these component times. However, the most recent years available from LPMS no longer report approach, entering or exit times for each lockage, therefore the decision was made to compute these times by taking the difference between total lock processing time and chambering time and then spread this difference out evenly among the approach, entering and exit categories. For Bayou Sorrel the approach, entering and exit times calculated for the without-project condition was also used for the improved lock scenarios since little variation in these times is expected.

Chambering time varies over the course of a year as a result of changing head conditions produced by various flow conditions. Variation in chambering time is the predominate reason for seasonal differences in average delay. In order to capture this seasonal effect, chambering times are specified on a quarterly basis. For all the locks, except Bayou Sorrel, 1991 - 1994 LPMS data was used to estimate these times. In developing the chambering times for Bayou Sorrel lock, a 50-year period of record for stage data and chamber size specific fill/empty times for varying head conditions were used. In addition, within each quarter or season, a probability distribution of head differentials was calculated in order to take into account the variation in head conditions within each of the seasons.

Table 5 - 1 displays the probability distributions of head conditions used in the analysis of Bayou Sorrel lock. As is shown in the table, along with the percent of time a head differential is expected to occur, the expected duration for each head differential is presented. Table 5 - 1 also shows that open pass conditions occur rather frequently at Bayou Sorrel lock. In the last quarter of the year, open pass conditions is expected to occur nearly 40 percent of the time.

As an added complication, the project flood flow line at Bayou Sorrel is expected to increase over time, which will have the affect of increasing the probability of higher head differentials from

Table 5 - 1

Head Differential Distribution by Season

December - February Time Frame

Headclass (ft)	Percent of Time	Duration (days)
-2	1.2	4.1
-1	5.8	4.5
0	18.4	10.3
1	25.7	6.5
2	21.1	4.7
3	14.9	6.3
4	8.5	6.7
5	3.7	5.1
6	0.6	6.7

May - June Time Frame

Headclass (ft)	Percent of Time	Duration (days)
-2	0.2	14.0
-1	1.1	3.6
0	6.5	11.1
1	14.5	7.0
2	19.7	5.6
3	20.3	7.5
4	16.5	6.8
5	9.9	9.0
6	4.9	5.6
7	2.3	7.5
8	1.8	5.0
9	0.8	6.4
10	0.5	3.7
11	0.5	3.4
12	0.3	3.5
13	0.2	15.0

July - August Time Frame

Headclass (ft)	Percent of Time	Duration (days)
-2	2.1	4.8
-1	8.5	2.2
0	24.9	17.6
1	27.9	8.6
2	19.1	6.5
3	9.3	5.3
4	5.1	6.5
5	2.1	6.8
6	0.8	5.0

September - November Time Frame

Headclass (ft)	Percent of Time	Duration (days)
-2	3.1	3.8
-1	8.9	3.3
0	37.9	20.0
1	32.8	6.2
2	8.6	7.2
3	5.8	6.1
4	2.4	4.3
5	0.3	1.0

occurring. This information was obtained from the New Orleans districts Hydrolics Branch which provided a similar probability distribution as the one shown in table 5 – 1 but for the year 2045. The impact this has on the analysis is that for the existing Bayou Sorrel lock and alternative with-project lock plans, lock capacities will have to be estimated for the existing time frame and for the year 2045. Lock capacities for the intermediate years will be estimated by interpolating between the existing and 2045 estimates.

Table 5 – 2 displays the estimated chambering times by head differential for the existing lock and with-project alternative lock sizes that will be evalulated in this study. Lifts of 4 feet and less are shown since the Bayou Sorrel lock experiences these conditions approximately 95 percent of the time. The chambering times for the existing lock were calculated from the four years of LPMS data. The chambering times for the with-project lock sizes were developed from the New Orleans districts Hydrolics branch.

Traffic Data

Individual tow sizes were evaluated and grouped into 35 classes. As with the timing information, four year average values (LPMS 1991 -1994), by tow size class, were used in the production of the traffic base. Information for each class consisted of average loads, average number of vessels (upbound and downbound) and, specific to the lock size being studied, the number of cuts that would be required and their dimensions. Table 5 - 3 displays the 35 towsize classes along with their expected frequency and average loads.

To capture the effects of stall events on lock operation, stall events were analyzed and represented in the model as a vessel type. Stall events also cause the lock to be unavailable for navigation until the event is concluded. Stall events generally fall into 4 conditions. The first is weather conditions, which consist of fog, rain, wind etc. The second is surface conditions consisting of river current, flood etc. The third is tow conditions consisting of interference by other vessels, tow malfunction or breakdown, etc. The fourth is lock conditions consisting of lock hardware malfunction, maintaining lock etc. The four year average for number of stalls and the times per stall at each of the locks was used as this estimate.

The last category of vessels, other than tows and ships, that need to be considered, is that of light boats. These are towboats that assist other tows requiring multicut lockages. All tows requiring multiple cuts are required to hire an assist vessel to power each additional cut (ready-to-service policy). When the light boat completes its assignment, it then receives priority as it returns to its home base. The Sim model generates a lightboat lockage(s) everytime a tow requiring assistance appears at the lock.

The traffic base, therefore, is comprised of 37 separate classes of traffic. Of these 35 are different tow configurations, one are stall events and the other is light boat traffic. Each of these classes is assigned a lock priority status, which enables the model to determine the order of service. The highest priority of "0" is assigned to lightboats, the priority of "2" represents a general locking policy for all tow classes and stall types. Each of these classes is assigned the appropriate component lockage times from the "lock time table" section of the input file.

Table 5 - 2

Chambering Times by Head Differential and Lock Size (Minutes)

	Lifts in feet				
Lock Size	4	3	2	1	0
Existing Lock	10.0	7.0	7.0	5.0	0.0
1200 x 75 Earth	5.7	3.8	2.1	0.9	0.0
1200 x 75 Concrete	3.6	3.0	2.0	0.8	0.0
1200 x 110 Earth	6.8	4.6	2.3	0.9	0.0
1200 x 110 Concrete	4.6	3.4	2.7	1.2	0.0

Table 5 - 3

Average Number of Tows and Loads
By Tow Size Class

Tow Size Class	Length (ft)	Width (ft)	Average # Of Tows	Average Tons
1	<=250	<=35	208	490
2	<=250	>=36 and <=40	40	481
3	<=250	>=41 and <=55	38	635
4	<=250	>=56 and <=70	2	850
5	<=250	>=71 and <=105	2	100
6	>=251 and <=460	<=35	724	1,474
7	>=251 and <=460	>=36 and <=40	88	1,378
8	>=251 and <=460	>=41 and <=55	572	1,427
9	>=251 and <=460	>=56 and <=70	16	2,438
10	>=251 and <=460	>=71 and <=105	2	100
11	>=461 and <=660	<=35	590	2,802
12	>=461 and <=660	>=36 and <=40	50	1,616
13	>=461 and <=660	>=41 and <=55	832	3,001
14	>=461 and <=660	>=56 and <=70	186	4,948
15	>=461 and <=660	>=71 and <=105	2	2,800
16	>=661 and <=800	<=35	186	2,834
17	>=661 and <=800	>=36 and <=40	20	1,771
18	>=661 and <=800	>=41 and <=55	852	3,293
19	>=661 and <=800	>=56 and <=70	144	5,699
20	>=661 and <=800	>=71 and <=105	2	2,600
21	>=801 and <=1060	<=35	1,064	4,844
22	>=801 and <=1060	>=36 and <=40	26	3,836
23	>=801 and <=1060	>=41 and <=55	1,018	4,936
24	>=801 and <=1060	>=56 and <=70	2	7,000
25	>=801 and <=1060	>=71 and <=105	8	4,262
26	>=1061 and <=1180	<=35	166	5,644
27	>=1061 and <=1180	>=36 and <=40	2	4,500
28	>=1061 and <=1180	>=41 and <=55	476	5,978
29	>=1061 and <=1180	>=56 and <=70	2	10,718
30	>=1061 and <=1180	>=71 and <=105	2	100
31	>=1181 and <=1800	<=35	38	5,304
32	>=1181 and <=1800	>=36 and <=40	2	100
33	>=1181 and <=1800	>=41 and <=55	18	6,551
34	>=1181 and <=1800	>=56 and <=70	2	1,400
35	>=1181 and <=1800	>=71 and <=105	2	7,300

Sample Input File

Table 5 - 4 shows a sample input file, representing a without- project condition at Bayou Sorrel lock, used by the Sim model. A brief description is provided alongside each line. Additional discussion is provided for some key inputs.

a. Seed numbers: The four seed numbers specify a chosen starting point for the arrivals generated randomly by the model.

b. Number of Seasons: The model results represent one 90 day season, which is divided into four separate "mini" seasons. The first four "mini" seasons consist of 23, 30, 15 and 22 days respectively. In addition, an initial warm-up period of 30 days was included which allows the model to begin tabulating results from an already operational lock.

c. Probability Distribution: As was discussed earlier and presented in table 5 - 1, this represents the probability distribution of head differentials and their associated chambering times for each of the seasons. The first column represents the probabilities of different lifts from occurring in that particular season. The second column represents the chambering times assigned to each of lifts. The third column would also include chambering times if the analysis assumed a second chamber. The fourth column represents the duration in days for each of the lifts.

d. Number of Days Vessel Arrival Data: Set at 365 days, the effect of reducing this variable is the same as increasing the traffic level. It is through use of this value that traffic can easily be scaled up or down to reflect runs of different traffic volumes or utilization levels.

e. Locking Policy: The locking policy the model analyzes is a first-come; first-serve policy (FCFS), which is the predominant type of locking policy on the IWW. This simply means that the first tow to arrive at the lock is the first considered for service.

MODEL OUTPUT

Table 5 - 5 displays the various information the Sim model produces as its output for without-project conditions at capacity for Bayou Sorrel lock. Under the heading of "Delay Information", the average delay per tow estimates for the initial 30 day warm up period and the following four "mini" seasons are presented. The total average delay per tow figure excludes the warm up period in its calculation. Under the heading of "Vessel Type Data", lockage information for the 35 tow classes are shown in the first 35 "vt types". Information on stalls and light boats are shown in vt 36 and vt 37, respectively. The maximum level of tons processed through the lock is presented under the heading of "Performance Measures". This figure must be annualized and adjusted to correct for the fact that this represents a 90 day period estimate.

DELAY FUNCTION CALCULATION

The delay function used in this analysis is a simple hyperbolic function. The two parameters that define this type of delay function are lock capacity (in terms of tons) and a k-value, which is the average delay per tow at half of lock capacity.

Table 5 - 4

Sim Model Sample Input File
For Without-Project Conditions

```
< Bayou Sorrel Lock <                           ** HEADER
1                                               ** NUMBER OF ITERATIONS
new.seeds                                       ** THE NEXT FOUR LINES
1136429300                                         SPECIFY AN ARRIVAL PATTERN
 514743810
1257240300
1317426630
120 5                                           ** # OF DAYS      # OF SEASONS
30 23 30 15 999                                 ** LENGTH OF EACH SEASON
                                                   (INCLUDES A WARMUP PERIOD)
1                                               ** # OF LOCKS IN THE SYSTEM

5                                               ** # OF SEGMENTS IN THE SYSTEM
QUP 1                                           ** SEGMENT ONE
999                                             ** QUEUE CAPACITY OF SEGMENT ONE
0                                               ** # OF BRIDGES BELOW SEGMENT ONE
arrival down                                    ** SEGMENT TYPE

STAGE_UP    2                                   ** SEGMENT TWO
1                                               ** QUEUE CAPACITY OF SEGMENT TWO
0                                               ** # OF BRIDGES BELOW SEGMENT TWO
staging                                         ** SEGMENT TYPE
LOCK_1  3                                       ** SEGMENT THREE
1                                               ** QUEUE CAPACITY OF SEGMENT
                                                   THREE
0                                               ** # OF BRIDGES BELOW SEGMENT
                                                   THREE
lock
    800 56  22 1                                ** LENGTH OF LOCK   WIDTH OF LOCK
                                                   QUEUE SEARCH LIMIT  # OF
                                                   CHAMBERS
0.0     0.0                                     ** FIXED CHAMBERING TIMES
       9                                        ** # OF CHAMBERING PROBABILITIES
        .01   7.0  0.   4                       ** PROB. DIST FOR WARMUP PERIOD
        .06   5.0  0.   5
        .18   0.0  0.  10
        .26   5.0  0.   7
        .21   7.0  0.   7
        .15   7.0  0.   6
        .09   10.0  0.   7
        .04   10.0  0.   5
        .01   11.0  0.   7
    0.0     0.0
       9
        .01   7.0  0.   4                       ** PROBABILITY DIST FOR SEASON 1
        .06   5.0  0.   5
        .18   0.0  0.  10
        .26   5.0  0.   7
        .21   7.0  0.   7
        .15   7.0  0.   6
        .09   10.0  0.   7
        .04   10.0  0.   5
        .01   11.0  0.   7
    0.0     0.0
      16
        .01   7.0  0.   14                      ** PROBABILITY DIST FOR SEASON 2
        .01   5.0  0.   4
        .07   0.0  0.   11
        .15   5.0  0.   7
```

```
          .20    7.0   0.    6
          .20    7.0   0.    8
          .17    10.0   0.    7
          .10    10.0   0.    9
          .05    11.0   0.    6
          .02    12.0   0.    8
          .02    13.0   0.    5
          .01    14.0   0.    6
          .01    15.0   0.    4
          .01    16.0   0.    3
          .01    17.0   0.    4
          .01    18.0   0.    15
      0.0      0.0
        9
          .02    7.0   0.    5                         ** PROBABILITY DIST FOR SEASON 3
          .09    5.0   0.    5
          .25    0.0   0.    18
          .28    5.0   0.    9
          .19    7.0   0.    7
          .09    7.0   0.    5
          .05    10.0   0.    7
          .02    10.0   0.    7
          .01    11.0   0.    5
      0.0      0.0
        8
          .03    7.0   0.    4                         ** PROBABILITY DIST FOR SEASON 4
          .09    5.0   0.    3
          .38    0.0   0.    20
          .33    5.0   0.    6
          .09    7.0   0.    7
          .06    7.0   0.    6
          .02    10.0   0.    4
          .01    106.0   0.    1
      0.0 8.0 0.0                                    ** TURNAROUND TIME FOR THE LOCK
      8      0                                       ** ADDED TIME FOR MULIVESSEL
                                                        LOCKAGES

STAGE.DN     4                                       ** SEGMENT FOUR
    1                                                ** QUEUE CAPACITY OF SEGMENT FOUR
    0                                                ** # OF BRIDGES BELOW SEGMENT FOUR
staging                                              ** SEGMENT FIVE

QDN          5
    999
    0
arrival up

365                                                  ** # OF DAYS VESSEL DATA REFLECTS
37                                                   ** # OF VESSEL CLASSES
1.0                                                  ** PERCENT OF FULL VESSELS
vt1      1                                           ** VESSEL NAME    VESSEL ID
   2     1    250 35    490                          ** PRIORITY STATUS   VESSEL LENGTH
                                                        AND WIDTH   AVG LOAD (TONS)
         1   250 35   3                              ** # OF CUTS   LENGTH & WIDTH OF
                                                        CUT   LINE ID # IN LOCK TIMING
                                                        TABLE
         104   104                                   ** # OF DOWNBOUND AND UPBOUND
                                                        OBSERVATIONS
vt2      2
    2    1   250 40    481
         1   250 40   3
         20   20
vt3      3
    2    1    250 55    635
         1   250 55   3
         19   19
```

```
vt4      4
    2    1   250 70   850
         2  250 35  3   250 35  3
         1  1
vt5      5
    2    1   250 105   0
         3  250 35  3   250 35  3   250 35  3
         1  1
vt6      6
    2    1   460 35   1474
         1  460 35  4
         362  362
vt7      7
    2    1   460 40   1378
         1  460 40  5
         44  44
vt8      8
    2    1   460 55    1427
         1  460 55  4
         286  286
vt9      9
    2    1   460 70   2438
         2  460 35  4   460 35  4
         8  8
vt10     10
    2    1   460 105  0
         3  460 35  4   460 35  4    460 35  4
         1  1
vt11     11
    2    1   660 35   2802
         1  660 35  6
         295  295
vt12     12
    2    1   660 40  1616
         1  660 40  4
         25  25
vt13     13
    2    1   660 55   3001
         1  660 55  6
         416  416
vt14     14
    2    1   660 70   4948
         2  660 35  6   660 35  6
         93  93
vt15     15
    2    1   660 105  2800
         3  660 35  6    660 35  6    660 35  6
         1  1
vt16     16
    2    1   800 35   2834
         1  800 35  7
         93  93
vt17     17
    2    1   800 40   1771
         1  800 40  7
         10  10
vt18     18
    2    1   800 55   3293
         1  800 55  8
         426  426
vt19     19
    2    1   800 70   5699
         2  800 35  7   800 35  7
         72  72
vt20     20
    2    1   800 105   2600
```

```
        3  800 35   7    800 35   7    800  35   7
        1  1
vt21    21
    2   1   1060 35   4844
        2  660 35   6    660 35    6
        532   532
vt22    22
    2   1   1060 40   3836
        2  660 40   4    660 40    4
        13  13
vt23    23
    2   1   1060 55   4936
        2  660 55   6    660 55    6
        509  509
vt24    24
    2   1   1060 70   7000
        2  660 35  6    660 35    6
        1  1
vt25    25
    2   1   1060 105  4262
        3  660 35  6   660 35  6   660 35  6
        4  4
vt26    26
    2   1   1180  35  5644
        2  660 35  6    660 35    6
        83  83
vt27    27
    2   1   1180  40  4500
        2  660 40  4    660 40    4
        1   1
vt28    28
    2   1   1180  55  5978
        2  660 55  6    660 55    6
        238  238
vt29    29
    2   1   1180  70  10718
        2  660 35  6    660 35    6
        1  1
vt30   30
    2   1   1180  105  0
        3  660 35  6     660 35    6      660 35  6
        1   1
vt31    31
    2   1   1800 35  5304
        3  660 35  6    660 35    6     660 35  6
        19   19
vt32    32
    2   1   1800 40  0
        3  660  40  4    660 40    4      660 40  4
        1  1
vt33    33
    2   1   1800 55  6551
        3  660  55  6   660 55    6     660 55  6
        9  9
vt34    34
    2   1   1800 70  1400
        3  660  35  6   660 35    6     660 35  6
        1  1
vt35    35
    2   1   1800 105  7300
        3  660 35  6    660 35    6     660 35  6
        1  1
stall   36                                   ** STALL EVENT
    2   1   800 56   0
        1  800 56  21
        40  40
```

```
lite     37                                              ** LIGHT BOAT TRAFFIC
    0    1    200 45   0
         1   200 45   1
         0    0
21                                                       ** # OF LINES IN LOCK TIME TABLE
    1    7    7    7    7    7    7    7                ** LINE ID #   LK COMPONENT TIMES
         0    0    0    0    0    0    0                ** SECOND CHAMBER INPUTS
    2    5    5    5    5    5    5    5
         0    0    0    0    0    0    0
    3    4    4    4    4    4    4    4
         0    0    0    0    0    0    0
    4    4    4    4    4    4    4    4
         0    0    0    0    0    0    0
    5    6    6    6    6    6    6    6
         0    0    0    0    0    0    0
    6    6    6    6    6    6    6    6
         0    0    0    0    0    0    0
    7    9    9    9    9    9    9    9
         0    0    0    0    0    0    0
    8    11   11   11   11   11   11   11
         0    0    0    0    0    0    0
    9    1    1    1    1    1    1    1
         0    0    0    0    0    0    0
   10    6    9    4    9    7    7    8
         0    0    0    0    0    0    0
   11    6    9    4    9    7    7    8
         0    0    0    0    0    0    0
   12    8    8    4    6    5    6    6
         0    0    0    0    0    0    0
   13    6    9    4    9    7    7    8
         0    0    0    0    0    0    0
   14    6    9    4    9    7    7    8
         0    0    0    0    0    0    0
   15    4    9    5    12   8    8    9
         0    0    0    0    0    0    0
   16    6    9    4    9    7    7    8
         0    0    0    0    0    0    0
   17    6    9    4    9    7    7    8
         0    0    0    0    0    0    0
   18    4    9    5    12   8    8    9
         0    0    0    0    0    0    0
   19    4    9    5    12   8    8    9
         0    0    0    0    0    0    0
   20    4    9    5    12   8    8    9
         0    0    0    0    0    0    0
   21    154  154  154  154  154  154  154
         0    0    0    0    0    0    0

FCFS     0                                               ** SPECIFIES LOCKING POLICY
```

Table 5 - 5

Sim Model Sample Output
Without Project Conditions

LENGTH OF RUN 120 days

ARRIVALS

Upward	1271
Downward	1285
Light Boats	968

DELAY INFORMATION

season	ave.delay(mins) up	ave.delay(mins) down	Q up	Q down	curfew inbound (mins)	curfew outbound (mins)
1	406.51	525.68	9.8	10.1	0.	0.
2	499.01	495.63	10.8	9.4	0.	0.
3	3670.99	1829.20	63.8	105.5	0.	0.
4	10704.09	4946.20	203.6	146.0	0.	0.
5	6600.98	5961.12	88.3	273.4	0.	0.
TOTAL	4572.08	5961.12	85.2	134.0	0.	0.

VESSEL TYPE DATA

Type	Delay(hrs) up	Delay(hrs) down	Processing Time(hrs) up	Processing Time(hrs) down	#Arrivals up	#Arrivals down
vt1	111.87	80.18	112.42	80.75	25	34
vt2	95.96	138.55	96.47	139.13	6	6
vt3	75.46	100.08	76.10	100.65	12	10
vt4	0.	0.	0.	0.	0	0
vt5	0.	0.	0.	0.	0	0
vt6	73.81	121.54	74.31	121.97	105	112
vt7	56.00	132.27	56.54	132.75	16	18
vt8	63.12	109.22	63.56	109.63	104	115
vt9	62.37	39.10	63.17	40.04	3	3
vt10	0.	0.	0.	0.	0	0
vt11	80.74	113.48	81.28	114.03	104	115
vt12	80.55	134.81	81.04	135.18	7	13
vt13	92.83	123.67	93.37	124.21	143	138
vt14	80.05	123.62	80.95	131.38	37	31
vt15	0.	21.53	0.	22.83	0	1
vt16	80.23	60.52	80.89	61.15	40	28
vt17	68.09	369.25	68.89	370.05	2	2
vt18	95.20	127.10	95.98	127.83	143	145
vt19	70.70	121.18	72.83	122.06	27	18
vt20	0.	0.	0.	0.	0	0
vt21	73.45	119.69	75.25	120.69	182	162
vt22	91.71	0.	92.53	0.	4	0
vt23	88.84	117.01	89.78	118.14	179	197
vt24	8.48	0.	15.79	0.	1	0
vt25	36.06	0.	37.19	0.	2	0
vt26	98.33	84.30	99.25	85.05	38	33
vt27	133.73	0.	134.46	0.	3	0
vt28	85.96	126.46	86.81	129.35	71	82
vt29	0.	33.06	0.	33.36	0	2
vt30	0.	0.	0.	0.	0	1
vt31	76.63	15.97	77.71	17.21	5	5
vt32	.13	0.	.47	0.	1	0
vt33	60.16	204.24	61.46	205.52	1	4
vt34	0.	272.91	0.	274.21	0	1

vt35	0.	0.	0.	0.	0	0
stall	73.72	149.30	81.45	156.86	10	9
lite	49.17	51.63	49.94	52.53	0	0

LOCKAGE INFORMATION - lock 1

Total number of lockages completed	3408
Total upbound	1860
Total downbound	1548

PERFORMANCE MEASURES (chamber 1)

Throughput (tons)	7767003.00	7767003.00

Using the Sim model to calculate lock capacity for a given condition involved a series of model runs with different seed numbers for each. A total of five runs (at existing traffic levels) were made each resulting in a different average delay per tow estimate. The seed values corresponding to the median delay estimate was then selected to represent a typical tow arrival pattern. Using these seed values, the arrival frequency of traffic was systematically increased until the level of tonnage processed by the lock no longer increased. This point defined lock capacity.

In order to calculate the corresponding k-values, the model was run at various traffic levels below capacity to provide additional points along the delay function. These estimates of tons processed and average delay per tow, along with the specified capacity, were used to calculate the k-value that generated the "best fit" hyperbola to the model values. The "best fit" function is identified as the function that minimizes the sum of the squared differences between the actual model estimates and the specified function estimate. The measure of the fit is referred to as the coefficient of determination or R-squared.

MODEL RESULTS

Table 5 - 6 presents lock capacities and k-values for each of the locks in the study area. As was noted earlier, due to the project flood flow line increasing over time, Bayou Sorrel lock capacities had to be estimated for the current time period as well as some future point in time (2045). These estimates are also displayed in table 5 – 6 along with the with-project lock sizes that were eventually evaluated in the GEM.

Table 5 - 6

Delay Function Parameters

Existing Locks	Current Time Frame Capacity (1,000 Tons)	Current Time Frame K-Value	Increased Project Flow Line Estimate Future Time Frame (Year 2045) Capacity (1,000 Tons)	Increased Project Flow Line Estimate Future Time Frame (Year 2045) K-Value
Old River	44.8	0.70		
Port Allen	37.2	0.72		
Bayou Sorrel	31.5	0.92	30.9	0.94
IHNC	27.6	2.05		
Algiers	26.9	0.55		
Harvey	11.6	1.27		
Bayou Boeuf	38.2	0.59		
Leland Bowman	161.0	0.96		
Calcasieu	113.0	2.76		
With-Project Bayou Sorrel Lock Alternatives				
1200 x 75 Earth	70.9	1.33	69.1	1.94
1200 x 75 Concrete	71.2	1.17	69.8	1.25
1200 x 110 Earth	97.8	1.14	95.2	1.29
1200 x 110 Concrete	97.6	1.16	96.6	1.22