Lock Performance: A Case Study of Firm Interdependence and Production with a Common Input

Byline: Wilson

Wesley W. Wilson, University of Oregon and Institute for Water Resources, Department of Economics, University of Oregon, Eugene, OR 97405, (541) 346-4690, (541) 346-1243 (Fax), wwilson@uoregon.edu

Word count: 4438 + 1250 (four tables and one figure) = 5688.

Abstract: The inland waterway system is comprised of a set of rivers and associated locks and dams. Through locks and dams, “pools” are established that allow rivers to be navigated. Locks allow barges to pass from pools of different elevation. The efficiency of the waterway depends critically on the performance of locks. Lock performance, i.e. the timely passage of barges, depends on a myriad of factors. Most notably, the time to pass through a lock depends on the structural design of the lock, the size of the tow (number of barges), the equipment both in the lock and the barges, weather conditions, river levels, etc. I develop and estimate a model of lock performance that allows each of these factors to be numerically evaluated. I find that each of these factors tends to have a strong influence on lock performance. More importantly, since vessels pass through multiple locks, I am able to treat power vessels as fixed effects and use panel data techniques. I find that different vessels and firms are quite different in passing through the locks.

INTRODUCTION

For the last 15 years, there have been on-going studies of the benefits and costs of improving the lock and dam structures of the Upper Mississippi-Illinois waterway system (UMISS). Locks and dams allow commercial use of waterways by establishing a set of “pools” providing depth and slower currents. Locks provide a mechanism through which waterway traffic can transition from one pool to another with different elevations.

Most of the locks in the UMISS system are 600 feet long and 110 feet wide. Most of the locks were built more than fifty years ago. Since then “flotillas” have grown longer. Today, the most frequent size “tow” on the Mississippi are 15 “hopper” barges which comprises a flotilla nearing 1200 feet. The result is that passage through the lock takes “two cuts” for the most common tow. Two cut passages, however, take more than twice as long as a single cut tow. As traffic has grown along with the size of the tows, there has been accompanying and significant delays and growing queues. This congestion, in conjunction with the age of the locks, has resulted in interest to redesign and invest in locks and dams on the UMISS. However, there is also considerable interest in using non-structural measures (e.g., congestion pricing, lockage fees, scheduling, tradable permits, etc.).

An understanding of the determinants of timely passage of tows through the locks is important to evaluating alternative policy actions and for use in planning models used to evaluate different policy actions. The purpose of this study is to assess the efficiency of locks on the waterway. For example, the results can be used to evaluate how lock extensions reduce lockage times; how different flotilla characteristics (e.g., number and type of barges) affect lockage times; and finally, how different configurations and characteristics of tows along with along with vessel and vessel company characteristics affect lockage times. Thus, the results can be used to estimate how delay times at locks would decline if locks operated more efficiently or if locks and vessels acquired the "more efficient" characteristics.

BACKGROUND

The UMISS waterway runs from Minneapolis to Cairo where the Ohio River joins the Mississippi. The waterway has 29 locks that run from Saint Louis to Minneapolis (Figure 1). Of these 29 locks 25 have one chamber, while locks 14, 15, 26 and 27 have two chambers (Table 1).[1] The two chamber locks have a main lock and an auxiliary chamber. The latter is used primarily when there is severe congestion or when the main chamber is not operating.

As is evident in Table 1, most locks were built in the 1930s (although, there has been considerable rehabilitation), and all but two were built more than 40 years ago. Only three of the chambers had dimensions of 1200 feet long and 110 feet wide; which is the minimum size to accommodate the standard fifteen-barge tow on the river. Twenty-four locks have dimensions of 600 by 110 feet. The remaining six locks have dimensions less than 600 by 110 feet. Four of these six chambers are located in the very north part of the waterway.[2] The remaining two are auxiliary locks for locks number 14 and 15.

Since many of the locks are 600 feet long or shorter and since tow sizes have increased over time, double lockages have become more common. Indeed, using ACE data for 2000, about 70 percent of lockages at 600 foot locks were double lockages.

Single and double lockages have very different production profiles. In a single lockage there are six production steps. These include:

1. Approach the lock
2. Enter the chamber
3. Close gates
4. Fill or empty the chamber
5. Open gates
6. Exit the lock

In a double lockage steps there are sixteen production steps. These include:

1. Approach the lock
2. Enter the chamber
3. Uncouple the tow and back the second cut out of chamber
4. Close gates
5. Fill or empty the chamber
6. Open gates
7. First cut exiting the lock chamber
8. Close gates
9. Fill or empty the chamber (opposite direction from 5)
10. Open gates
11. Second cut enters the lock chamber

---

[1] Auxiliary chambers for locks number 1 and 2 were not listed because these locks were not used in 2000. I use lock processing data for 2000 in this study.

[2] Tows in this part of the river must run in smaller sizes (at least below 1200 feet) because there are no triple lockages recorded.

12. Close gates
13. Fill or empty chamber (same direction as 5)
14. Open gates
15. Recouple the tow
16. Exit the lock

Indeed, double lockages require more production steps than *two* single lockages. Since there are added production steps, time to pass are expected and are longer.

In addition to the number of cuts to pass through a lock, there are a wide range of other factors that influence the time it takes to pass through a lock. These include: 1. the configuration of the tow; 2. the type of lockage; 3. river and weather conditions; 4. the direction of travel; and 5. firm/vessel characteristics.

Tow configuration may cause there to be extra production steps. The tow configuration requiring the fewest steps is a "straight single". In this case, the length and width of the tow does not exceed those of the lock chamber. The tow can pass through the lock without being reconfigured. Other types of tow configurations require additional production steps. In a "knockout" tow configuration, the length of the barges and towboat is too long for the lock chamber. But, if there is room in the barge configuration, the towboat may fit into an empty spot in the flotilla, and allow passage. In a "setover" the towboat and one or more barges are separated from the flotilla and moved to another side with the result that the flotilla can pass through the lock in a single cut. These later two, knockout and setover, each require extra production steps and should, therefore, require more time than a straight single.

In addition to tow configurations, there are also different types of lockages. These are fly, exchange, and turnback lockages. A fly entry occurs when the lock is idle and prepared for entry. An exchange entry occurs when an exiting flotilla and an entering flotilla, travel in different directions. In such cases, the water is at the proper level to receive the incoming flotilla. A turnback entry occurs when the exiting flotilla and the incoming flotilla are traveling in the same direction. In such cases, the water must be "turned back" or raised (lowered) to the proper level for the inbound flotilla.

A variety of location factors also influence the time to transit a lock. The position of the lock, the approach walls, the current of the river, weather conditions and direction of travel each have an influence. The lock and dam cause outdrafts (movements away from the lock) and may impede entry into and exit from the lock. Such outdrafts are much easier to handle traveling upstream than downstream with the result that locking times tend to be faster upstream than downstream. Such effects are particularly strong during periods of high water. The time of day (day or night) as well as weather conditions (ice, rain, fog) each can have an influence. The "lift", the difference in the elevation between the pools transited, affect the time it takes to fill or empty the chamber. In the UMISS, these lifts range from six to forty-nine feet.

Finally, there is a wide range of towboats each of which has a set of characteristics which may affect lock transit times. Such characteristics include horsepower, screw and rudder configuration, and the length, draft, beam and hull shape of the towboat. Towboats also have a crew that have different skill levels, are attached to firms with different training programs and which have different types of equipment.

EMPIRICAL MODEL

The empirical model(s) I use rest on the production analog. Specifically, locks produce lockages. Observed in the data, described in the next section, are the times associated with individual lockages. This time is explained by a set of variables representing lock, flotilla, and lockage-specific characteristics as well as a variety of other factors.

$$t = t(cuts,\ flotilla, lock, lockage, vessel) + \varepsilon \tag{1.1}$$

where:

cuts is the number of cuts for a flotilla to transit a lock;

flotilla represents a set of variables representing flotilla characteristics. These variables include the number of barges, percent of empty barges and flotilla area (length*width);

lock represents lock characteristics to capture length, width, lift, gate types, etc.;

lockage represents a set of variables that capture lockage characteristics such as fly, exchange, turnback, knockout, setovers, etc.;

vessels represents variable specific to the power vessel towing the flotilla.

The specific variables employed are in Table 2 along with definitions. These are discussed in detail in the next section following a description of the data.

DATA

The Army Corps of Engineers collects detailed information on the operations of locks in its Lock Performance Monitoring System (LPMS) data. This information includes the dates and time of lock activities, flotilla characteristics (including the number of barges, barge types, vessels, etc), lock characteristics, and vessel characteristics. The data used in this study represent flotillas that passed through at least one of the 29 locks on the Upper Mississippi river between January 1st and December 31st of 2000.

The locks are used for commercial, government, and recreational purposes. While some of the variables are constructed using all of the data, the econometric work is based solely on data representing commercial (non-governmental and non-recreational uses) at the flotilla level. To this end, there were 69,374 flotillas that were locked during the year. Of these, I excluded 834 observations that were “stopped”, i.e., there was a stall-stoppage during the locking period. I then calculated the number of barges per flotilla and removed 223 flotillas that had more then 16 barges[3]. I also omitted 284 flotillas that had “excessive” lockage times. Excessive was defined as times in excess of three hours. Again, those omitted represent less than ½ of one percent of the data. Finally, I calculated the number cuts from the data. Specifically, the flotillas were sorted by lock number, chamber number and start of lockage date. If a particular flotilla had multiple cuts, it would be reflected in different start of lockage times. However, from the flotilla data, the dimensions of the flotilla are reported. A comparison of the dimensions of the flotilla and the dimensions of the lock allow for a consistency check on the data. To this end, there were 1,668 observations that were not consistent (about 2 percent of the sample) which were omitted. Finally, not all vessel data could be matched to the data. Those that could not be matched were omitted – a total of 4669 observations. The final data set then contains 60,342 observations, representing flotillas passing through the UMISS locks during the year 2000.

There are a number of key variables discussed here. These include process time; the dependent variable. It is defined as the time to be processed at the lock (end of lockage minus

---

[3] Discussions with industry analysts, lock masters, and others pointed to the fact that these are unusual events which would require additional complications into modeling. Since they represent less than 1/3 of one percent, I simply omitted them.

start of lockage). On average, time of processing is about 41 minutes for one cut and 107 minutes for two cuts (Table 2). There is considerable variation across locks but that depends on the configuration of the locks and traffic passing through the locks. In particular, lock number 27 averages 42 minutes while lock number 25 averages 98. A primary explanation is that lock no 27 has a 1200 foot chamber, while lock no 25 has only a 600 foot chamber. Thus, about 83 percent of flotillas locked at lock no 25 are double cuts, while nearly all of the flotillas locked at lock no 27 are single cuts.

Primary flotilla characteristics include the number of barges towed, the percentage that are empty, and the length of the flotilla. As reported in Table 2, the number of barges averages about 10, with a range from 1 to 16. The number of barges for a single cut averages about 7 and for a double cut about 14 barges. The average flotilla length, of course, is shorter for a single cut than a double. For a single cut, the average length is about 723 and for a double cut about 1065 feet.

As discussed earlier, there are a variety of lock dimensions. Entry of lock characteristics into the empirical model can take a variety of forms. The length, width, and/or area could be entered. Alternatively, since most of the locks have a 600 by 110 configuration, and only a few lock/chambers have less than 110 feet, another approach is to “dummy” the length of the locks. Finally, locks have a set of observed characteristics and unobserved characteristics. A final approach is to enter the lock numbers as fixed or random effects. This allows unobserved characteristics that are systematic to the lock to be accounted for in the estimation, but does not directly provide estimates on the observed characteristics.

There are a set of variables that reflect entry patterns into the lock. These include fly, turnback and exchange entry patterns.[4] In this study, I organized traffic data by flotilla, and allowed “non-flotillas” to remain in the data. I sorted the data by start of lockage. With this information, I observed whether a lock was empty when a flotilla arrived. If there were no delays between arrival and start of lockage (within a minute), I defined this as a fly entry. A turnback entry means that the chamber was occupied on arrival and the direction of the occupant was the same as the flotilla. An exchange entry means that the chamber was occupied on arrival, but the direction of the occupant was different than that of the flotilla. In the data, 41 percent of the lockages were fly entries; there were 29 percent exchange and 29 percent turnback entries. There were 1110 entries which could not be characterized due to excessive delays (i.e., they were all potential fly enties in the sense that the chamber was not occupied on arrival, but the delay between arrival and entry was larger than one minute). These were omitted from the remainder of the analysis. These different types of entry patterns are reflected with dummy variables in the empirical analysis.

There were also a variety of different actions that a vessel operator can take to make a cut. These include primarily knockouts and setovers. Specifically, straight and consecutive lockages are embedded in the definition of cuts and account for about 90 percent of lockages. Setover, knockout, jackknife each involve additional production steps. I account for these with a dummy variable. These represent the bulk of the lockages other than straight and consecutive. Average lock times for single cuts are longer, on average, for these other types of lockages.

---

[4] See memo “How the Current System Operates,” provided by ACE, Institute of Water Resources (IWR).

Vessel characteristics are treated in a variety of different ways. Vessels with greater horsepower are likely to transit the locks faster. However, flotillas with loaded barges are more likely to have vessels with greater horsepower than flotillas with a preponderance of empty barges.[5] To reflect this observations, I use horsepower per barge as a measure of vessel power.

Finally, I include a variety of other variables. These include a dummy for daytime or not, a set of monthly dummies (to reflect different weather and river conditions, etc.) , whether the flotilla is traveling upstream or downstream, and a set of variables to reflect the type of barges carried on the flotilla. On this latter, there are 9 different characterizations of barge types. These include covered and uncovered hopper barges (hauls primarily coal, grains, aggregates) and tank barges (hauls liquids) which account for about 90 percent of barges transported. However, these barge types differ in size and commodities hauled. Covered hoppers are most commonly between 28 and 36 feet wide and between 195 and 259 feet long. Tank barges, on the other hand, can be much larger. Specifically, tank barges are often 50 to 54 feet wide and 290-300 feet long. As a result, the number of barges in the flotilla tend to be lower for tank barges than for hopper barges. The data are represented at the flotilla basis with number of barges included. I calculated the percentage barges by type of barge, and include a percent of barges that are hopper, tank, or other as explanatory variables (using hopper as the suppressed variable).[6] In the data, I note that for “small” flotilla (five or fewer barges), the percentage of hopper barges is about 52 percent with about 36 percent liquid barges. However, for “larger” flotillas (more than 10 barges), over 96 percent of barges in a flotilla are covered or uncovered hopper barges.

EMPIRICAL RESULTS

Provided in Table 4 is a set of different empirical specifications. In the “base” column, a straight regression of time on the variables in table 3 is provided.[7] The overall explanatory power of the variables as measured by R^2 is quite high (84%) and signs and statistical significance of the individual parameter is reasonably good. Double cuts positively influence time by about one hour. Flotilla characteristics have a strong impact on time. An increase in the number of barges increases time slightly (.26 minutes); a one percentage point increase in the percent of empty barges reduces time by 12 minutes; and flotilla length increases time by about .02 minutes per foot. Finally, liquid and tank barges and other barges take longer than standard covered and uncovered barges.

Lock characteristics also have expected results. Lock length tends to reduce times and lock lift tends to increase times. Lockages in the daytime reduce time as do upriver movements.

---

[5] Indeed, a simple regression of horsepower on number of barges and percent of empty barges yields an R^2 of 51%, with significant coefficients on barge number of barges and percent of empty barges.

[6] The sum of percentages adds to one, introducing perfect collinearity. One of the groups must be suppressed and treated as the base reference point against which the others are measured.

[7] Initial regressions suggested that horsepower needed more care. I introduced a variety of interactions with cut, number of barges and type of barges.

Horsepower is a flotilla characteristic that bears further discussions. Initial regressions suggested that horsepower has a positive influence on lockage times. The results in Table 1 still have that result. However, I added horsepower per barge (negative influence), horsepower with percentage of tank/liquid barge (hrpb_t) which yielded a positive influence, and horsepower with doublecut (hrpbc) which yielded a negative influence.

The type of lockages yielded mixed effects. TURN has a negative sign suggesting that turnback lockages are faster than FLY (a counterintuitive result). EXCH has a positive sign suggesting that exchange lockages are slower than fly lockages. In single cuts involving reconfigurations, there is an increase in time (KNOCK).

The results beg for further examinations. To this end, I explored two different specifications. First, I treated locks as having fixed effects. That is, if length and lift do not explain all of the systematic patterns across locks, the fixed effects should pick up other effects (gate types, outdrafts, etc.). It is a more general estimation strategy than that reported above and may remove any correlations of the error with variables in the model owing to lock effects.[8] With very few exceptions, the results are qualitatively equivalent and numerically similar to those discussed above. The exceptions include a sign reversal on EXCH (from the intuitive to the counterintuitive sign) and on b_other.[9]

Second, there is considerable discussion of experiences with different companies (and vessel operators) in the locking process. Indeed, the time to transit a lock depends critically on the vessel operator, crew and barge equipment. To this end, I also estimated a model of fixed effects with the vessel_no as the fixed effect. Recall, the same vessel may pass through several different locks or through the same lock multiple times. This allows a vessel effect to be estimated. The results are in the third column of Table 4.

The results are quite comparable to those in the base model column. However, the effect of the number of barges seems much larger as do the lock characteristics. The effect of single lockages with reconfiguration (KNOCK) is much larger as well, while the effects of barge types are smaller. The results suggest that vessel characteristics (both observed and unobserved) have strong effects on the time of passage model.

CONCLUSIONS

This study provides an overview of locks and lock operations on the UMISS. It develops an econometric model to evaluate the effects of different lockage characteristics, flotilla characteristics, and lock characteristics on the time it takes to transit locks. The results suggest that double cut lockage increase the time to pass through a lock by about one hour, that empty barges, hopper barges, and others pass through a lock more quickly than other types. The results also suggest that lock characteristics such as lock length reduce times and lift increases times. In addition, daytime and upriver lockages are faster than nighttime and downriver lockages. Finally, the results are quite robust to treating locks as fixed effects, but

---

[8] The fixed effect variables were lock and chamber. This treats, effectively, different chambers at the same lock as being different locks.

[9] This suggests that any definitional difficulties of FLY, EXCH, and TURN may be lock related.

are somewhat sensitive to the inclusion of vessel fixed effects. This later may point to future research in an attempt to identify the sources associated with vessels.

ACKNOWLEDGEMENTS: * I gratefully acknowledge the comments of Rich Manguno, Keith Hofseth, Don Sweeney, and the audiences at various NETS workshops as well as research assistance from Helen Naughton. This research was supposed by the Army Corps of Engineers (ACE), Institute for Water Resource, Navigation Economic Technologies (NETS) program

List of Tables:

Table 1**:** Lock Characteristics

Table 2: Variable Names and Definitions

Table 3: Descriptive Statistics

Table 4: Coefficient Estimates

List of Figures:

Figure 1: Location of Locks

Table 1. Lock Characteristics

Lock	Chamber	River Mile	Year Open	Length	Width	Lift	Gate Type
27	Aux	186	1953	600	110	21	Miter
27	Main	186	1953	1200	110	21	U.S. Vertical lift, D.S. Miter
26	Aux	201	1994	600	110	24	Miter
26	Main	201	1990	1200	110	24	U.S. Vertical lift, D.S. Miter
25	Main	241	1939	600	110	15	Miter
24	Main	273	1940	600	110	15	Miter
22	Main	301	1938	600	110	10	Miter
21	Main	325	1938	600	110	10	Miter
20	Main	343	1936	600	110	10	Miter
19	Main	364	1957	1200	110	38	Fixed
18	Main	411	1937	600	110	10	Miter
17	Main	437	1939	600	110	8	Miter
16	Main	457	1937	600	110	9	Miter
15	Aux	483	1934	360	110	16	Miter
15	Main	483	1934	600	110	16	Miter
14	Aux	493	1939	320	80	11	Miter
14	Main	493	1922	600	110	11	Miter
13	Main	523	1938	600	110	11	Miter
12	Main	557	1939	600	110	9	Miter
11	Main	583	1937	600	110	12	Miter
10	Main	615	1936	600	110	8	(L) 4 Miter (D) Moveable, 4 Roller gates,
09	Main	648	1938	600	110	9	(L) 4 Miter (D) Moveable, 5 Roller gates,
08	Main	679	1937	600	110	11	(L) 4 Miter (D) Moveable, 5 Roller gates,
07	Main	703	1937	600	110	8	(L) 4 Miter (D) Moveable, 5 Roller gates,
06	Main	714	1936	600	110	6	(L) 4 Miter (D) Moveable, 5 Roller gates,
55	Main	729	1936	600	110	5	(L) 4 Miter (D) Moveable, 5 Roller gates,
05	Main	738	1935	600	110	9	(L) 4 Miter (D) Moveable, 6 Roller gates,
04	Main	753	1935	600	110	7	(L) 4 Miter (D) Moveable, 6 Roller gates,
03	Main	797	1938	600	110	8	(L) 4 Miter (D) Moveable, 4 Roller gates

Wilson

02	Main	815	1930	500	110	12	(L) 4 Miter (D) Moveable, 19 Tainter
01	Main	848	1930	400	56	38	(L) 4 Miter (D) Fixed
52	Main	853	1959	400	56	25	(L) 1 Tainter, 2 Miter (D) Moveable, 3 Tai
51	Main	854	1963	400	56	49	(L) 4 Miter, 1 Tainter (D) Fixed

Table 2. Variable Names and Definitions

Variable	**Description**
Time	Process Time
number	Number of Barges
peremp	Percent of Empty Barges
flot_length	Flotilla Length
length	Lock Length
fly	A fly entry
turn	A turnback entry
exch	An exchange entry
knock	A knockout, jacknife, or setover
hrp	Vessel Horsepower
hrpb	Vessel Horsepower per barge
daytime	A dummy indicating day or night
upriver	A dummy indicating upstream
b_hopper	Percent of Hopper Barges
b_tank	Percent of Tank/Liquid Barges

Table 3. Descriptive Statistics

Variable	All	Single Cut	Double Cut
Time	74.77252	41.64542	107.1192
number	10.29926	6.914329	13.60446
peremp	0.3578029	0.3973948	0.3191438
flot_length	898.1809	726.8218	1065.503
length	719.0792	842.4393	598.6252
fly	0.4162615	0.4887059	0.3455237
turn	0.2923251	0.2728018	0.3113884
exch	0.2914134	0.2384923	0.3430879
knock	0.0995746	0.1904453	0.0108445
hrp	4191.068	3326.316	5035.448
hrpb	577.6962	775.0567	384.985
daytime	0.5578066	0.5479616	0.5674197
upriver	0.4982948	0.5010081	0.4956455
b_hopper	0.8289814	0.6929791	0.9617798
b_tank	0.130508	0.2303226	0.0330448
b_other	0.0405106	0.0766984	0.0051753
N	59232	29263	29969

Table 4. Coefficient Estimates

	Base	Lock Effects	Vessel Effects
Variable	Estimate (t-value)	Estimate (t-value)	Estimate (t-values)
doublecut	61.089	54.199	60.385
	(96.89)**	(90.72)**	(91.44)**
number	0.265	0.319	0.617
	(4.75)**	(6.16)**	(9.63)**
peremp	-11.872	-11.921	-11.926
	(-70.85)**	(-77.25)**	(-72.10)**
flot_length	0.024	0.025	0.015
	(28.04)**	(31.36)**	(15.59)**
lift	0.038	0	0.478
	(3.96)**	(.)	(39.19)**
length	-0.006	0	-0.015
	(-10.63)**	(.)	(-25.40)**
turn	-10.443	-12.537	-10.969
	(-67.53)**	(-85.12)**	(-73.68)**
exch	0.406	-2.093	-0.303
	(2.63)**	(14.27)**	(-2.04)*
knock	1.534	6.914	7.938
	(4.32)**	(19.49)**	(20.42)**
hrp	0.001	0.001	0
	(17.47)**	(7.07)**	(.)
hrpb	-0.001	-0.001	-0.001
	(-2.94)**	(-6.68)**	(-6.44)**
hrpb_t	-0.001	-0.001	-0.002
	(-3.55)**	(2.91)**	(-5.61)**
hrpbc	-0.019	-0.009	-0.017
	(-16.51)**	(8.29)**	(-14.49)**
daytime	-4.577	-4.358	-4.522
	(-36.52)**	(-37.80)**	(-37.80)**
upriver	-1.697	-1.591	-1.506
	(-12.17)**	(-12.41)**	(-11.30)**
b_tank	11.512	8.588	6.489
	(-24.49)**	(19.48)**	(7.67)**
b_other	3.374	-1.152	2.071
	(9.14)**	(-3.25)**	(3.45)**
Constant	30.078	32.17	41.03
	(65.13)**	(88.85)**	(70.11)**
N	59232		
R^2	0.84	0.83	0.84
F-test for FE		352*	16*

Figure 1. Location of Locks

Note: Melvin-Price is lock number 26, Upper and Lower St. Anthony Falls locks correspond to lock numbers 51 and 52, and lock 5a is lock number 55 in our study.

Source: US Army Corps of Engineers, Restructured Upper Mississippi River-Illinois Waterway System Navigation Study, from http://www2.mvr.usace.army.mil/umr-iwwsns/index.cfm?fuseaction=home.showmap.