SURVEY MODEL

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Survey Model Operation

1. Introduction

During the investigations of the Upper Mississippi River-Illinois Waterway (UMR-IWW) navigation system it became clear that spatial price equilibrium theory, a well developed economic concept, provided the appropriate theoretical framework for analyzing the UMR-IWW navigation system in particular and inland navigation systems in general. Hence, a spatial equilibrium framework was adopted as the *conceptual model*..

Real world modeling problems must be concerned not only with the theoretical but also the pragmatic. These pragmatic concerns include, but are not limited to, availability of data, mathematical tractability, and limited study resources. The *practical model* described here is referred to as the Survey Model. This document details the construction, calibration, and execution of the Survey Model. It is intended to be of sufficient detail to inform the reader of what is contained in every cell of the spreadsheet as well as to detail which cells are critical to the operation of the model. The experience analyst, using this documentation as a guide, should be able to understand, use, modify and calibrate the model.

2. Survey Model Overview

The Survey Model was developed and is run in Microsoft Excel. This software was chosen because the spreadsheet format facilitated model development and also because the solver capabilities available in Excel were suitable for finding the equilibrium conditions. The spreadsheet formulation makes input, output, and the relationships between them readily accessible.

The Excel workbook containing the Survey Model consists of four work sheets. The first sheet contains the model itself (Equilibrium), the second sheet contains the traffic forecasts (Forecasts), the third sheet (Inputs) contains most of the inputs that would typically be modified to specify a particular model execution, and a fourth sheet (Output Summary) summarizes system savings, system, traffic by commodity group, and tonnage and average delay by lock. Embedding the traffic forecasts in the workbook facilitates the automation of traffic updates for out year runs. Placing the typically modified input parameters in a separate sheet somewhat simplifies model execution. The Output sheet, which is not necessary for model execution, conveniently summarizes basic model output in one location.

There are three essential components to the model. They are 1) calculation of lock congestion (supply), 2) determination of system movements (demand), and 3) calculation

of the NED benefit. Since lock congestion is a function of traffic, which in turn is influenced by lock congestion, these two elements must be co-determined. To accomplish this, the solver module of Excel is employed. The description of the Survey Model proceeds in the order described below and unless otherwise stated, all row, column and cell references apply to the Equilibrium sheet.

Section 3: Lock Performance
Section 4: Movements
Section 5: Opportunity Cost
Section 6: System Equilibrium
Section 7: Calculation of System NED Benefits
Section 8: Calibration and Verification
Section 9: Forecasts
Section 10: Modeling of Potential System Actions

3. Lock Performance

[*The presentation of lock performance that follows is broken down by two classes of locks, non-critical and critical. Non-critical locks are defined as those that do not currently experience significant levels of congestion nor are these locks anticipated to experience significant levels of congestion in the future. Critical locks, on the other hand, currently experience or are expected to experience significant congestion in the future under one or more anticipated sets of future conditions. Lock performance for the non-critical locks (locks above Lock 11 on the Mississippi River and locks above Peoria on the Illinois Waterway) is handled through use of queuing theory, while lock performance for critical locks makes use of exogenously supplied transit curves developed with use of the Waterway Analysis Model (WAM).*

The motivation for distinguishing between non-critical and critical locks is the level of effort associated with WAM-based transit curves. The simulation environment of WAM requires significant data development and model execution requirements. Because the non-critical locks are not expected to experience significant congestion, predicting levels of low magnitude future congestion that do not vary significantly over a relatively large range of traffic is not a major concern. Therefore, the less demanding queuing theory procedure was adopted for the non-critical locks. Having said this, there is no technical reason that would prevent modification of the Survey Model structure such that all lock performance was represented by WAM-based transit curves, or by transit curves developed by other means.]

<u>Non-Critical Locks.</u> Modeling the operation of the non-critical system locks, specifically, predicting lock transit time, is accomplished in the block of cells defined by H5 through BH32. In particular each of the columns I through AS correspond to one of

the 37 lock sites explicitly modeled. The lock site labels are provided in Row 5 and again, for convenience in Row 22. Rows 6 through 20 provide statistics on base year operations, while rows 23 through 31 are concerned with the modeled year. With the exception of locks 26 and 27, locks are modeled as single chamber sites with all data and calculations necessary to accomplish the transit time estimate arrayed in the single column corresponding to the lock. The labels describing the cells in each row are provided in column H. Since data and calculations are similar for all sites (except 26 and 27) one example will be provided in detail.

Because the estimation of lock performance is based largely on Lock Performance Monitoring System (LPMS) data, while traffic is estimated from Waterborne Commerce Statistics Center (WCSC) data, it is important to verify that there is not a disconnect between these two data sources. Referring to Table 1 below, rows 6 and 7 of the spreadsheet display the base year lock tonnage based on these two data sources. These rows of cells are not a necessary component of the model.

As described in the following section on movements, traffic data consists of both front-haul and back-haul movements. The movements are arrayed in the spreadsheet so that front-hauls appear first. The front-haul tons are calculated by summing the front-haul movement tons using a particular lock. This parameter, calculated for the base year, appears in row 8. It is used in the calculation of front-haul tons per tow, which is displayed in row 13. The other parameter used in calculating front-haul tons per tow is number of tows. This is displayed in row 9 and comes directly from LPMS data.

Rows 10 and 11 contain the mean and standard deviation of Tow Service time as calculated from LPMS data, except for locks 26 and 27. Since these parameters were originally calculated in days they are converted to hours by multiplying by 24.

Rows 12 and 13 contain Tons per Tow and Front Haul Tons per Tow, respectively. These parameters are calculated from parameters previously discussed. It is important to note that these parameters are constructed from the combination of WCSC and LPMS data. "Tons per Tow" is provided for information only and is not necessary for executing the model. Front-Haul tons per tow is an important determinant of future lock traffic. Since we do not expect much change in tow configuration over the study horizon, this parameter is assumed to be invariant. The reason Front-Haul Tons per Tow is used (rather than Tons per Tow) is because there is sufficient empty equipment to accommodate increased back-haul movements without requiring additional lockages. In other words, Tons per Tow is not invariant over the study horizon because, depending on the circumstances, back-haul movements may increase or decrease, depending only on the traffic forecast, since inelastic movements are assumed not price sensitive.

Rows 14, 15 and 16 contain the parameters, which describe the demands placed on the lock by non-commercial lockages. They are number of non-commercial lockages, mean

service time, and standard deviation of service time for non-commercial lockages, respectively. Since multiple vessel lockages are common for non-commercial traffic, it is a model assumption that the number of non-commercial lockages is invariant over the study horizon. That is to say that, even if the number of non-commercial vessels utilizing the locks increases, there is no clear evidence that this will result in increased lockages.

Rows 17, 18, 19, 20 compute the mean and standard deviation of service time over all traffic along with the expected wait time and total tow transit time. Note that these parameters are provided for use in base year validation only. They are not involved in the actual running of the model. Some of the formulas used in these calculations are interesting and should be discussed. Row 17 is the mean service time. It is computed as the weighted average of the average service times for commercial tows and recreational lockages. The formula in row 18 performs a similar function for the standard deviations. The formula is:

$$\sigma = \sqrt{\left[\frac{\left(\mu_T^2 + \sigma_T^2\right) * N_T + \left(\mu_R^2 + \sigma_R^2\right) * N_R}{N_T + N_R}\right] - \mu^2}$$

This explains how the standard deviation for a population consisting of two sub-populations can be determined from the means and standard deviations as well as the size of the two subgroups.

The estimated lock wait time is found using the following formula from queuing theory:

$Ex(D) = [(:_s^2+\Phi_s^2)/2(:_a-:_s)][(\Phi_a^2+ \Phi_s^2)/(:_a^2+ \Phi_s^2)]$, where $:_s$ represents the mean service time, Φ_s represents the standard deviation of the service time, $:_a$ represents the mean inter-arrival time at the lock, Φ_a represents the standard deviation of the inter-arrival times at the lock. This formula provides an approximation that should become increasingly accurate with congestion. Further the interarrival times are assumed to be exponentially distributed, hence the mean interrarival time is equal to the standard deviation of interarrival time, and hence the second term, $[(\Phi_a^2+ \Phi_s^2)/(:_a^2+ \Phi_s^2)]$, in the equation is equal to 1. This formula, as it actually appears in the model, can be inspected below in cell U19. Note that the average interarrival time is computed by dividing the number of lockages by the number of hours in a 270 day navigation season. For locks on the Illinois Waterway, as well as locks 26 and 27, a 365 day navigation season is used. It should be noted that, since this calculation is the expected value of a random variable, we would not expect to see exact replication of wait times actually observed on the navigation system. What we look for is wait times that are consistent with those that we have historically observed. Row 20 contains the expected tow transit time which is simply the sum of the average tow service time and the expected wait time.

Rows 23 through 31 contain the lock specific outputs for the model run. They are, in many cases, analogous to the inputs previously discussed. Tons and front-haul tons are contained in rows 23 and 24. They are calculated by summing the tonnage in the system movements using the lock in the scenario being modeled. Tons locked are provided merely for interest, but front-haul tons are necessary to compute the number of commercial tows found in row 25. Note that number of tows is calculated by dividing the front-haul tons by the "front-haul tons per tow" (row 13) which was assumed to be invariant.

Once the number of tows is determined, the mean interarrival time, mean service time, and standard deviation can be computed in an exactly analogous manner to that previously discussed. Note again that these are critical parameters used in calculating the wait time and are not inputs entered directly as specific values.

Rows 29 and 30 show a capacity estimate assuming no recreation lockages and a calculation of lock utilization. These outputs are calculated in a straightforward manner which the reader can determine by inspection of the cells. Note that these outputs are provided purely for interest and are not essential to executing the model.

Finally, row 31 computes the expected value of tow lock transit by adding the mean service time to the wait time computed using the formula discussed above.

Both the Melvin Price Lock and Dam (26) and Lock 27 have 600' and 1200' chambers capable of moving significant quantities of commercial traffic. It was determined that delay estimation for these sites could be accomplished using techniques and formulas similar to the single chamber formulation if traffic could be properly allocated between the two chambers. This allocation is done using Excel's Solver feature.

The portion of the spreadsheet which accomplishes this is contained in the section defined by cells AW1 through BH32. Table 2 below shows an extract of that section. The allocation is accomplished as follows. First the LPMS data is examined to determine the proportion of the commercial tows which would require a double lockage in the 600' chamber. This proportion is about 0.75 and is displayed in cell AY4 (cell AY3 displays the proportion requiring only a single lockage). Next LPMS data is used to determine the mean and standard deviation of single, double and recreation service times in the 600' chamber. For the 1200' chamber we identify the mean and standard deviation of service times for tow lockages and for recreation lockages (since all commercial lockages in the 1200' chamber are accomplished in a single cut). These values are input into rows 16 through 18 (mean) and rows 20 through 22 (standard deviation). Note that for the main (1200') chamber the mean and standard deviation are nearly identical for both tow lockage types since, in this chamber, both would require a single lockage. Given that this is a non-critical lock in the analysis, this assumption is inconsequential to the analysis

results. From these parameters the weighted averages of the mean and standard deviation of lock service time over all traffic is computed in a way analogous to that used in the single chamber case. Note that the average is now over three subgroups (single, double, recreation) rather than the two used in the single chamber case. These calculations are accomplished in rows 25 and 26 of the spreadsheet. Interarrival time is computed by dividing the total hours in the year by the number of lockages allocated to the chamber in row 30. The calculation of average tow transit time for the chamber takes place in row 32 and is identical to the calculation used for the single chamber site. The lock transit time for tows for the total site is then found (in cells BA32 and BE32) by calculating the weighted average of this parameter for each chamber. The solver is employed to minimize this number (total average tow transit time) by adjusting the allocation of single, double and recreation lockages in the auxiliary (600') chamber to any non-negative number. These "floating cells" are AZ10, AZ11, and AZ12. The allocation of lockages to the main chamber is done in cells AY10, AY11, AY12 and is simply the difference between the total number of lockages of a given type and those allocated to the auxiliary chamber.

Since this process must be performed for two sites, the solver is used to minimize the sum to the transit times across all two-chamber sites. Since these parameters are independent and non-negative, minimizing the sum is equivalent to minimizing each separately.

Those familiar with queuing theory may recognize that this algorithm will theoretically overestimate transit time. This is because the allocation is done a priori rather than in real time. This is only a minor problem since there are factors, such as vessel interference and bias towards a particular chamber, that would tend to increase observed delays. Further, in the limit of large queues, the formulation described above becomes theoretically correct. As these are non-critical locks, utilization rates at locks 26 and 27 are relatively low. Low utilization means that the most efficient situation of multiple cut tows using the main chamber is typically the action chosen by multiple cut tows (i.e. there is little navigation to consider use of the auxiliary due to heavy delays at the main.) Consequently, the allocation of lockage types across chambers generally has a minimal influence on the mean processing.

Table 1. Calculation of Lock Transit Time – Non-Critical Locks

Row	G	U
5		UM 10
6	LPMS Tons	20173000
7	WCSC Tons	20165591
8	WCSC Front Haul Tons	16580313
9	LPMS Tows	1848
10	Mean Service Tows (hrs)	1.33
11	Stnd Dev Service Tows (hrs)	=0.0239*24
12	Tons/Tow	=U7/U9
13	Front Haul Tons/Tow	=U8/U9
14	Other Lockages	=4079-1848
15	Mean Service Other (hrs)	0.2
16	Stnd Dev Service Other (hrs)	0.1
17	Mean Service All (hrs)	=(U9*U10+U14*U15)/(U9+U14)
18	Stnd Dev Service All (hrs)	=(((U10^2+U11^2)*U9+(U15^2+U16^2)*U14)/(U14+U9)-U17^2)^0.5
19	Estimated Lock Wait Time (hrs)	=(0.5*(U17^2+U18^2)/((270*24)/(U9+U14)-U17))
20	Estimated Total Tow Transit Time (hrs)	=U10+U19
21		
22	LOCK	UM 10
23	Tons	=SUMPRODUCT($G$48:$G$1969,U48:U1969)
24	Front Haul Tons	=SUMPRODUCT($G$48:$G$1134,U48:U1134)
25	Tows	=U24/U13
26	Mean Interarrival Time All (hrs)	=270*24/(U14+U25)
27	Mean Service Time All (hrs)	=(U25*U10+U14*U15)/(U25+U14)
28	Stnd Dev Service Time All (hrs)	=(((U10^2+U11^2)*U25+(U15^2+U16^2)*U14)/(U25+U14)-U27^2)^0.5
29	Main Chamber Capacity with no Rec Lockages (tons)	=(270*24/U10)*(U12)
30	Utilization	=U27/U26
31	Total Tow Transit Time from Lock Data (hrs)	=U10+(0.5*(U27^2+U28^2)/(U26-U27))

Table 2. A Two Chamber Lock Transit Time

Row	AW	AX	AY	AZ	BA
1		LOCK 26 DETAIL			
2					
3		PERC 1	0.25		
4		PERC 2	0.75		
5					
6			MAIN	AUX	TOTAL
7	TOWS		7924.62	2641.54	10566.16
8					
9					
10	TOWS1		0.00	2641.54	2641.54
11	TOWS2		7924.62	0.00	7924.62
12	REC		0.00	1722.00	1722.00
13					
14	TOTAL VESSELS		7924.62	4363.54	12288.16
15					
16	Mean Service Tows (hrs) 1		0.63	0.56	0.56
17	Mean Service Tows (hrs) 2		0.63	1.54	0.63
18	Mean Service Rec (hrs)		0.23	0.24	0.24
19					
20	Stnd Dev Service Tows (hrs)		0.29	0.20	
21	Stnd Dev Service Tows (hrs)		0.29	0.30	
22	Stnd Dev Service Rec (hrs)		0.10	0.10	
23					
24					
25	Mean Service All (hrs)		0.63	0.43	0.56
26	Mean Service All Tows (hrs)		0.63	0.56	0.61
27					
28	Stnd Dev Service All (hrs)		0.29	0.23	
29					
30	Mean Interarrival Time All (hrs)		1.11	2.01	0.71
31					
32	Total Tow Transit Time All (hrs)		1.13	0.64	1.00

Table 2. (continued)

ROW	AW	AX	AY	AZ	BA
1		LOCK 26 DETAIL			
2					
3		PERC1	0.25		
4		PERC2	=1-AY3		
5					
6			MAIN	AUX	TOTAL
7	TOWS		=AY10+AY11	=AZ10+AZ11	=AJ25
8					
9					
10	TOWS1		=BA10-AZ10	2641.53998992027	=BA7*AY3
11	TOWS2		=BA11-AZ11	0.00001	=BA7*AY4
12	REC		=BA12-AZ12	1721.99999	=AJ14
13					
14	TOTAL VESSELS		=SUM(AY10:AY12)	=SUM(AZ10:AZ12)	=SUM(BA10:BA12)
15					
16	Mean Service Tows (hrs) 1		0.6264	=33.7/60	=(AY16*AY10+AZ16*AZ10)/(AY10+AZ10)
17	Mean Service Tows (hrs) 2		0.6264	=92.4/60	=(AY17*AY11+AZ17*AZ11)/(AY11+AZ11)
18	Mean Service Rec (hrs)		0.2323	0.2358	=(AY18*AY12+AZ18*AZ12)/(AY12+AZ12)
19					
20	Stnd Dev Service Tows (hrs)		0.2928	0.2	
21	Stnd Dev Service Tows (hrs)		0.2928	0.3	
22	Stnd Dev Service Rec (hrs)		0.1	0.1	
23					
24					
25	Mean Service All (hrs)		=(AY10*AY16+AY11*AY17+AY12*AY18)/(AY10+AY11+AY12)	=(AZ10*AZ16+AZ11*AZ17+AZ12*AZ18)/(AZ10+AZ11+AZ12)	=(AY25*AY14+AZ25*AZ14)/BA14
26	Mean Service All Tows (hrs)		=(AY10*AY16+AY11*AY17)/(AY10+AY11)	=(AZ10*AZ16+AZ11*AZ17)/(AZ10+AZ11)	=(BA10*BA16+BA11*BA17)/(BA10+BA11)
27					
28	Stnd Dev Service All (hrs)		=(((AY16^2+AY20^2)*AY10+(AY17^2+AY21^2)*AY11+(AY18^2+AY22^2)*AY12)/(AY14)-AY25^2)^0.5	=(((AZ16^2+AZ20^2)*AZ10+(AZ17^2+AZ21^2)*AZ11+(AZ18^2+AZ22^2)*AZ12)/(AZ14)-AZ25^2)^0.5	
29					
30	Mean Interarrival Time All (hrs)		=(365*24)/AY14	=(365*24)/AZ14	=(365*24)/BA14
31					
32	Total Tow Transit Time All (hrs)		=AY26+(0.5*(AY25^2+AY28^2))/(AY30-AY25)	=AZ26+(0.5*(AZ25^2+AZ28^2))/(AZ30-AZ25)	=(AY7*AY32+AZ7*AZ32)/(AY7+AZ7)

Critical Locks. The Survey Model is structured to accept exogenously generated transit curves to describe the performance of critical locks. These transit curves are defined by three parameters, lock processing time, lock capacity, and a scaling factor referred to as k. The performance of an individual lock in a particular year is can be defined by a family of transit curves. The various curves in the family represent different lock unavailability, or closure conditions. A closure condition typically represents a number of days during the navigation season that a lock would not be in service.

Transit curve parameters, and the frequency of each closure case, are input to the model in the Inputs sheet. In the Inputs sheet the processing time (in hours) is represented in row 10 for the "base" or no closure case. Rows 11 and 12 represent the k value (in hours) and capacity (in tons), respectively, for the no closure case. Processing time is not repeated for each of the closure case transit curves, as each uses the same processing time as the no closure case. Consequently, rows 13, 14, and 15 represent the k value, capacity, and closure frequency for the next closure case. This three row sequence repeats three additional times meaning that the Inputs sheet is structured to accept a total of five transit curve closure cases (including the no closure case) for each critical lock. Values are input to the Inputs sheet over column B to column Q for the 16 critical locks (Locks 11-25 on the Mississippi River and Locks at Peoria and LaGrange on the Illinois Waterway.) Table 3 below displays a portion of this input section. (The input structure is identical for those locks not represented below.)

Table 3. Transit Curve Inputs – Critical Locks

	A	H	I	J
Row				
		UM 17	UM 18	UM 19
10	Normal Operation Service Time (in hrs)	1.516597111	1.426254889	1.016241556
11	Normal Operation K	1.116055286	1.026012708	0.667453937
12	Normal Operation Cap	48,902,002	49,069,791	66,738,287
13	Closure Duration #1 K	1.214664201	1.089751751	0.725744172
14	Closure Duration #1 Cap	48,902,002	49,024,208	66,738,287
15	Closure Duration #1 Frequency	1	2	3
16	Closure Duration #2 K	1.214664201		0.725744172
17	Closure Duration #2 Cap	48,545,390		66,738,287
18	Closure Duration #2 Frequency	1		
19	Closure Duration #3 K			
20	Closure Duration #3 Cap			
21	Closure Duration #3 Frequency			
22	Closure Duration #4 K			1.35373118
23	Closure Duration #4 Cap			94,794,889
24	Closure Duration #4 Frequency			1

The transit curve data in the Inputs sheet is read into the Equilibrium sheet by cell reference. The Equilibrium sheet formulas in the example below in Table 4 are for Lock 11, which is positioned in column B of the Inputs sheet and in column V of the Equilibrium sheet.

Table 4. Transit Curve Computations

Row	T	V
35	Service Time (in hrs)	=Inputs!B10
36	Normal Operation Delay	=Inputs!B11*V23/(Inputs!B12-V23)
37	Closure Duration #1 Delay	=Inputs!B13*V23/(Inputs!B14-V23)
38	Closure Duration #2 Delay	=Inputs!B16*V23/(Inputs!B17-V23)
39	Closure Duration #3 Delay	=Inputs!B19*V23/(Inputs!B20-V23)
40	Closure Duration #4 Delay	=Inputs!B22*V23/(Inputs!B23-V23)

The formula in row 35 restates the processing time for Lock 11. The formulas in rows 36 thru 40 calculate the expected average delay for each closure case. Note that the reference to Equilibrium sheet cell V23 is total tonnage for Lock 11. Unlike the non-critical locks, where formulation of expected average delay is based on front haul tons, the externally generated transit curves for the critical locks are formulated using total tons.

The final step is to calculate a composite expected average transit time that incorporates the full family of curves for an individual lock. This calculation takes place in the Equilibrium sheet in row 31. The formula for Lock 11, in column V is:

=Inputs!B10+V36+((V37-V36)*Inputs!B15)+((V38-V36)*Inputs!B18)+((V39-V36)*Inputs!B21)+((V40-V36)*Inputs!B24)

Note: Average processing time can vary with lock utilization levels and closure assumptions. This is specifically the case for multiple chamber sites. For this reason, it can be better to imbed the service times in the estimation of the hyperbolic curve parameters and define a tonnage-transit curve instead of a tonnage-delay curve, as was employed here. However, since the critical projects defined in this model are single lock chamber projects, and the fleet is assumed fixed through time, this potential problem is avoided in this specific use of the model.

4. Movements

After aggregation by origin, destination, and commodity group, base year movements are entered into the Equilibrium sheet beginning in row 48. The parameters defining these movements, along with the movement specific calculations are discussed next. An important distinction between movements occurring on the system are those whose water transportation prices will be sensitive to lock congestion and those whose water prices

will be insensitive. These are referred to as elastic and inelastic movements, respectively. It should be noted, however, that (almost) all movements are considered to be price elastic, but the focus of this model is the impact of lock congestion. Movements that are considered inelastic are: 1) movements that do not use any system locks and 2) back-haul movements.

Back-haul movements are defined as movements that utilize resources (barges, tows) which, in the absence of the movement would transit the locks empty. Generally, back-haul movements are long-haul northbound movements of commodities utilizing hopper barges. Since, for back-haul movements, the opportunity cost of production foregone is incurred in either case, lock congestion should not impact the back-haul rate and therefore these movements should be inelastic with respect to lock congestion. Conversely, front-haul movements incur congestion on both the trip and return, hence their prices are doubly sensitive to the opportunity foregone while awaiting lockage.

Also treated as inelastic are movements (typically a small number) where the existing transportation cost analysis indicates no economic incentive to use the waterway. Since these movements are observed, the conclusion must be that their reasons for using the waterway, economic or otherwise, are not fully understood. This leads to the decision to model these movements as inelastic (in volume) to lock congestion, even through their water prices increase with increasing congestion.

Note the extract of the first 8 cells (columns A through H) of one example movement below in Table 5.

Table 5. Movement Tonnage and NED Calculation

A	B	C	D	E	F	G	H
				2000			
				Forecasted Tons	Base Year	2000	
Origin	Destination	Com		Annual Volume	WCSC	Water	2000
Reach	Reach	Grp	Rvr	Adjusted	Tons	Tons	NED ($/Ton)
26	99	1	I	77,199	77,199	77,199	5.69

The first four cells of the movement are straightforward. They are movement origin, destination, commodity group, and river. The commodity groups are listed on the Forecasts sheet. Column D indicates whether the movement takes place primarily on the Mississippi River or the Illinois Waterway.

The calculation that applies the forecast to the individual movement takes place in column E. This is one of the essential features of the model so it will be explored in some detail. The formula in this cell computes the potential annual quantity for the

movement after adjustment for any change in the price of water transportation. Adjustments to movement annual quantity are based on the work described in two documents authored by Kenneth Train and Wesley Wilson, *Transportation Demand for Agricultural Products in the Upper Mississippi and Illinois Basin,* and *Transportation Demands for the Movement of Non-Agricultural Commodities Pertinent to the Upper Mississippi and Illinois River Basin.* However, before proceeding with the discussion of the Train-Wilson work, additional portions of the Equilibrium sheet dealing with movements must first be described.

The information contained in Column G also is based on the referenced Train-Wilson work. Column G performs the calculation that estimates the quantity of forecast potential tonnage (adjusted for any rate change) which will have the economic incentive to use the waterway system. Detailed discussion of this feature will also be deferred until the remaining portions of the movements section of the spreadsheet are presented.

Columns I through AS contain the lock use indicators and correspond directly to the 37 lock sites in the modeled system. A "1" in the cell indicates that the lock is used by the movement, a "0" indicates that it is not used. The use of this scheme allows for the efficient calculation of predicted lock tonnage by multiplying movement tonnage by the appropriate indicator then summing across all movements.

Column AT contains the opportunity cost of net revenues foregone due to congestion. For convenience it is expressed on a per-ton hour basis. The values of this cell are zero for back-haul movements or movements not utilizing system locks. More will be said about the construction of these numbers in a later section.

Table 6. Movement Water Rate Calculation

AT	AU	AV	AW	AX	AY	AZ
Hourly		Base	Base		=A6	Base
Unit	Total	No Lock	Total	=A6	Total	Maximum
Opptnty	Opp	Water	Water	Cost	Water	Alternative
Cost	Cost	Cost	Cost	Increase	Cost	Cost
0.031	=AT48*SUMPRODUCT($I$32:$AS$32,I48:AS48)	15.49	15.65	=AY48-AW48	=AU48+AV48	19.62

Column AU is used to determine total (per ton) net revenues foregone due to all of the movements lock transits. This is done by summing the product of the lock indicators with the lock transit times and multiplying this by the per hourly costs presented in column AT.

Note that the lock transit times come from cells I32 through AS32. The purpose of this distinction between the transit times (delay + service) used in the movement calculation and those computed via lock usage will be explained in the section on equilibrium.

Column AV contains the adjusted water rate of the movement if no loss is incurred at the locks. This column contains numeric entries that are generated in the model calibration. Prior to calibration this column contains the formula AYxx-AUxx (where xx represents the row number.) Refer to section 8 for further explaination.

The existing base water costs are contained in column AW. The next column (AX) shows the difference in water rate for the modeled year and/or action and the base. This is provided for interest only and is not essential to the model.

Column AY shows the constructed water rate for the year and/or action being modeled. It is constructed by adding the opportunity cost (AU) to the no congestion base rate (AV). As mentioned previously, column AZ contains the alternative mode transportation cost.

At this point the discussion returns to the Train-Wilson work. The work by Train-Wilson addresses the issue of the own-price elasticity of the demand for water transportation. It employs an econometric analysis of data compiled from a survey of shippers' revealed and stated preferences.

The authors performed econometric analyses using the survey results as input into a theoretical shipper's modal choice models. In particular, the survey results formed the basis for estimating econometric models based on current data of shippers' revealed best and stated next best preferences which in turn were ultimately used to estimate arc elasticities of shippers' responses to rate increases for both annual volume decisions and mode choice decisions (where and how to ship the product.) *[Note the Train-Wilson work generated estimates of annual volume and mode choice responses to rate, time, and reliability. Only the response to rate has been incorporated into the Survey Model.]*

One of the effects captured in the Train-Wilson work is the annual volume response by shippers to a change in the price of water transportation. Train-Wilson generated annual volume arc elasticities with respect to rate over a range of rate increases up to 60 percent. Using these elasticities, a percentage adjustment to annual volume can be directly computed for a given change in rate (volume adjustment = elasticity x rate change.) Table 7 summarizes the the arc elasticities and the associated volume adjustments for agricultural products and non-agricultural products.

[In Train-Wilson, agricultural products primarily included corn, wheat, and soybeans. These commodities correspond directly to Survey Model commodity groups 1-3. Non-agricultural products for Train-Wilson are broken down into three groups. Group A includes NAIC codes in the 200's (oil and gas extraction, mining, aggregates.) Survey Model commodity group 8, Construction Materials, maps to Group A. Group C includes NAIC codes 327-332 (minerals, metals.) Survey Model commodity group10, Iron & Steel, maps to Group C. Group B includes NAIC codes 300-326 and 454 (wood, paper,

petroleum, coal, chemicals, plastics, fuel.) All remaining Survey Model commodity groups map to Group B.]

The annual volume responses in Table 7 can be used to adjust the unconstrained traffic forecasts to reflect the impact of rate changes on shipper volume decisions. However, an expression of these volume responses over a continuous range of rate change, as opposed to the discrete changes represented in the table, are required for incorporation into the Survey Model. It was necessary to find a well behaved function that could be used to approximate the tabular data. A third degree polynomial was found to provide an excellent fit.

The third degree polynomial approximation is displayed below in Figure 1 for the agricultural commodities. Figure 2 through Figure 4 display the third degree polynomial approximations for the non-agricultural commodity Groups A through C, respectively.

As previously described, the calculation that applies the unconstrained forecasts to the individual movements takes place in column E. With explanation of the annual response by shippers to a rate change completed, the discussion of column E can be resumed. The formula in column E is:

for an Illinois Waterway movement of agricultural products:

=MAX(0,F48*VLOOKUP(C48,Forecasts!$B$23:$BK$35,$A$12+1)/VLOOKUP(C48,Forecasts!$B$23:$BK$35,2)*(100-(Inputs!$B$54*BB48^3+Inputs!$B$53*BB48^2+Inputs!$B$52*BB48))/100

or for a Mississippi River movement of agricultural products:

=MAX(0,F48*VLOOKUP(C48,Forecasts!$B$7:$BK$19,$A$12+1)/VLOOKUP(C48,Forecasts!$B$7:$BK$19,2)*(100-(Inputs!$B$54*BB48^3+Inputs!$B$53*BB48^2+Inputs!$B$52*BB48))/100)

The only difference in these two formulas is the section referenced in the Forecast sheet, *VLOOKUP(C48,Forecasts!$B$7:$BK$19,$A$12+1)/VLOOKUP(C48,Forecasts!$B$7:$BK$19,2)*. This portion of the formula looks up, in sheet two of the model, the unconstrained forecast tonnage for the proper river system and Survey Model commodity group, and calculates the ratio of forecast tonnage to base year traffic. (Note that the tonnage in the Forecast sheet is that which is forecast to move on the river system if the price of water transportation remains at existing levels.)

The ratio of forecast to base tonnage is then adjusted by the estimated change in annual volume for a given rate change. The formula defining the annual volume response relates the percent of annual volume lost to the percent increase in rate. The relevant portion of the formula in column E is, *(100-(Inputs!$B$54*BB48^3+Inputs!$B$53*BB48^2+Inputs!$B$52*BB48))/100).* The references, *Inputs!$B$54*, *Inputs!$B$53*, and *Inputs!$B$52*, are the coefficients that define the annual volume

response function. These coefficients are entered in the designated cells on the Inputs sheet. Column BB is also referenced here. It contains the computation of "Percentage Water Increase." This information, along with the coefficients of the annual volume response function, defines the percentage adjustment made to the unconstrained traffic forecasts. (The Survey Model is configured to reflect an annual response function individually for agricultural products, non-agricultural products Group A, non-agricultural products Group B, and non-agricultural products Group C. These coefficients are entered in the Inputs sheet on rows 52 through54 and columns B through E. Table 8 displays the section of the Inputs sheet where these values are located.)

This overall proportional change in traffic is then multiplied by the base year traffic found in column F to produce the movement specific forecast.

The final component of the formula in column E compares the computed quantity to zero, and assigns the greater of the two. This final component insures against a negative quantity.

To reflect a specific future forecast year, the desired year is input into the cell B4 of the Inputs sheet, which updates cell A6 of the Equilibrium sheet, which in turn updates the appearance of the year in the column labels as well as affecting cell A12, the lookup column.

At this point the discussion returns to column G, the estimate of actual waterway quantity. The Train-Wilson work produces estimates of the percent of movements that would switch transportation modes or destinations in response to a rate increases. Survey Model implementation of Train-Wilson employs the parameterized tabular data for rate responses presented in Train-Wilson, and is described in detail below.

Train-Wilson estimated the shipper' response to rate increases. Since the Train-Wilson results are independent of which mode is primary and which mode is alternate, the results can (at least for small changes) be reflected across the origin and used to estimate a percentage volume increase for a corresponding percentage rate decrease. The results for agricultural and non-agricultural commodities are displayed in Table 9. Train-Wilson, in estimating mode choice responses to rate, evaluated non-agricultural commodities using the same three groups as were used in the estimation of annual volume response. However, as implemented into the Survey Model, all non-agricultural commodities were considered as a single group. This was due to the extremely small differences in estimated responses across the three groups. As actually applied, the specific responses for Group B were used to represent all non-agricultural commodities.

As with implementation of the annual volume response, an expression of mode choice response over a continuous range of rate change, as opposed to the discrete changes represented in the table, was required for incorporation into the Survey Model.

Therefore, it was necessary to find a well behaved function that could be used to approximate the tabular data. A fourth degree polynomial was found to provide an excellent fit to the data.

The fourth degree polynomial approximation is displayed below in Figure 5 for agricultural commodities and in Figure 6 for non-agricultural commodities.

Table 7. Annual Volume Response to a Rate Change - Agricultural and Non-Agricultural

				Non - Agricultural					
		Agricultural		Group A		Group B		Group C	
Source	Percent Rate Increase	Elasticity	Percent Volume Lost	Elasticity	Percent Volume Lost	Elasticity	Percent Volume Lost	Elasticity	Percent Volume Lost
Extension of results	-20	-0.15	-3.1	-0.55	-11.1	-0.42	-8.3	-0.28	-5.6
Extension of results	-10	-0.08	-0.8	-0.87	-8.7	-0.64	-6.4	-0.42	-4.2
Train - Wilson	0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Train - Wilson	10	-0.08	0.8	-0.87	8.7	-0.64	6.4	-0.42	4.2
Train - Wilson	20	-0.15	3.1	-0.55	11.1	-0.42	8.3	-0.28	5.6
Train - Wilson	30	-0.21	6.2	-0.47	14.0	-0.36	10.7	-0.25	7.4
Train - Wilson	40	-0.25	9.8	-0.43	17.3	-0.34	13.6	-0.24	9.7
Train - Wilson	50	-0.27	13.6	-0.42	21.2	-0.34	17.0	-0.25	12.4
Train - Wilson	60	-0.29	17.3	-0.42	25.4	-0.35	20.8	-0.26	15.5

Table 8. Annual Volume Response to Rate - Polynomial Coefficients

	A	B	C	D	E
Row					
	Annual volume response to rate ploynomial coefficients	Com. Grp. 1-3 (Agricultural)	Com. Grp. 8 (Non-Agricultural "A")	Com. Grp. 4,5,6,7,9,11 (Non-Agricultural "B")	Com. Grp. 10 (Non-Agricultural "C")
51	b0	0.0000000000	0.0000000000	0.0000000000	0.0000000000
52	b1	0.1501000000	0.5697000000	0.4260000000	0.4247000000
53	b2	0.0014000000	-0.0031000000	-0.0021000000	-0.0079000000
54	b3	0.0000200000	0.0000070000	0.0000100000	0.0000900000

Figure 1. Annual Volume Response of Agricultural Products to a Rate Change

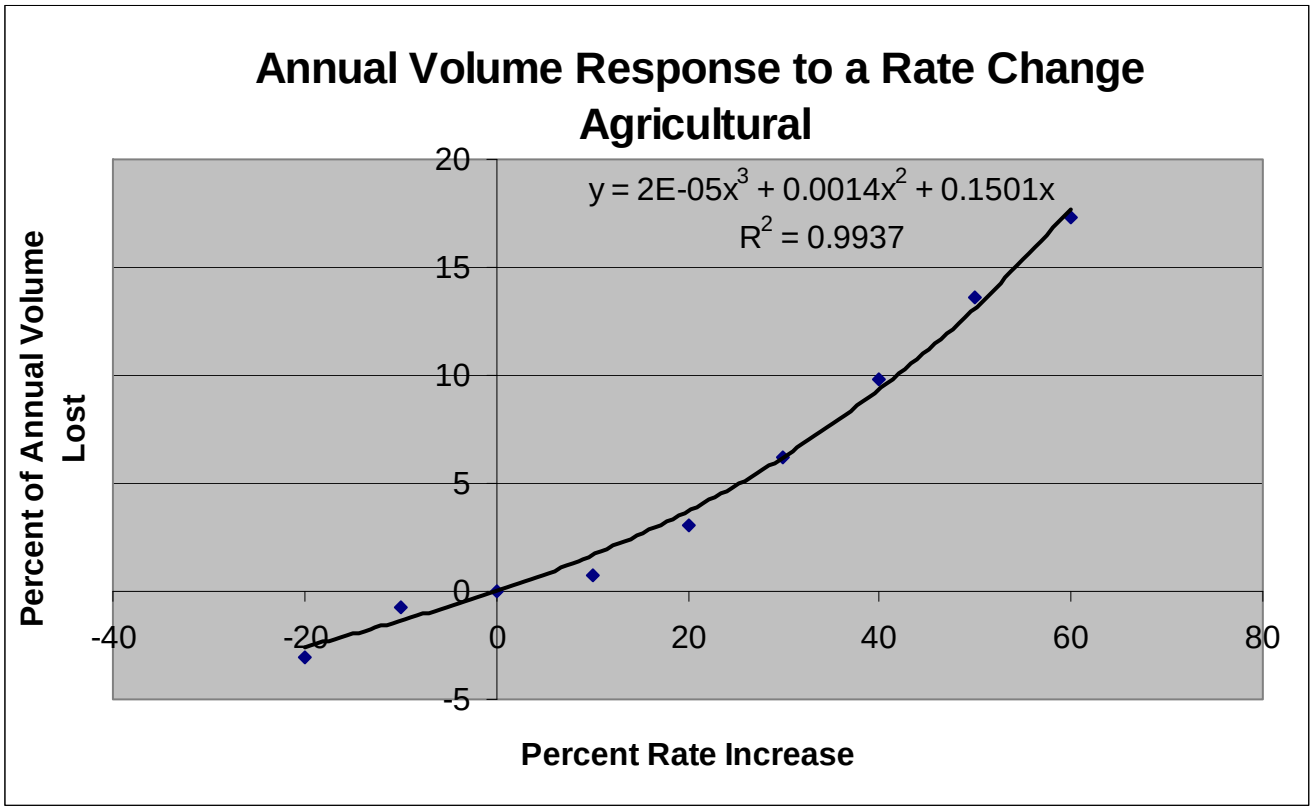


Figure 2. Annual Volume Response of Non-Agricultural (Group A) Products to a Rate Change

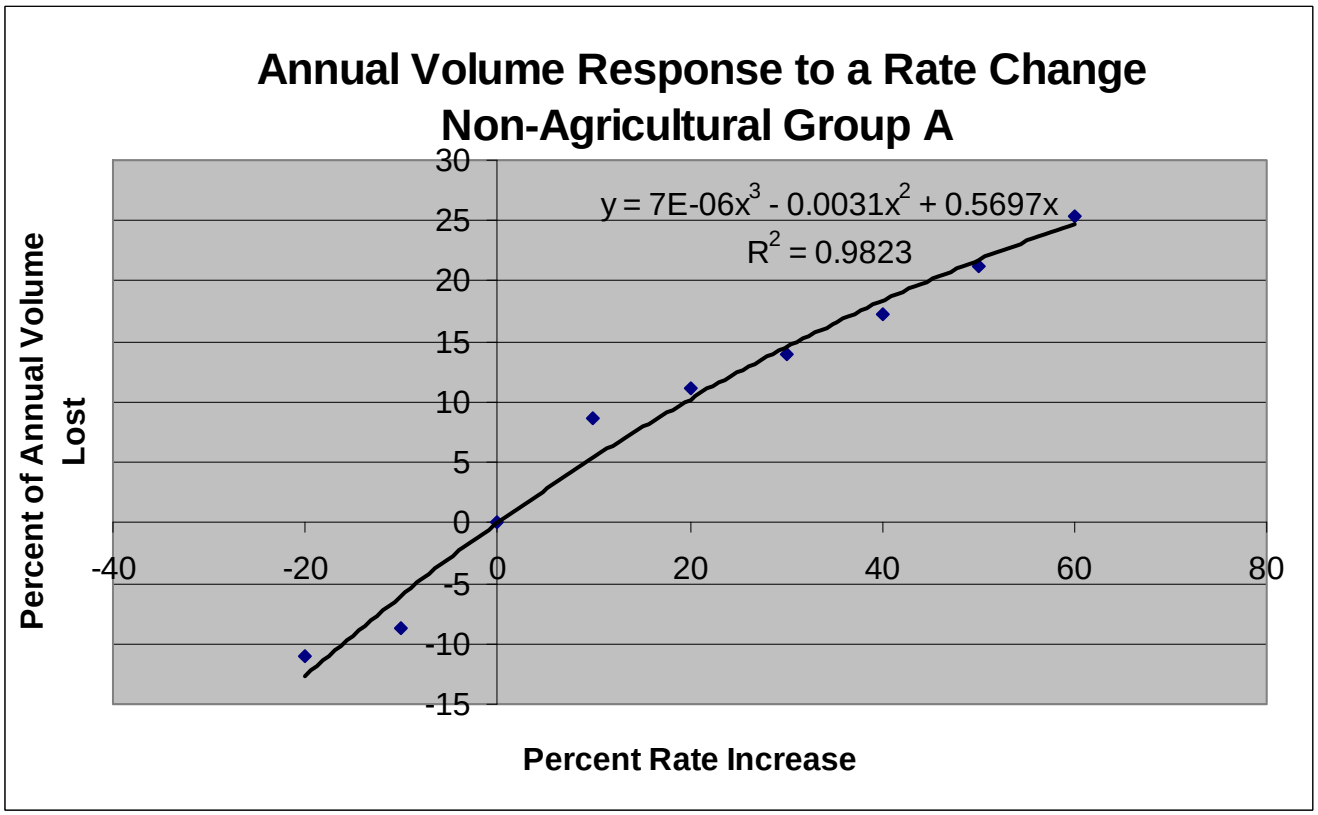


Figure 3. Annual Volume Response of Non-Agricultural (Group B) Products to a Rate Change

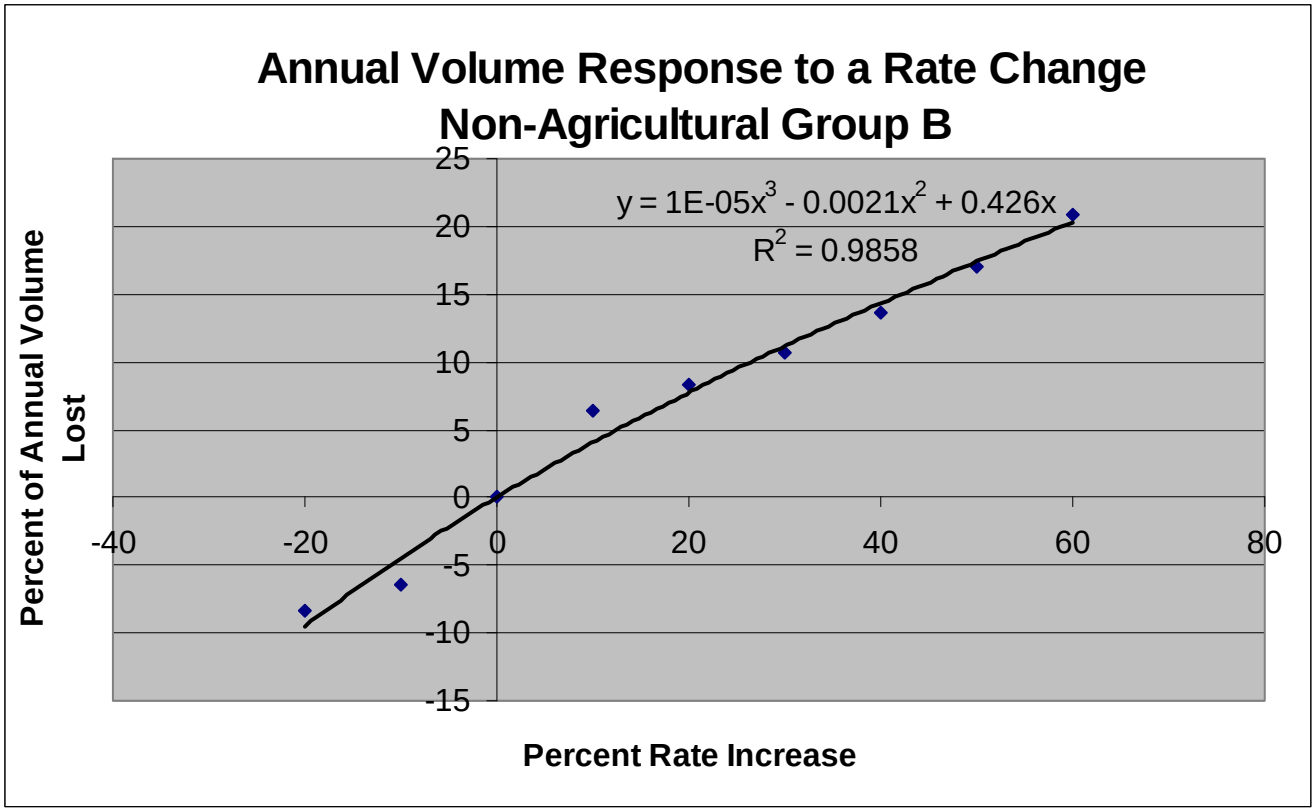


Figure 4. Annual Volume Response of Non-Agricultural (Group C) Products to a Rate Change

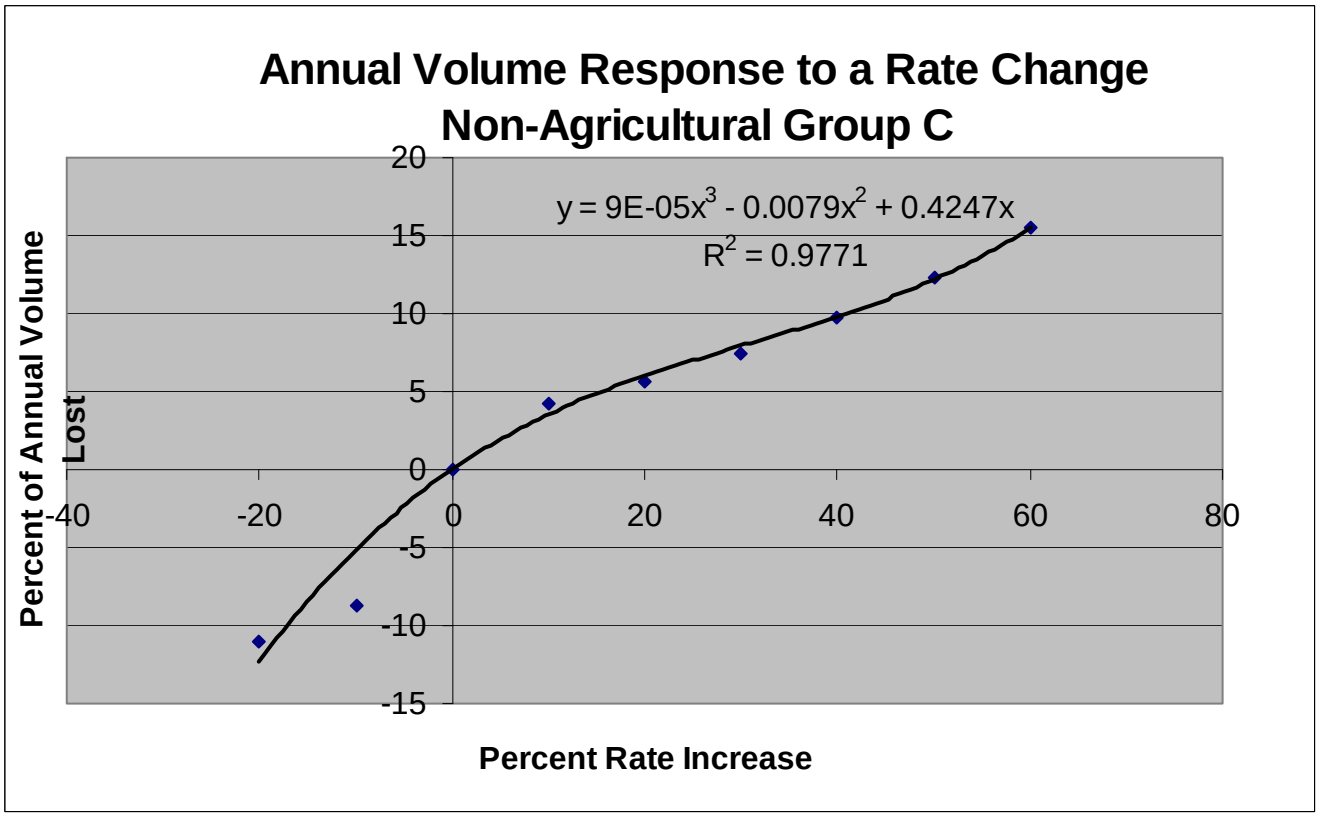


Table 9. Shipper Mode Choice Response as a Function of Rate
Agricultural and Non-Agricultural

Source	Percent Rate Increase	Agricultural Percent Switching	Non-Agricultural Percent Switching
Extension of results	-20	-11.2	-17.9
Extension of results	-10	-5.9	-8.9
Train - Wilson	0	0.0	0.0
Train - Wilson	10	5.9	8.9
Train - Wilson	20	11.2	17.9
Train - Wilson	30	15.9	25.8
Train - Wilson	40	20.2	32.7
Train - Wilson	50	24.3	38.7
Train - Wilson	60	28.2	43.8
Train - Wilson	70	31.9	48.3
Train - Wilson	80	35.6	52.1
Train - Wilson	90	39.0	55.5
Train - Wilson	100	42.3	58.8

Figure 5. Shipper Mode Choice Response as a Function of Rate – Agricultural

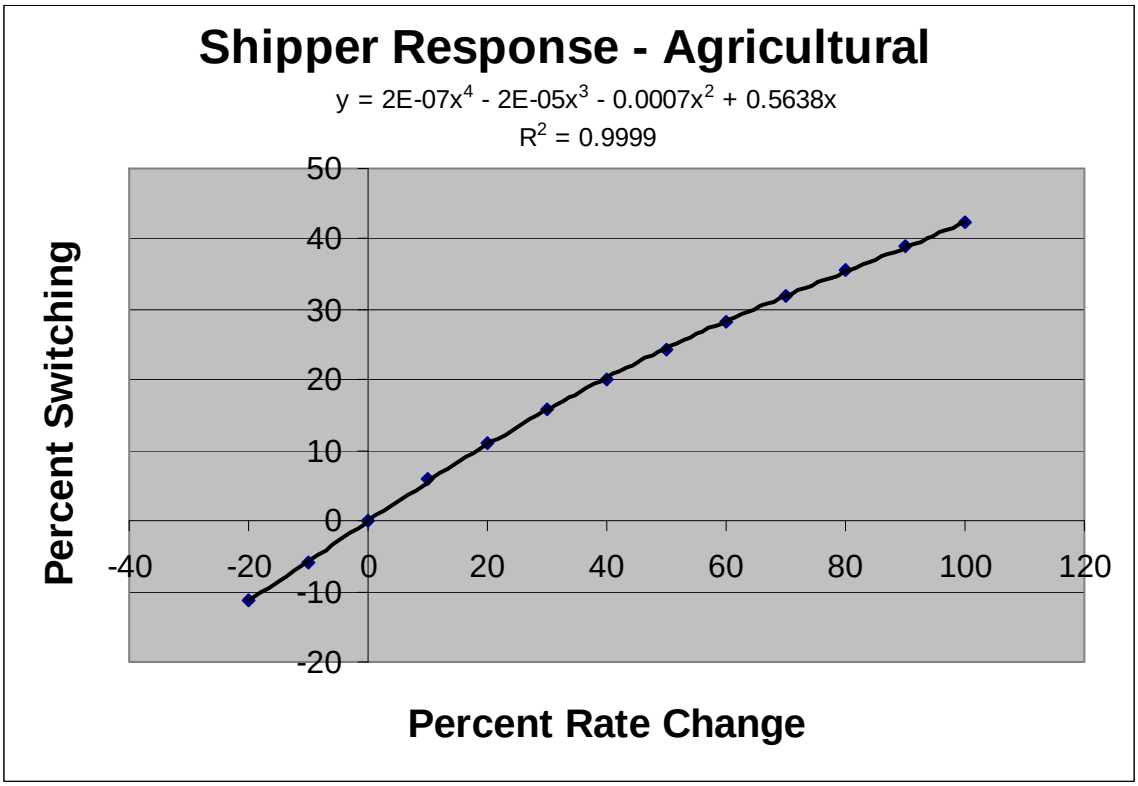
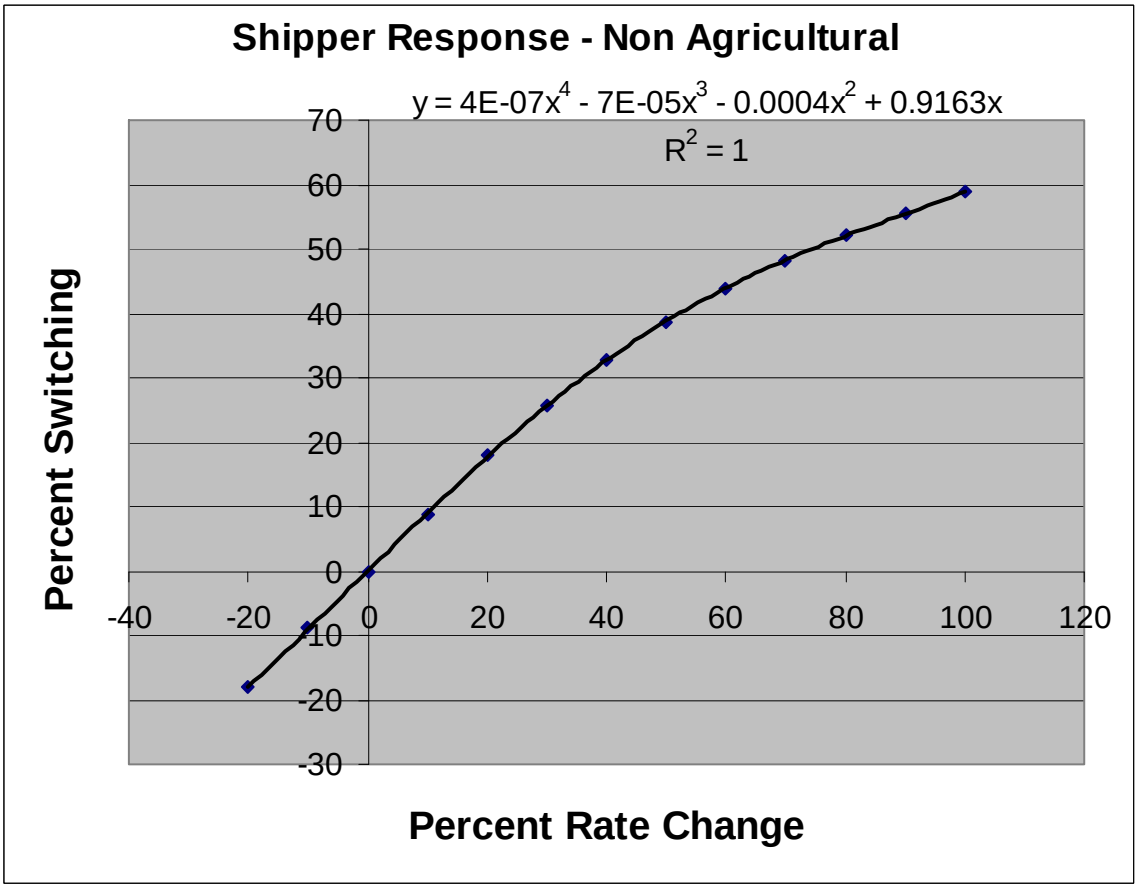


Figure 6. Shipper Mode Choice Response as a Function of Rate – Non Agricultural



Note that the percent of shippers switching modes or destinations is calculated based on the percent increase in the total water transportation rate. It should be noted that the defined domain of this function is from a rate decrease of 20 percent to a rate increase of 100 percent, yielding a defined range of an 11.2 percent increase in traffic to a 42.3 percent decrease in traffic for agricultural commodities. For non-agricultural the defined domain is the same as for the agricultural commodities which yielded a defined range of a 17.9 percent increase in traffic to a 58.8 percent decrease in traffic. These are typically sufficient definitions for evaluating the economic impacts of the range of navigation alternatives. *[These conditions have been tested in the context of the 2007 Re-Evaluation Report for the Upper-Mississippi River-Illinois Waterway Navigation System and found to be true for the vast majority of cases. The maximum rate reduction was never exceeded for any condition. However, the maximum rate increase was exceeded in a limited number of cases. In the extreme, represented as year 2060 of the without-project condition for the High Traffic Scenario, the maximum rate increase was exceeded for movements representing approximately one half of one percent of the tonnage for movements modeled as price responsive.]* Note that a check is included in the Output Summary sheet that identifies price changes outside the defined range.

These response functions are implemented as follows. The coefficients of the estimated polynomial equations are entered into the Inputs sheet as displayed in Table 10. Note that rows 35 and 36 of the Inputs sheet specifiy the defined range of price change for the function. These values are used to identify if the price change for any movement is outside the defined range. This indication is provided in the Output Summary sheet in cells A37 through F45.

Table 10. Shipper Response Function Inputs

Row	A	B	C
	percent of traffic diverted		
	polynomial coefficients	Com. Grp. 1-3	Com. Grp 4-11
30	b0	0.0000000000	0.0000000000
31	b1	0.5638000000	0.9163000000
32	b2	-0.0007000000	-0.0004000000
33	b3	-0.0000200000	-0.0000700000
34	b4	0.0000002000	0.0000004000
35	Max defined price increase	100.00	100.00
36	Max defined price decrease	-20.00	-20.00

On the Equilibrium sheet cells BB48 through BBxx (xx indicating the last row of an elastic movement) are used to compute the percentage rate change for the movements. This calculation is accomplished using cells AX48 through AXxx and AW48 through AWxx, the rate increase and the total (base) rate, respectively. The calculation in cell BB48 is provided as an example:

Row	BB Percentage Water Increase
48	=(AX48/AW48)*100

In cells BC48 through BCxx of the Equilibrium sheet, the percentage rate increases in the BB column along with the polynomial coefficients discussed above are used to calculate, for each movement, the percentage of traffic change. The calculation in cell BC48 is shown as an example:

Row	BC Percentage Traffic Change
48	=-1*(BB48*Inputs!$B$31+BB48^2*Inputs!$B$32+BB48^3*Inputs!$B$33+BB48^4*Inputs!$B$34)

Note that the calculated value is multiplied by -1 indicating traffic declines with increasing rate.

The calculation of traffic in the cells G48 through Gxx is now accomplished using the cells E48 through Exx in conjunction with the percentage of traffic change from cells BC48:BCxx. The example calculation from cell G48 is shown:

Row	G 2000 Water Tons
48	=MAX(0,E48*(1+BC48/100))

Note that for all movements that are considered to be inelastic, column G takes on the value of column E, the forecast volume for the year in question.

The above operations are sufficient to allow the model to find an equilibrium condition. This is where the Excel Solver add-in is used to find the balance between traffic estimated by willingness to pay for additional units of output and the additional costs of lock delay caused by this same traffic transiting the navigation locks.

The NED contribution of the movement to the system is calculated in Row H. This is discussed in detail in a later section.

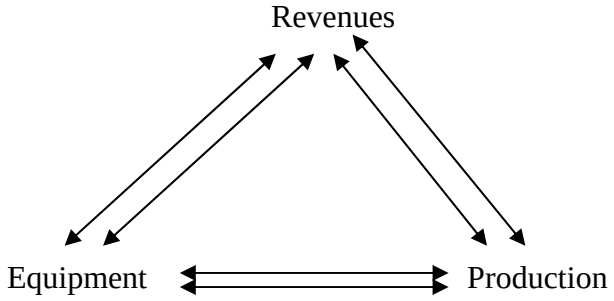
5. Opportunity Cost

Opportunity Cost is located in column AT and is the estimate of the value of production foregone due to lock congestion. The calculation of this parameter utilizes the fact that, in equilibrium, the marginal value of a unit of production is equal to the cost of providing an additional unit of productive capacity (i.e. towboats, barges, labor, etc.). These costs are constructed based upon towboat and barge operating cost data. Applying these data to typical equipment and configurations found on the UMR-IW system hourly per ton operating costs are identified for dry and liquid cargoes.

As noted previously, the opportunity cost of back-hauls is zero. For the front-haul movements the estimated opportunity cost is doubled to reflect both the northbound and southbound congestion incurred.

6. Definition of Equilibrium and Solving the Model

Before proceeding further it is useful to discuss what is meant by equilibrium. In a general sense the graphic below illustrates what is meant by system equilibrium.



where:

Production = movements accomplished on the waterway

Revenues = payments received for movements
Equipment = Towboats + Barges + Labor + Fuel + etc. (Privately owned resources)

A formal definition states:

For each movement on the system, the willingness to pay for the final increment of output is equal to the observed rate which in turn is equal to the (per unit) economic cost of providing the privately owned resources to accomplish that production.

This definition is put into operation by recognizing that it allows us to consider delay at system locks in two distinct ways. First, delay is an operational characteristic of the lock determined as a function of traffic. Second, delay represents the increase in the private costs of producing a movement, hence a change in the observed rate that the shippers are willing to incur to produce movements. For example, if we observe X tons of traffic at a particular lock with Y hours of delay we can say that those X tons produced those Y hours of delay **OR** that the Y hours of delay permitted only the X tons of traffic willing to incur the costs associated with that delay.

This concept is specifically modeled by specifying lock transit time twice in the spreadsheet. As explained in section 4 it appears in cells I31 through AS31 where it is computed based upon the traffic traversing the locks. It appears again in cells I32 through AS32 where it impacts the rate of water transportation.

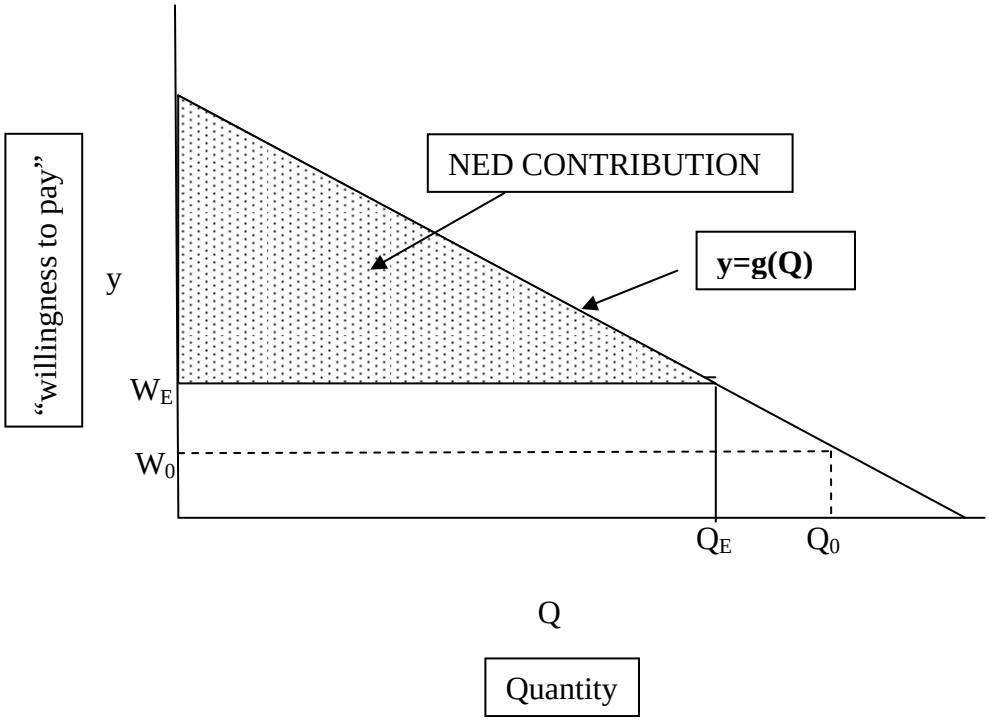
The equilibrium solution is found by specifying in the Excel Solver Module that these corresponding times must be equal and that cells I32 through AS32 may be adjusted to create this equality. Note how this works, if the time as specified in row 32 is larger than that in row 31, solver will adjust cell 32 downward. This will in turn decrease water prices and hence increase system traffic. This change in traffic will then cause a new delay to be computed in row 31. Solver iterates to a solution.

One note of caution, before starting solver the model user must ensure that a feasible starting point is in effect. This is done by placing enough time in the cells in row 32 to ensure that lock traffic does not exceed the capability of the lock(s) to process it. If this happens negative numbers will appear in some of the cells in row 31 and the solver will not be able to iterate to a solution. Once any feasible solution is specified the model can be solved simply by selecting “Tools”, “Solver”, “Solve”.

7. Calculation of system NED benefits.

The added benefits from a particular movement can be illustrated as follows:

Figure 7. Calculation of NED Contribution per Elastic Movement.



where:

W_E = Equilibrium Water Rate per Ton
Q_E = Quantity Moved at Equilibrium Water Rate
W_0 = Baseline Water Rate per Ton
Q_0 = Quantity Moved at Baseline Rate

As illustrated above the per-ton contribution to system benefits from a movement would be given by:

Average NED = $$\frac{1}{Q_E}\int_0^{Q_E}(y - W_E)dQ$$

Where y=g(Q) gives rate as a function of Quantity.

To find a suitable form for y we return to the Train-Wilson results, but for convenience we now work in proportions rather than percentages, and rather than consider proportion switching we look at proportion retained. The results in this form are displayed in Table 11, and Figures 8 and 9.

Note that since this is done in proportions the actual rate would be $y*W_0$. As illustrated above an excellent fit can be obtained using a fourth degree polynomial. The polynomial can then be substituted into the integral above and integrated to yield the following:

Per ton contribution to NED benefits:

$$(b_4/5*Q_E^4 + b_3/4*Q_E^3 + b_2/3*Q_E^2 + b_1/2*Q_E + b_0)*W_0 - W_E$$

Or:

$$W_0*((b_4/5*Q_E^4 + b_3/4*Q_E^3 + b_2/3*Q_E^2 + b_1/2*Q_E + b_0) - W_E/W_0)$$

where the coefficients (b4, b3, etc.) are as defined above.

From a mathematical perspective the function is only defined over the domain of approximately 0.57 to 1.11 for agricultural commodities, and approximately 0.41 to 1.18 for non-agricultural commodities. Therefore (as long as the model stays within the defined range discussed above) the integral will be incorrect by some constant value. This is not a problem for computing the benefits of a particular action, since the constant terms will cancel in subtraction.

The necessary data to evaluate the NED benefits associated with the computed equilibrium tonnage are place in the inputs sheet in cells F40 through G44 as illustrated in Table 12. The mode response as an inverse function of rate coefficients for agricultural commodities are located in column F. The mode response as an inverse function of rate coefficients for non-agricultural commodities are located in column G. The formulas in cells B40 through C44 convert the inverse function coefficients to the integration coefficients as described earlier. The coefficients for agricultural commodities are located in column B. The coefficients for non-agricultural commodities are located in column C.

Table 11. Shipper Mode Choice Response as a Function of Rate (Proportions) Agricultural and Non-Agricultural

Source	Proportion of Rate	Agricultural Proportion Retained	Non-Agricultural Proportion Retained
Extension of results	0.8	1.1118	1.1790
Extension of results	0.9	1.0586	1.0890
Train - Wilson	1.0	1.0000	1.0000
Train - Wilson	1.1	0.9414	0.9110
Train - Wilson	1.2	0.8882	0.8210
Train - Wilson	1.3	0.8410	0.7420
Train - Wilson	1.4	0.7978	0.6730
Train - Wilson	1.5	0.7572	0.6130
Train - Wilson	1.6	0.7183	0.5620
Train - Wilson	1.7	0.6806	0.5170
Train - Wilson	1.8	0.6445	0.4790
Train - Wilson	1.9	0.6100	0.4450
Train - Wilson	2.0	0.5773	0.4120

Figure 8. Shipper Mode Choice Response as an Inverse Function of Rate – Agriculture

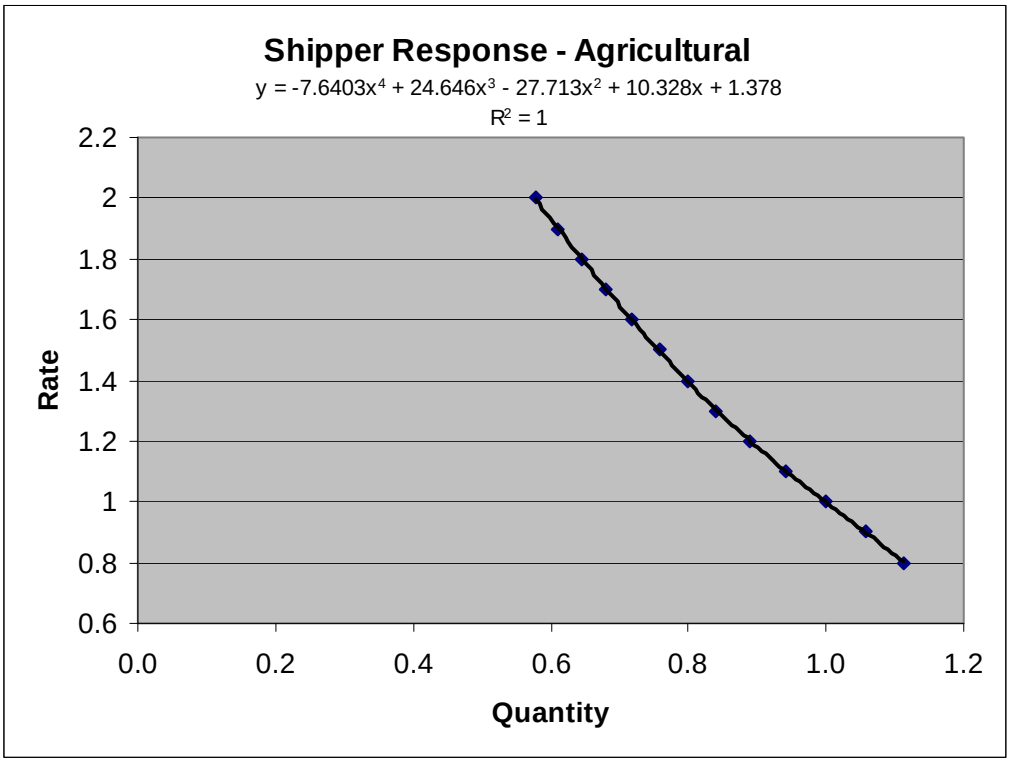


Figure 9. Shipper Mode Choice Response as an Inverse Function of Rate – Non Agriculture

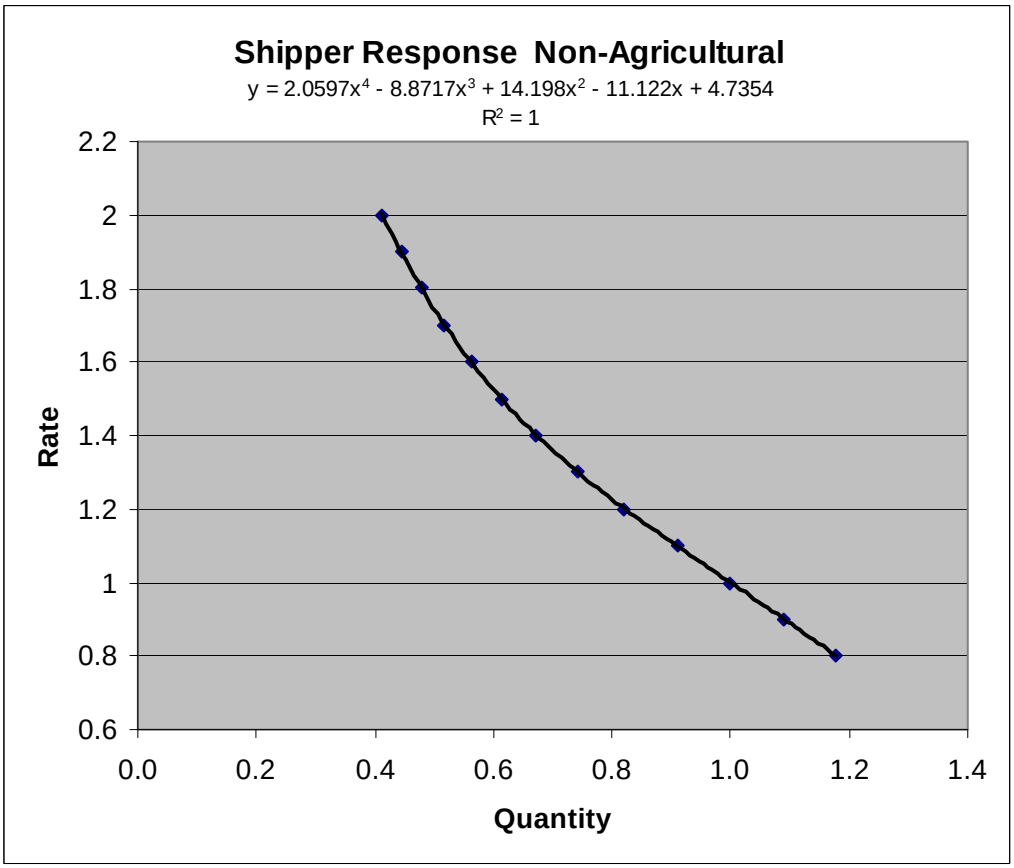


Table 12. Consumer Surplus Inputs

Row	A	B	C	F	G
				Polynomial Coefficients	
	Consumers' Surplus integration coefficients	Com. Grp 1-3 (Grain)	Com. Grp 4-11 (Non-Grain)	Com. Grp 1-3 (Grain)	Com. Grp 4-11 (Non-Grain)
40	b1	=F40/1	=G40/1	1.37800000	4.73540000
41	b2	=F41/2	=G41/2	10.32800000	-11.12200000
42	b3	=F42/3	=G42/3	-27.71300000	14.19800000
43	b4	=F43/4	=G43/4	24.64600000	-8.87170000
44	b5	=F44/5	=G44/5	-7.64030000	2.05670000

The per-ton (unscaled) contribution to NED is then computed on the Equilibrium sheet in cells BE48 through BExx. The calculation is illustrated below.

Row	BE
	Total Unscaled Surplus per Water Ton
48	=((Inputs!$B$44*(BD48^5)+Inputs!$B$43*(BD48^4)+Inputs!$B$42*(BD48^3)+Inputs!$B$41*(BD48^2) +Inputs!$B$40*BD48)/BD48)-(1+BB48/100)

Finally, in cells H48 through Hxx, this result is multiplied by the base water rate W_0 to provide the per-ton NED benefit. This is illustrated to for cell H48 below.

Row	H
	2000 NED ($/Ton)
48	=AW48*BE48

.

The total system NED benefits are found by multiplying the movement tonnage (column G) by the per-ton benefit (column H) and then summing across all system movements.

The results of this calculation are displayed in the model in cell D11 of the equilibrium sheet and cell B11 of the Output Summary Sheet.

Note that for all movements that are considered to be inelastic the savings the per-ton contribution to the NED benefits are calculated as water rate minus alternative mode rate or column AZ minus column AY.

For those movements designated as inelastic (Backhauls and No Lock Use) NED benefit per ton is measured as the difference between alternative mode cost and water cost. Note that incremental NED benefits (With Project minus Without Project) will be zero for inelastic movements.

8. Pre-Processing Step and Validation

The pre-processing step is a straightforward procedure. First the analyst must ensure that the base year is entered in cell B4 of the Inputs sheet and that the cells reflecting lock performance in rows 10, 11, 14, 15, and 16 of the Equilibrium sheet reflect the base year operating conditions for non-critical locks, and that the cells in rows 10-24 of the Inputs sheet reflect the base operating conditions for the critical locks.

After the above is verified, the Excel Solver is then invoked to solve the model. This procedure calculates the "no congestion" water price. The AV column, which initially contains the formula AWxx-AUxx is then copied and pasted onto itself using Excel's "paste special values" option. The AV column now contains numeric values and the model is now pre-processed.

Validation of the model consists of inspecting the congestion level (lock transit time in row 31) and ensuring that these numbers correspond to observed values. Again it should be noted that these numbers represent the expected value of a random variable so an exact match is neither expected nor desired.

9. Forecasts of Potential Traffic Demands

The Forecasts sheet of the Excel workbook contains the forecasts of future traffic demands for the UMR-IW navigation system. These forecasts of potential system demands for transportation are determined exogenously from the Survey Model. The potential movement demands should be forecast based on the analytical assumption that transportation costs remain at base levels for all modes of transportation. Consequently, these demands serve to increment the quantity demanded at existing water transportation prices dependent on the year of analysis.

The Equilibrium sheet of the model uses base year commodity flows as the basis for forecasting future demands. Consequently, the base year flows in the Equilibrium sheet are increased by the ratio of the exogenously forecast tonnage to the base tonnage in order to estimate traffic demands with existing transportation costs for the various years of analysis.

10. Modeling of Potential System Actions

Potential actions at system locks are modeled at a point in time in the spreadsheet by altering one of the parameters that describe the operation of the lock or locks being acted upon. Then the Equilibrium sheet is re-solved for the new resultant equilibrium and subsequent new system NED benefits. The new equilibrium will then reflect the altered performance of the lock chambers and the impact those changes have on supply and demand for water transportation at that time.

The remaining cells of the workbook that have not been discussed are cells B1 through B3 in the Inputs sheet. These cells are descriptive labels that help to identify the specific condition being modeled. The cells do not influence model operation and are not required for model execution.