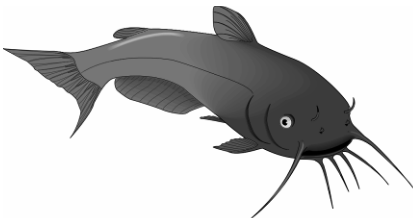
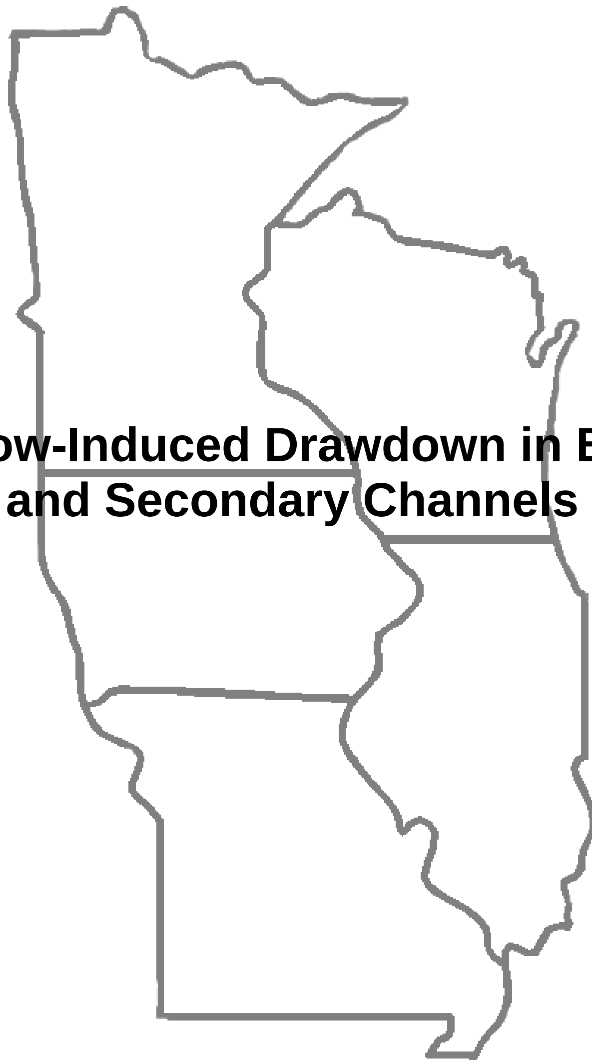
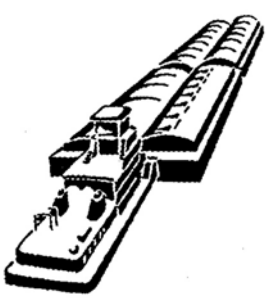
ENV Report 45

Interim Report For The Upper Mississippi River – Illinois Waterway System Navigation Study





Decay of Tow-Induced Drawdown in Backwaters and Secondary Channels



June 2005

US Army Corps of Engineers®

Rock Island District
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Upper Mississippi River - Illinois Waterway System Navigation Study

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Decay of Tow-Induced Drawdown in Backwaters and Secondary Channels

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Interim report

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ABSTRACT: Field data were collected on the decay of tow-induced drawdown along backwaters and compared to predictions from the UNET model. Drawdown from tows was measured along 10 backwaters on the Illinois Waterway. At the longest channel, Bath Chute, drawdown could be clearly detected at 11.6 km (7.2 miles) from the point of origin although the magnitude was significantly reduced. The UNET model predictions of drawdown ranged from 10 percent overprediction to 30 percent underprediction for all backwaters except Bath Chute. At Bath Chute, UNET predictions overpredicted drawdown by 40 percent or more, particularly at the three gages located about 7 miles above the mouth of the backwater where drawdown magnitude was about 0.015 m (0.05 ft). Drawdown for various probabilities of exceedance was determined for the entrances of backwaters and secondary channels used in the UMR-IWW study. Based on the data and model comparisons presented herein, the UNET model is appropriate for determining drawdown decay along backwaters.

Contents

Preface

The work reported herein was conducted as part of the Upper Mississippi River – Illinois Waterway (UMR – IWW) System Navigation Study. The information generated for this interim effort will be considered as part of the plan formulation process for the System Navigation Study.

The UMR – IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts of Rock Island, St. Louis, and St. Paul under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing and, in consideration of existing system lock constraints, will result in traffic delays that will continue to grow in the future. The System Navigation Study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic. The study will determine the location and appropriate sequencing of potential navigation improvements on the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report which is the decision document for processing to Congress.

This study was conducted in the Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The work was conducted under the direction of Mr. Thomas A. Richardson, Director, CHL. This report was written by Dr. Stephen T. Maynord, CHL.

At the time of publication of this report, COL James R. Rowan, EN, was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

During passage of commercial tow traffic in navigation channels, the water level is lowered alongside the tow, which is commonly referred to as drawdown. Drawdown results from the movement of water from in front of the tow to behind the tow. The water movement is caused by the volume of water displaced by the moving tow. Drawdown magnitude increases with increasing tow speed, increasing tow size, and decreasing channel size. Drawdown reaches a maximum near the stern of the tow and recovers after passage of the stern. Drawdown duration is about twice the time required for a tow to pass a fixed location. This duration relationship results in a large, fast tow producing a large but short-lived drawdown, while the same large tow traveling at a lesser speed will produce a lesser maximum drawdown but having a longer duration.

Drawdown from tow traffic is one of the few physical effects of tows that can propagate large distances from the main navigation channel. Drawdown can extend up backwaters, secondary channels, and tributaries entering the main channel. The magnitude of drawdown along the length of backwaters and secondary channels is needed to determine the ecological effects of tow traffic on spawning habitat along the shoreline of backwaters and secondary channels. The Navigation Effects (NAVEFF) model (Maynord 1996, 1999a) provides tow-induced drawdown along the shoreline of the navigation channel which coincides with the entrances of backwaters and secondary channels. The objective of this study is to determine the decay of drawdown along the length of the backwater or secondary channel. A previous study (Maynord 1999b) demonstrated application of the one-dimensional unsteady flow model “UNET” to determine drawdown decay in backwaters. The UNET model application in the previous study was based on a single field data point, and that study stated additional validation data were needed. This study provides that additional data and is comprised of a field data collection effort on the Illinois Waterway (IWW) and comparisons with UNET calculations. In addition, the magnitude of drawdown at the mouth of selected backwaters and secondary channels on the UMR – IWW will be determined based on the NAVEFF model.

2 Field Data Collections

Field data were collected in the LaGrange Pool of the IWW during 27 November to 1 December, 2001. LaGrange was selected because (a) it has sufficient traffic in November and (b) the channel is small enough to result in adequate tow-induced drawdown that can be easily distinguished from any natural variations. The water level variations were measured with pressure cells that recorded the absolute pressure every two seconds. All gages were synchronized in time and all times shown herein are Central Standard Time. The pressure cells were mounted in a framework that positioned the transducer of the cell approximately 20 cm above the channel bottom.

During 27 November to 1 December, 2001, the river stage varied less than 0.15 m and averaged 433.1 at Havana, IL (RM 120), 430.0 at Beardstown, IL (RM 89), and 429.2 at LaGrange Pool (RM 80). Flat pool at LaGrange is 429.0.

Channel depth was measured at the gage, at a known distance from the right and left banks, and at the center of the channel. The channel water surface width was also determined at the cross section of the gage location. From the width and depth data, an estimate was made of the channel area from which the hydraulic depth was determined as area/water surface width.

Global Positioning System (GPS) coordinates were measured at the location of each gage.

Depth averaged velocity (at 0.6* depth below surface) was measured at the center of the backwater channel using a hand-held acoustic Doppler velocity meter. Velocities were generally less than 0.4 m/sec.

The physical characteristics of the 10 backwater and secondary channels used in this study are shown in Table 1. Data were also collected at Lilly Lake (RM 83.1) but drawdown was too small to provide reliable data. Matanzas Bay (RM 114.6) was not measured because it had a control structure just above the entrance. The unnamed entrance at RM 124.2 and the entrance to Liverpool Lake at 127.5, both shown on the navigation charts, could not be found. The navigation charts can be obtained from the Rock Island District.

A time history of water level from one selected tow event from each backwater is shown in Figures 1-10. All time histories are based on a 10 sec moving average. With the exception of Bath Chute, the plots were positioned with the ambient water level at an even increment of 0.1 m. The ambient water level was determined by averaging the water level for about 20 minutes prior to arrival of the tow. At Bath Chute, the ambient water level was established at the beginning of the record. Only tows producing drawdown easily recognized from ambient variations were used in the analysis. Minimum entrance drawdown was 0.044 m and maximum was 0.19 m. The drawdown data are summarized in Table 2.

Specific comments on each backwater are provided to highlight characteristics and describe application of the data as follows:

a. *Sangamon River* - three events, channel has large width-to-depth ratio, no gage response at farthest gage for two events.

b. *La Moine River* - three events, relatively deep channel.

c. *Sugar Creek Island* - one event, short island, time history in Figure 3 shows drawdown wave reflected from upstream connection to main channel.

d. *Bach Slough* - two events, narrow channel.

e. *Panther Slough* - three events, short backwater, embankment with culvert across slough about 200 m upstream of upstream gage, time history in Figure 5 shows reflected drawdown wave from embankment not typical of other backwaters having upstream end far from gages, gage 10259 malfunctioned at this location.

f. *Bath Chute* - four events for tows at the downstream entrance, three events for tows at the upstream entrance; data shows that drawdown propagates full length of 11.6 km (7.2 mile) long chute for highest drawdown at the entrance, no structures along length of chute but shallow entrance at upstream end, gage 10288 not used in analysis because no cross-section data.

g. *No-name* - two events, shallowest backwater and has increasing width.

h. *Quiver Island* - three events, only used two downstream gages (10288 and 10209) because gage 10371 looked questionable and gage 10405 was upstream of the opening to the main channel near gage 10371. All three events used in the analysis were tows passing the downstream entrance. In all three events, a large drawdown followed the initial drawdown at gage 10405. This second drawdown could have been some type of reflection or simply the drawdown as the tow passed the upstream entrance if this was an upbound tow. What makes the second drawdown unusual is that it does not appear to propagate back down the channel.

i. *Quiver Lake* - three events, expansion from entrance to upstream gages.

j. *Chautauqua* - three events, data not used in analysis because of bifurcation being different from single channel.

Tow Traffic

Since (1) this study focuses on the decay of drawdown and (2) techniques have already been developed for drawdown in the main channel (Maynord 1996, 1999a), the characteristics of each tow moving past the entrances to the backwaters was not documented. This documentation of tow characteristics would have been difficult for tows passing during the night for those backwaters where gages were left overnight. However, information was gathered from the LaGrange Lock (just downstream of study reach) and Peoria Lock (upstream of study reach) that documented the arrival and departure times of tows as well as the number of barges and loaded/empty information. Use of this data is complicated by the fact that some tows travel within a pool and may leave one lock but not arrive at the second lock. Table 2 shows the tow characteristics from the lock data. Some events are shown with a "?" where tow characteristics could not be determined.

3 UNET Model

The UNET model (HEC, 1996) simulates one-dimensional unsteady flow through a full network of open channels. In addition to solving the network system, UNET provides the user with the ability to apply many external and internal boundary conditions, including: flow and stage hydrographs, rating curves, gated and uncontrolled spillways, pump stations, bridges, culverts, and levee systems. UNET has been incorporated into the HEC-RAS system developed by the USACE Hydrologic Engineering Center. This study used an earlier version of UNET (2.0) that the author had available and was familiar with. The input data description is provided in Maynord (1999b). In addition to being a USACE supported program, UNET has several advantages including a provision that interpolates cross sections into the input file if needed.

4 Comparison of Selected Field Data With UNET Model

The five backwaters selected for comparison to the UNET model are described in the following paragraphs. One tow event, usually the largest, was selected from each of the five backwaters for the comparison. The computed data from UNET are shown as data points on the observed data plots. In some of the plots, the data points are close together and appear as a heavy line. Because the water level at the downstream gage located at the mouth of the backwater was the input boundary conditions for the UNET model, the data points on the plots at the downstream gage show close agreement to the measured data. With one exception, the seven-mile long Bath Chute, computed water levels were largely insensitive to Manning's n value of 0.025 to 0.040 that would be typical of channels like the selected backwaters. A value of 0.03 was used in the UNET calculations.

La Moine River. La Moine River was selected because it was the deepest backwater in which data was collected. Figure 2 shows the observed and computed water levels at the 3 gages in La Moine River. The time history of drawdown for the selected tow event was complicated with non-typical variations throughout the drawdown. The UNET model overpredicted the drawdown magnitude by 5-10 percent at gages 10259 and 10367.

Bach Slough. Bach Slough was selected because it was the narrowest backwater in which data was collected. Figure 4 shows the observed and computed water levels at the three gages in Bach Slough. The UNET model predicted drawdown magnitude to within less than 5 percent at gages 10128 and 10215.

Bath Chute. Bath Chute was selected because it was the longest backwater in which data was collected. Figure 6 shows the observed and computed water levels at six of the seven gages in Bath Chute. Cross section data was not available at gage 10288 which prevented UNET calculations. The UNET model overpredicted drawdown magnitude by 15 percent at gage 10367 and by about 40 percent at gage 10209. At the three gages about 7 miles from the mouth, the UNET model overpredicted the drawdown by more than 50 percent but observed magnitudes were only about 0.015 m. Bath Chute was tested to see if the Manning's n value could be raised enough to result in observed and computed water level agreement at the gages located about 7 miles above the mouth. A

Manning's n of 0.060 resulted in computed drawdown of 0.015 m measured in the prototype at the far gages. The Bath Chute comparisons of the gages at 7 miles from the mouth are limited in that cross sections were not available in the middle 4 - 5 miles of the chute and the cross sections used in UNET were simply interpolated sections from the available cross sections.

No-name. No-name backwater at river mile 124.8 was selected because it was the shallowest backwater in which data was collected. Figure 7 shows the observed and computed water levels at the two gages in No-name backwater. The UNET model underpredicted drawdown by about 30 percent at gage 10363.

Quiver Lake. Quiver Lake was selected because it was the widest backwater in which data was collected. Figure 9 shows the observed and computed water levels at the three gages in Quiver Lake. The UNET model underpredicted drawdown by about 30 percent at gages 10128 and 10215.

5 Drawdown at the Mouth of Selected Backwaters from NAVEFF Model

NAVEFF is a one-dimensional model with empiricism used to calculate drawdown and other physical effects of tows in the UMR – IWW study and is documented in Maynord et al (2004). Drawdown was calculated for 108 different combinations of number of barges, barge draft, tow speed, direction of travel (up or downbound), and whether the propeller was an open wheel or Kort nozzle. These 108 combinations were determined in NAVEFF for 3 different sailing lines and 3 different stages yielding a total of 972 combinations. Previous traffic data from the UMR – IWW were used to determine the percentage of the 972 different tow combinations of tow type, stage, and sailing line. The percentages varied by pool along the river and by month of the year. After trying various sample sizes, a random sample of 5000 tows was found to be large enough to provide a consistent probability distribution. The drawdown from NAVEFF for the 5,000 tow events were sorted in a spreadsheet program to allow evaluation of drawdown for different probabilities of occurrence. Drawdown is provided for probability of exceedances by a single tow of 0.5, 0.1, 0.05, 0.02, and 0.01 for the month of June. June was selected for this analysis because it is representative of the spawning period for many species. Also note that results presented are for probability of exceedance by a single tow.

Drawdown at the inlets of backwaters and secondary channels is provided for trend pools 4, 8, 13, 96 (pool 26 above confluence of IWW), 26, and 31 (LaGrange Pool) in Tables 4 through 10.

6 Summary and Conclusions

The study described herein provided field data on the decay of tow-induced drawdown along backwaters and compared the data to predictions from the UNET model. Drawdown from tows was measured along 10 backwaters on the Illinois Waterway. At the longest channel, Bath Chute, drawdown could be clearly detected at 11.6 km (7.2 miles) from the point of origin although the magnitude was significantly reduced. The UNET model predictions of drawdown ranged from 10 percent overprediction to 30 percent underprediction for all backwaters except Bath Chute. At Bath Chute, UNET predictions overpredicted drawdown by 40 percent or more, particularly at the 3 gages located about 7 miles above the mouth of the backwater where drawdown magnitude was about 0.015 m. Drawdown for various probabilities of exceedance was determined for the entrances of backwaters and secondary channels used in the UMR – IWW study. Based on the data and model comparisons presented herein, the UNET model is appropriate for determining drawdown decay along backwaters.

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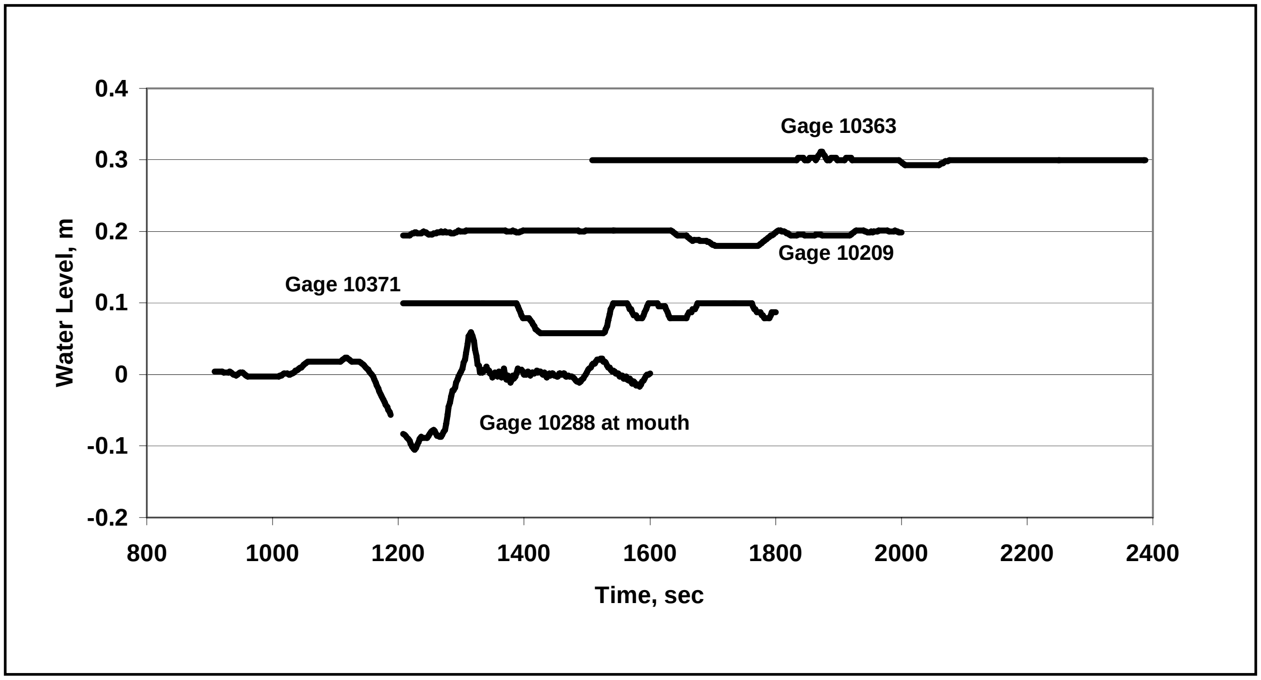

Figure 1. Tow induced drawdown in Sangamon River, 0 sec = 0220 hrs, 11/28/2001

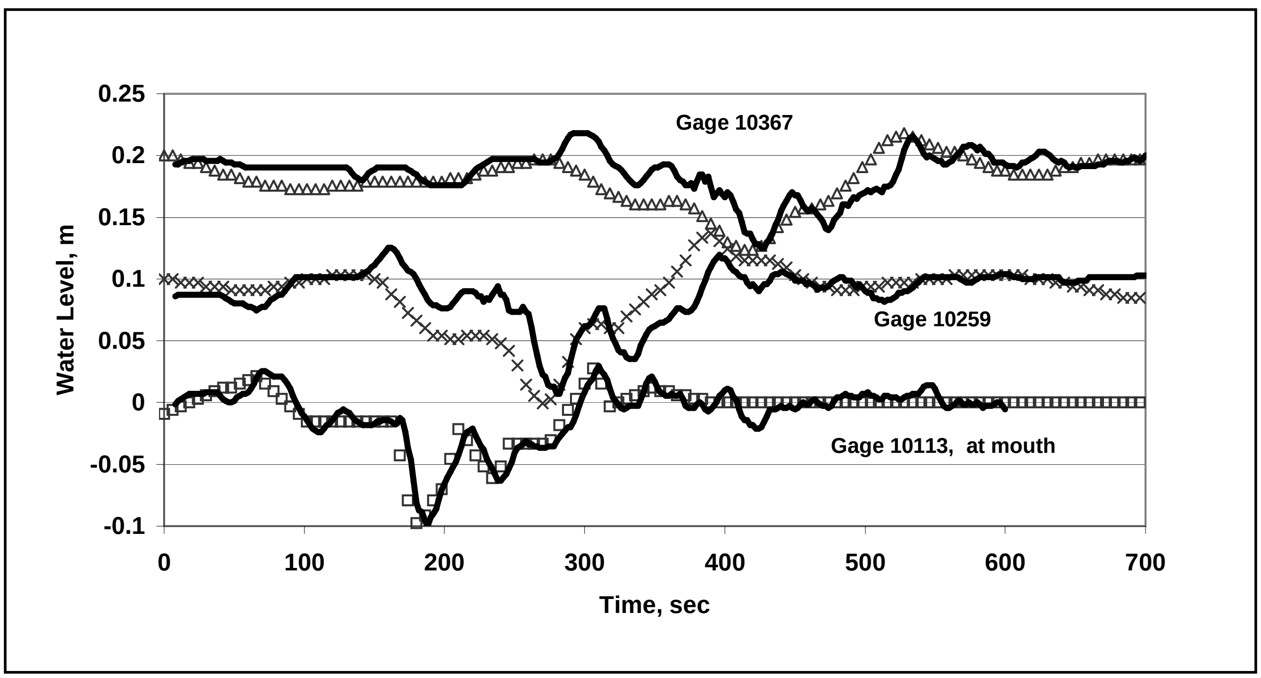

Figure 2. Tow induced drawdown in La Moine River, 0 sec = 1500 hrs, 11/27/2001. UNET calculations shown as data points

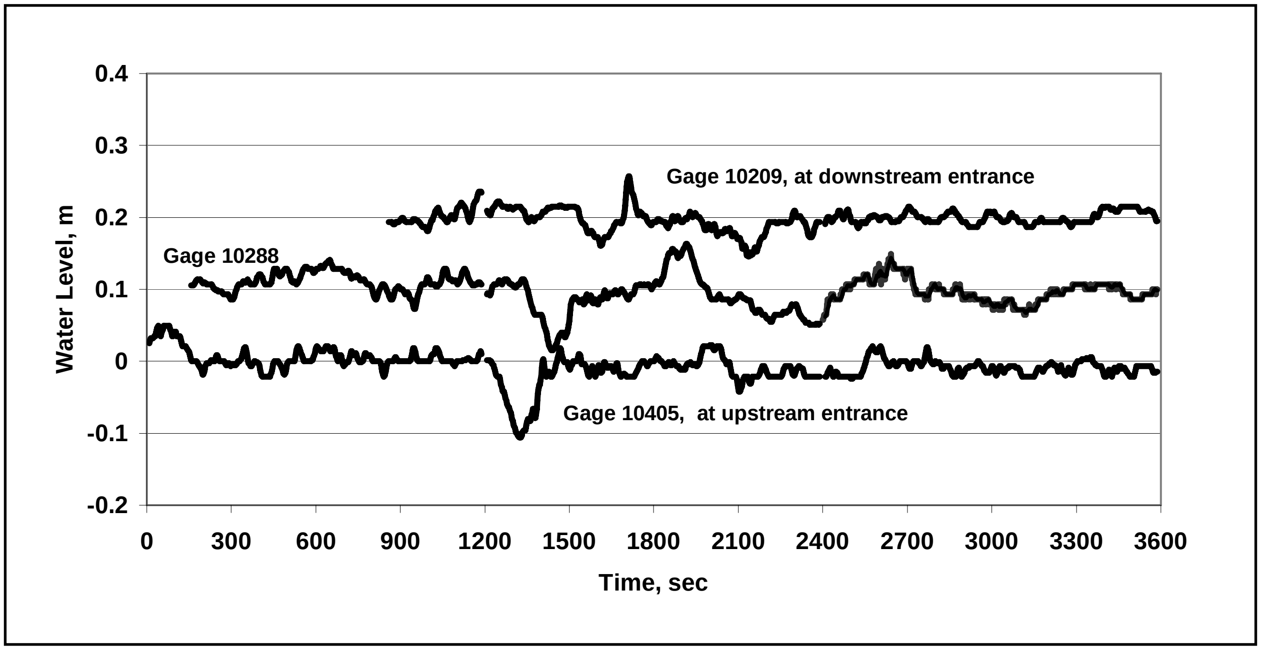

Figure 3. Tow induced drawdown in Sugar Creek Island, 0 sec = 1120 hrs, 11/28/2001

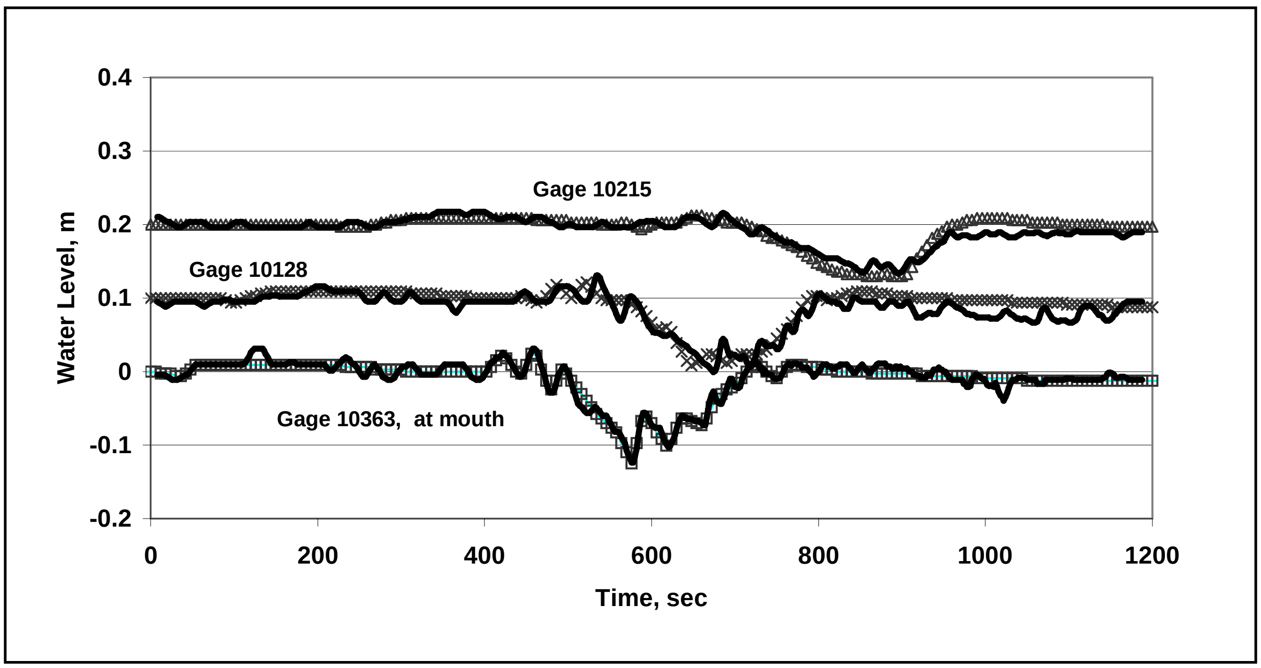

Figure 4. Tow induced drawdown in Bach Slough, 0 sec = 1140 hrs, 11/28/2001. UNET calculations shown as data points

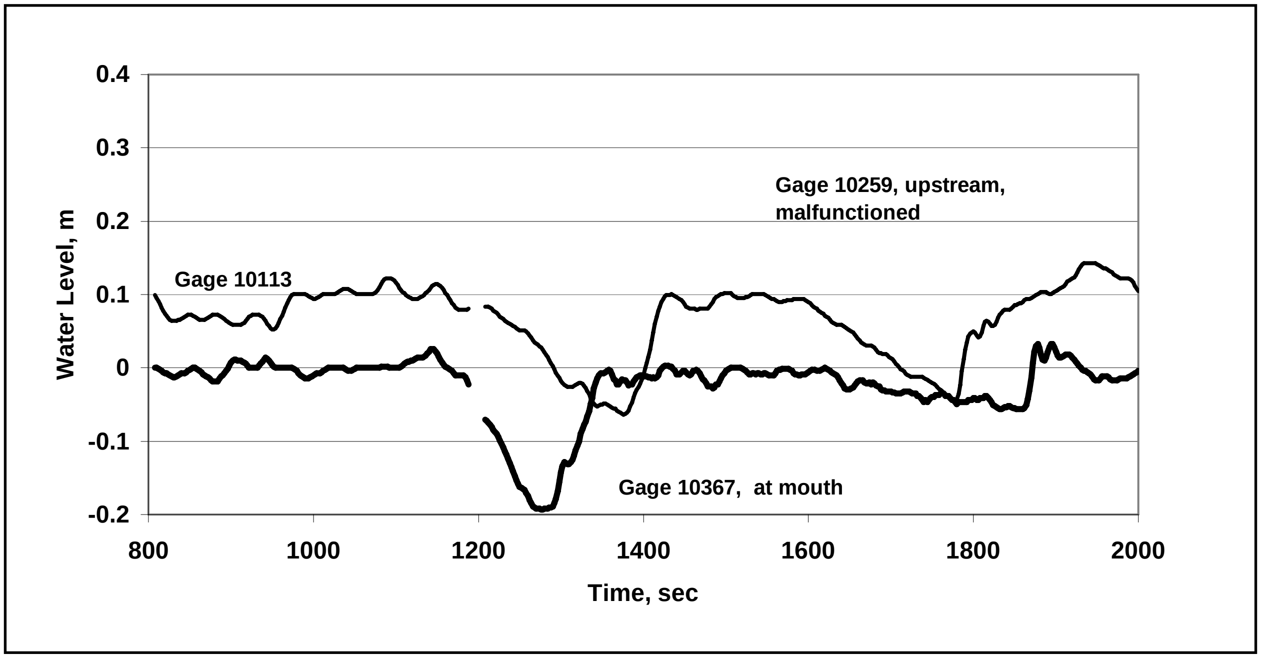

Figure 5. Tow induced drawdown in Panther Slough, 0 sec = 1140 hrs, 11/28/2001

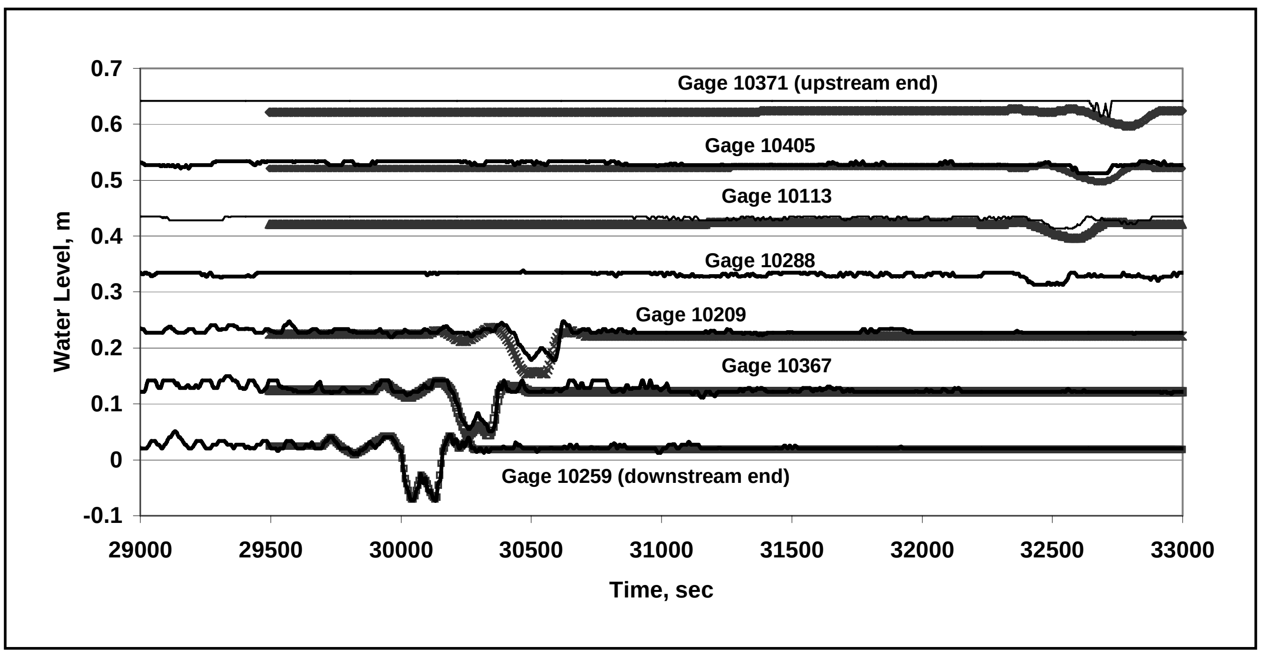

Figure 6. Tow induced drawdown in Bath Chute, 30,000 sec = 2,100 hrs, 11/30/2001, event 5. UNET calculations shown as data points

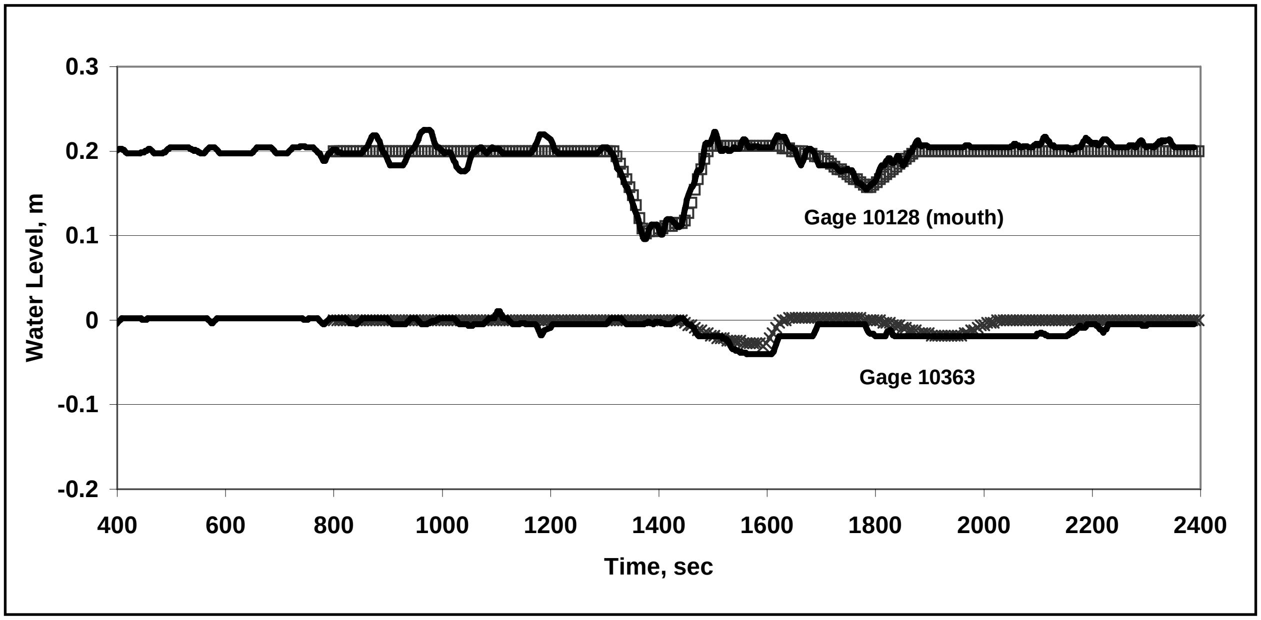

Figure 7. Tow induced drawdown in No-name backwater, 0 sec = 1720 hrs, 11/30/2001. UNET calculations shown as data points

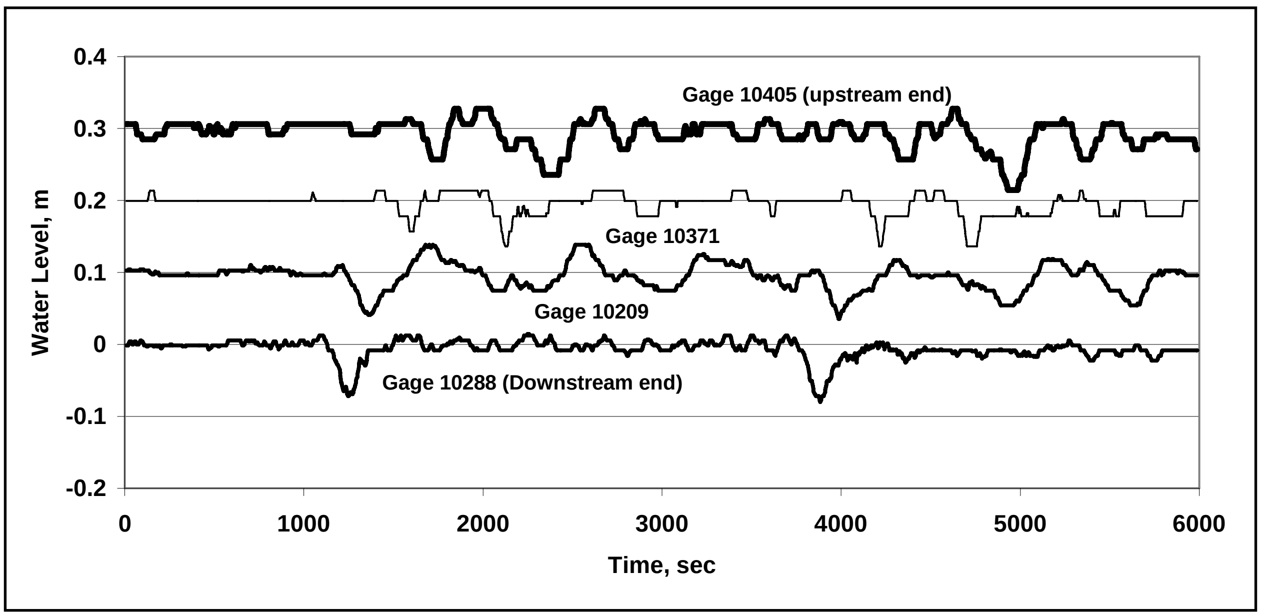

Figure 8. Tow induced drawdown in Quiver Island, 0 sec = 1620 hrs, 11/29/2001

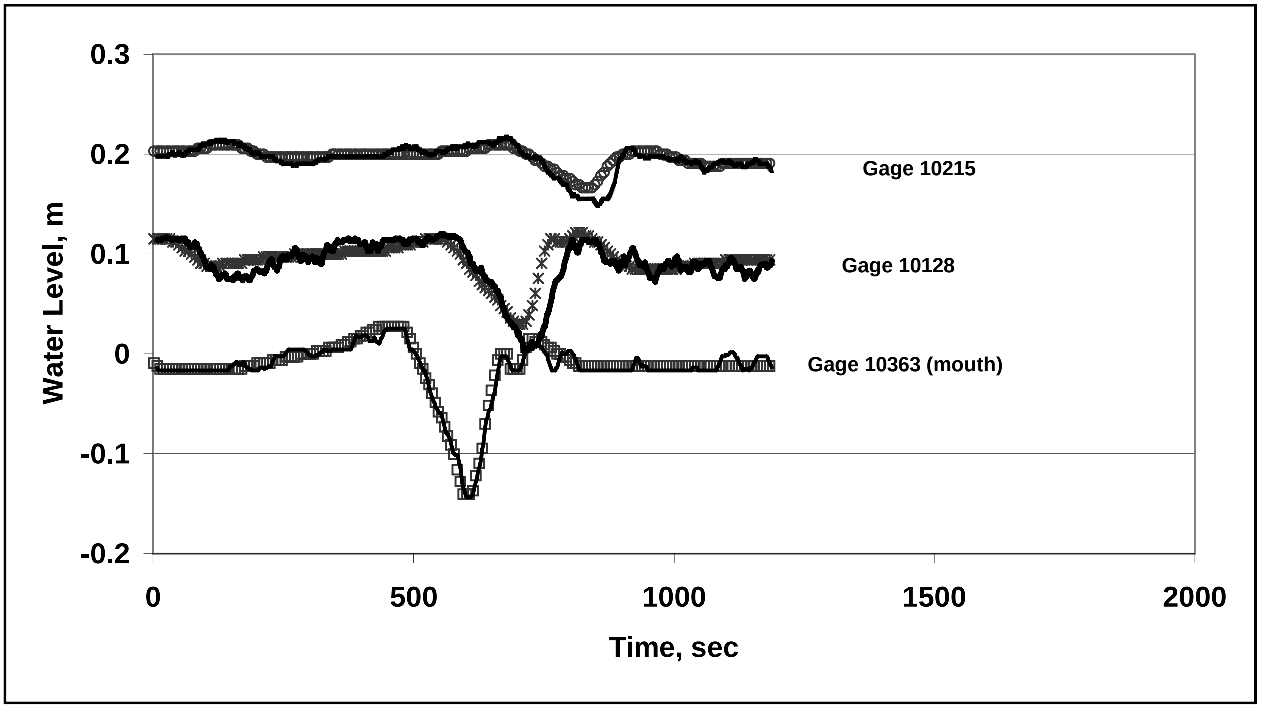

Figure 9. Tow induced drawdown in Quiver Lake, 0 sec = 1120 hrs, 11/29/2001. UNET calculations shown as data points

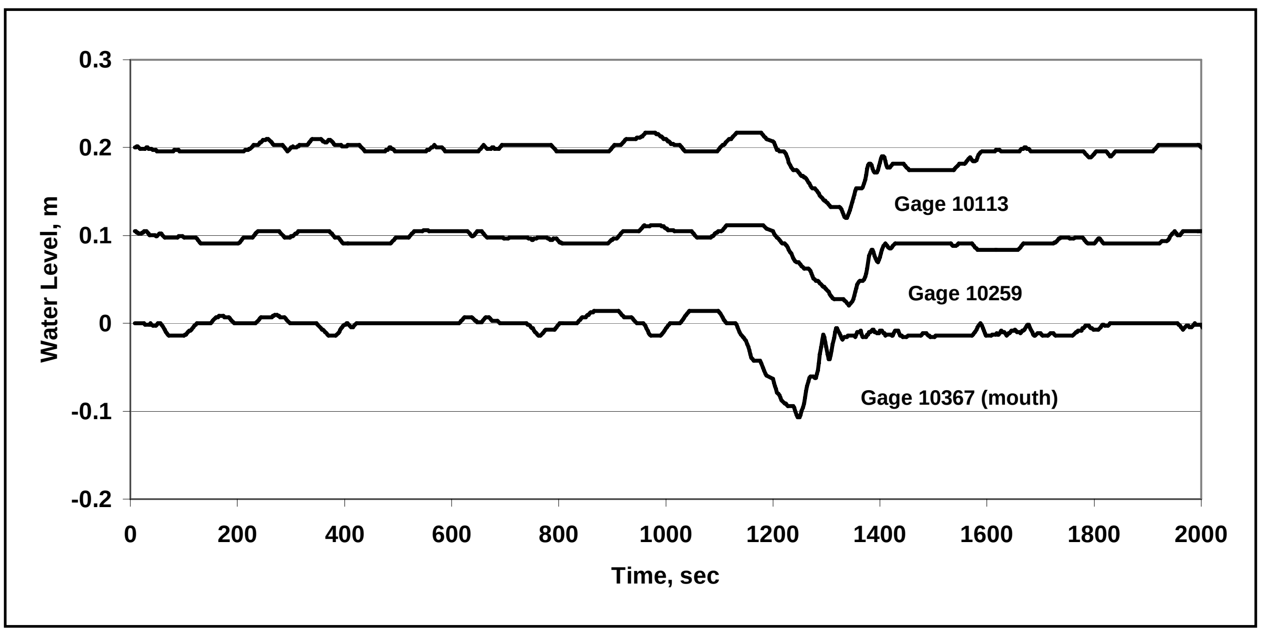

Figure 10. Tow induced drawdown in Chautauqua, 0 sec = 1220 hrs, 11/29/2001

Table 1
Physical Characteristics of Backwaters

Backwater/ Secondary Channel (River mile)	Meter #	Distance From Gage Nearest Downstream (upstream) End[1]	Top Width[1]	Hydraulic Depth (area/ top width)[1]	Depth at Center of Channel[1]	Depth Averaged Velocity at Center of Channel, m/sec
Sangamon River (89)	10288	0	110	0.66	1.37	0.38
	10371	600	86.9	1.26	1.52	0.35
	10209	1350	82.3	0.91	1.37	0.29
	10363	2000	91.5	0.81	1.10	0.61
La Moine River (83.7)	10113	0	59.5	2.6	3.87	0.13
	10259	410	43.0	2.25	3.14	0.24
	10367	1060	45.7	2.08	3.45	0.23
Sugar Creek Island (95)	10209	0 (1200)	45.7	1.12	2.01	0.27
	10288	770 (430)	42.7	1.10	1.68	0.34
	10405	1200 (0)	40.2	1.17	1.62	0.24
Bach Slough (98)	10363	0	16.8	0.69	1.07	0.08
	10128	210	16.8	0.73	1.16	0.12
	10215	605	15.2	0.65	0.87	0.15
Panther Slough (98.7)	10367	0	26.5	1.05	1.65	0
	10113	225	29.3	0.93	1.52	0
	10259	440	26.5	1.05	1.83	0
Bath Chute (107 & 113)	10259	0 (11584)	57.6	1.65	3.14	0.38
	10367	883 (10701)	50.3	2.05	4.12	0.37
	10209	1833 (9751)	52.1	1.99	3.81	0.40
	10288	10364 (1220)	No data	No data	No data	0.26
	10113	10735 (849)	74.1	1.84	3.26	0.24
	10405	11164 (420)	71.3	1.91	3.35	0.23
	10371	11584 (0)	81.4	1.27	1.92	0.23
No-name (124.8)	10128	0	18.3	0.38	0.61	0
	10363	250	32.9	0.37	0.55	0
Quiver Island (121)	10288	0 (1760)	176.5	2.21	3.81	0.24
	10209	550 (1210)	168.3	1.73	2.99	0.46
	10371	1360(400)	67.3	1.78	3.20	0.34
	10405	1760 (0)	73.2	0.95	1.22	0.23
Quiver Lake (122.3)	10363	0	140	1.00	1.37	0.05
	10128	290	175	1.17	1.83	0.06
	10215	690	300	1.05	1.55	0
Chautauqua (129)	10367	0	29.3	1.7	3.35	0
	10259	291	29.3	1.37	2.13	0
	10113	380	29.3	1.46	2.62	0

[1] Measurements are shown in meters.

Table 2
Drawdown Data Summary

Backwater Event #	Date/Time	Meter #	Drawdown[1]	Distance from Entrance[1]	Drawdown/ Drawdown at Entrance	Tow Characteristics: # barges, # loaded, direction
Sangamon-1	11/27/01-1217:10	10288	0.138	0	1.0	16,0,U
	11/27/01-1221:40	10371	0.042	600	0.30	
	11/27/01-1225:50	10209	0.013	1350	0.094	
	?	10363	0	2000	?	
Sangamon-2	11/27/01-1439:02	10288	0.058	0	1.0	14,9,D
	11/27/01-1443:20	10371	0.063	600	1.09	
	11/27/01-1447:24	10209	0.010	1350	0.17	
	?	10363	0	2000	?	
Sangamon-3	11/28/01-0240:40	10288	0.106	0	1.0	15,7,U
	11/28/01-0244:25	10371	0.042	600	0.40	
	11/28/01-0248:55	10209	0.019	1350	0.18	
	11/28/01-0253:45	10363	0.007	2000	0.066	
La Moine-1	11/27/01-1503:14	10113	0.100	0	1.0	14,9,D
	11/27/01-1504:40	10259	0.090	410	0.90	
	11/27/01-1507:08	10367	0.075	1060	0.75	
La Moine-2	11/28/01-0207:55	10113	0.066	0	1.0	15,7,U
	11/28/01-0209:22	10259	0.059	410	0.89	
	11/28/01-0211:52	10367	0.054	1060	0.82	
La Moine-3	11/28/01-0727:52	10113	0.077	0	1.0	16,0,U
	11/28/01-0729:20	10259	0.069	410	0.90	
	11/28/01-0732:09	10367	0.061	1060	0.79	
Sugar Creek-1	11/28/01-1142:10	10405	0.104	0	1.0	15,15,D
	11/28/01-1143:55	10288	0.080	770	0.77	
	11/28/01-1146:45	10209	0.038	1200	0.37	

(Sheet 1 of 5)

[1] Measurements are shown in meters.

Table 2 (Continued)

Backwater Event #	Date/Time	Meter #	Drawdown 1	Distance from Entrance 1	Drawdown/ Drawdown at Entrance	Tow Characteristics: # barges, # loaded, direction
Bach Slough-1	11/28/01-1110:50	10363	0.098	0	1.0	15,15,D
	11/28/01-1112:27	10128	0.083	210	0.85	
	11/28/01-1115:15	10215	0.053	605	0.54	
Bach Slough-2	11/28/01-1150:00	10363	0.12	0	1.0	16,0,U
	11/28/01-1151:45	10128	0.098	210	0.82	
	11/28/01-1154:32	10215	0.065	605	0.54	
Panther Slough-1	11/28/01-1041:02	10367	0.082	0	1.0	15,12,U
	11/28/01-1042:03	10113	0.074	225	0.90	
	11/28/01-1043:20	10259	0.078	440	0.95	
Panther Slough-2	11/28/01-1102:05	10367	0.093	0	1.0	15,15,D
	11/28/01-1103:20	10113	0.093	225	1.0	
	11/28/01-1104:55	10259	0.106	440	1.14	
Panther Slough-3	11/28/01-1201:10	10367	0.193	0	1.0	16,0,U
	11/28/01-1202:20	10113	0.160	225	0.83	
	Malfunction	10259	-	440	-	
Bath Chute-1-DS	11/30/01-1257:00	10259	0.122	0	1.0	15,0,U
	11/30/01-1301:00	10367	0.092	883	0.75	Same tow as 2-US
	11/30/01-1304:50	10209	0.057	1833	0.47	Same tow as 2-US
	Uncertain	10288	-	10364	-	
	Uncertain	10113	-	10735	-	
	Uncertain	10405	-	11164	-	
	Uncertain	10371	-	11584	-	
Bath Chute-2-US	11/30/01-1358:30	10371	0.044	0	1.0	15,0,U
	11/30/01-1400:00	10405	0.027	420	0.61	Same tow as 1-DS
	11/30/01-1401:15	10113	0.032	849	0.73	Same tow as 1-DS
	11/30/01-1403:20	10288	0.030	1220	0.68	
	11/30/01-1431:20	10209	0.010	9751	0.23	
	Uncertain	10367	-	10701	-	
	Uncertain	10259	-	11584	-	

(Sheet 2 of 5)

Table 2 (Continued)

Backwater Event #	Date/Time	Meter #	Drawdown 1	Distance from Entrance 1	Drawdown/ Drawdown at Entrance	Tow Characteristics: # barges, # loaded, direction
Bath Chute-3-US	11/30/01-1949:35	10371	0.090	0	1.0	?,?,D
	11/30/01-1951:00	10405	0.10	420	1.11	Same tow as 4-DS
	11/30/01-1952:30	10113	0.090	849	1.0	Same tow as 4-DS
	11/30/01-1954:20	10288	0.095	1220	1.06	
	11/30/01-2023:00	10209	0.030	9751	0.33	
	11/30/01-2025:40	10367	0.035	10701	0.39	
	Uncertain	10259	-	11584	-	
Bath Chute-4-DS	11/30/01-2101:10	10259	0.10	0	1.0	?,?,D
	11/30/01-2104:50	10367	0.075	883	0.75	Same tow as 3-US
	11/30/01-2109:00	10209	0.050	1833	0.50	Same tow as 3-US
	11/30/01-2141:30	10288	0.020	10364	0.20	
	11/30/01-2142:20	10113	0.020	10735	0.20	
	11/30/01-2144:20	10405	0.012	11164	0.12	
	11/30/01-2145:00	10371	0.020	11584	0.20	
Bath Chute-5-US	11/30/01-2306:30	10371	0.12	0	1.0	15,15,D
	11/30/01-2307:40	10405	0.10	420	0.83	Same tow as 6-DS
	11/30/01-2309:10	10113	0.092	849	0.77	Same tow as 6-DS
	11/30/01-2311:10	10288	0.092	1220	0.77	
	11/30/01-2339:35	10209	0.032	9751	0.27	
	11/30/01-2342:05	10367	0.025	10701	0.21	
	11/30/01-2344:35	10259	0.015	11584	0.13	
Bath Chute-6-DS	12/01/01-0000:50	10259	0.12	0	1.0	15,15,D
	12/01/01-0004:35	10367	0.085	883	0.71	Same tow as 5-US
	12/01/01-0008:30	10209	0.056	1833	0.47	Same tow as 5-US
	12/01/01-0041:00	10288	0.020	10364	0.17	
	12/01/01-0042:50	10113	0.015	10735	0.13	
	12/01/01-0043:20	10405	0.018	11164	0.15	
	Uncertain	10371	-	11584	-	

Table 2 (Continued)

Backwater Event #	Date/Time	Meter #	Drawdown 1	Distance from Entrance 1	Drawdown/ Drawdown at Entrance	Tow Characteristics: # barges, # loaded, direction
Bath Chute-7-DS	12/01/01-0551:00	10259	0.12	0	1.0	10,10,U
	12/01/01-0555:00	10367	0.095	883	0.79	
	12/01/01-0559:00	10209	0.056	1833	0.47	
	12/01/01-0631:40	10288	0.012	10364	0.10	
	12/01/01-0632:55	10113	0.007	10735	0.06	
	12/01/01-0635:00	10405	0.018	11164	0.15	
	Uncertain	10371	-	11584	-	
No-name-1	11/30/01-1743:20	10128	0.10	0	1.0	15,0,U
	11/30/01-1746:20	10363	0.040	250	0.40	
No-name-2	11/30/01-2048:55	10128	0.095	0	1.0	10,5,D
	11/30/01-2051:55	10363	0.020	250	0.21	
Quiver Island-1	11/29/01-1641:00	10288	0.070	0	1.0	8,8,U
	11/29/01-1642:50	10209	0.059	550	0.84	Petrochemical
	11/29/01-1649:00	10405	0.040	1760	0.57	
Quiver Island-2	11/29/01-1724:40	10288	0.075	0	1.0	?,?,U
	11/29/01-1726:30	10209	0.060	550	0.80	
	11/29/01-1732:50	10405	0.038	1760	0.51	
Quiver Island-3	11/29/01-1110:30	10288	0.091	0	1.0	12,4,U
	11/29/01-1113:10	10209	0.073	550	0.80	
	11/29/01-1118:40	10405	0.049	1760	0.54	
Quiver Lake-1	11/29/01-1130:00	10363	0.145	0	1.0	12,4,U
	11/29/01-1131:40	10128	0.095	290	0.66	
	11/29/01-1133:40	10215	0.051	690	0.35	
Quiver Lake-2	11/29/01-1704:00	10363	0.104	0	1.0	8,8,U
	11/29/01-1705:50	10128	0.058	290	0.56	Petrochemical
	11/29/01-1707:45	10215	0.029	690	0.28	

Table 2 (Concluded)

Backwater Event #	Date/Time	Meter #	Drawdown 1	Distance from Entrance 1	Drawdown/ Drawdown at Entrance	Tow Characteristics: # barges, # loaded, direction
Quiver Lake-3	11/29/01-1746:55	10363	0.105	0	1.0	?,?,U
	11/29/01-1748:35	10128	0.081	290	0.77	
	11/29/01-1750:20	10215	0.037	690	0.35	
Chautauqua-1	11/29/01-1240:40	10367	0.106	0	1.0	12,4,U
	11/29/01-1242:10	10259	0.079	291	0.75	
	11/29/01-1242:10	10113	0.080	380	0.75	
Chautauqua-2	11/29/01-1829:15	10367	0.083	0	1.0	8,8,U
	11/29/01-1830:50	10259	0.065	291	0.78	Petrochemical
	11/29/01-1830:50	10113	0.070	380	0.84	
Chautauqua-3	11/29/01-2049:55	10367	0.091	0	1.0	?,?,?
	11/29/01-2051:20	10259	0.076	291	0.84	
	11/29/01-2051:15	10113	0.080	380	0.88	

(Sheet 5 of 5)

Table 3
Observed and Computed Travel Time for Drawdown

Backwater	Gage to Gage	Distance[1]	Average depth[1]	Average Ambient Velocity, m/sec	Average Observed Time[2]	Calculated Time[2]
Bach Slough	10363-10128	210	0.71	0.10	101	83
	10363-10215	605	0.67	0.115	268	247
	10128-10215	395	0.69	0.135	167	160
Bath Chute-DS	10259-10367	883	1.85	0.375	228	227
	10367-10209	950	2.02	0.385	242	234
	10367-10405	10281	1.95	0.31	2365	2531
	10209-10113	8902	1.91	0.30	2032	2210
Bath Chute-US	10371-10405	420	1.59	0.23	87	101
	10371-10113	849	1.56	0.235	168	205
	10405-10209	9331	1.91	0.28	1905	2025
	10113-10367	9852	1.96	0.32	1988	2094

1 Measurements are in meters.
2 Measurements are in seconds.

Table 4
Drawdown Versus Probability of Exceedance for Backwaters in Pool 4 for June

Backwater	Cellid	Drawdown, meters				
		$P_e = 0.5$[1]	$P_e = 0.1$	$P_e = 0.05$	$P_e = 0.02$	$P_e = 0.01$
BW2	85R7955[2]	0.044	0.090	0.102	0.123	0.130
BW3	115L7890	0.045	0.091	0.104	0.132	0.136
BW3	65L7900	0.055	0.118	0.142	0.189	0.231
BW3	145L7935	0.036	0.067	0.083	0.120	0.150
BW6	215R7900	0.041	0.083	0.099	0.135	0.159
BW8	495L7640	0.015	0.029	0.031	0.032	0.037
BW9	185L7570	0.045	0.088	0.103	0.127	0.148
BW9	105L7585	0.070	0.143	0.163	0.170	0.200
BW9	165L7600	0.054	0.100	0.124	0.150	0.177
BW10	215R7625	0.038	0.073	0.091	0.102	0.141
BW12	165R7595	0.047	0.090	0.107	0.123	0.152

1 Probability of exceedance by a single tow.
2 Cellid shows this inlet at River Mile 795.5 on the right side of the river looking downstream.

Table 5
Drawdown Versus Probability of Exceedance for Backwaters and Secondary Channels in Pool 8 for June

Backwater/ Secondary Channel	Cellid	Drawdown, meters				
		Pe = 0.5[1]	P_e = 0.1	P_e = 0.05	P_e = 0.02	P_e = 0.01
BW1	85L6985[2]	0.055	0.103	0.115	0.152	0.153
BW1	135L7005	0.050	0.092	0.111	0.150	0.151
BW1	105L7015	0.038	0.067	0.079	0.101	0.102
BW2	225R6965	0.027	0.047	0.054	0.070	0.071
BW3	345L6890	0.037	0.075	0.119	0.166	0.167
BW3	185L6910	0.069	0.120	0.139	0.188	0.189
BW3	295L6920	0.037	0.065	0.084	0.115	0.116
BW3	75L6940	0.055	0.097	0.116	0.157	0.158
BW3	175L6945	0.050	0.089	0.116	0.162	0.163
BW3	235L6950	0.029	0.050	0.058	0.076	0.077
BW4	135R6905	0.051	0.115	0.173	0.220	0.221
BW6	95R6870	0.092	0.199	0.301	0.382	0.383
BW6	95R6875	0.089	0.212	0.266	0.341	0.357
BW6	245R6880	0.055	0.124	0.183	0.235	0.236
SC1	195R7010	0.036	0.068	0.082	0.112	0.113
SC2	195R6995	0.036	0.074	0.085	0.112	0.113
SC3	185L6960	0.032	0.055	0.066	0.082	0.091
SC4	285R6950	0.025	0.043	0.051	0.066	0.067
SC6	205R6915	0.038	0.067	0.083	0.116	0.117
SC7	135R6905	0.051	0.115	0.173	0.221	0.222
SC8	265L6885	0.051	0.099	0.140	0.224	0.225

1 Probability of exceedance by a single tow.
2 Cellid shows this inlet is at River Mile 698.5 on the left side of the river looking downstream.

Table 6
Drawdown Versus Probability of Exceedance for Backwaters in Pool 13 for June

Backwater	Cellid	Drawdown, meters				
		$P_e = 0.5$[1]	$P_e = 0.1$	$P_e = 0.05$	$P_e = 0.02$	$P_e = 0.01$
BW1	105L5555[2]	0.024	0.048	0.052	0.060	0.071
BW1	315L5560	0.016	0.031	0.034	0.039	0.046
BW2	65L5520	0.041	0.079	0.090	0.107	0.122
BW4	115R5465	0.036	0.065	0.076	0.094	0.106
BW5	85L5385	0.057	0.105	0.118	0.128	0.141
BW5	125L5390	0.050	0.092	0.101	0.114	0.127
BW5	135L5390	0.049	0.089	0.097	0.109	0.120
BW5	355L5400	0.021	0.036	0.040	0.046	0.049
BW6	195R5410	0.033	0.056	0.064	0.072	0.081
BW7	565L5335	0.014	0.025	0.029	0.034	0.040
BW7	545L5340	0.015	0.026	0.029	0.032	0.034
BW7	385L5345	0.022	0.039	0.043	0.051	0.053
BW7	395L5345	0.022	0.038	0.042	0.050	0.052
BW7	265L5370	0.028	0.053	0.062	0.078	0.094
BW10	685R5300	0.015	0.026	0.028	0.032	0.035
BW10	325R5305	0.039	0.068	0.080	0.091	0.097
BW10	165R5310	0.040	0.069	0.077	0.087	0.093
BW10	315R5335	0.026	0.049	0.056	0.066	0.079
BW11	15L5290	0.064	0.118	0.134	0.146	0.157
BW11	75L5300	0.035	0.062	0.066	0.077	0.081
BW11	475L5310	0.018	0.032	0.036	0.039	0.041
BW11	95L5325	0.038	0.066	0.071	0.082	0.086
BW11	435L5330	0.016	0.029	0.032	0.036	0.038
BW11	445L5330	0.016	0.029	0.032	0.035	0.037
BW11	455L5330	0.016	0.028	0.032	0.035	0.037

[1] Probability of exceedance by a single tow.
[2] Cellid shows this inlet is at River Mile 555.5 on the left side of the river looking downstream.

Table 7
Drawdown Versus Probability of Exceedance for Secondary Channels in Pool 13 for June

Secondary Channel	Cellid	Drawdown, meters				
		$P_e = 0.5$[1]	$P_e = 0.1$	$P_e = 0.05$	$P_e = 0.02$	$P_e = 0.01$
SC1	385R5555[2]	0.013	0.025	0.029	0.032	0.037
SC2	75L5545	0.033	0.067	0.079	0.090	0.105
SC3	225L5530	0.025	0.049	0.056	0.067	0.078
SC4	325R5530	0.019	0.037	0.043	0.050	0.058
SC5	415R5500	0.015	0.028	0.033	0.037	0.043
SC6	345L5480	0.022	0.042	0.048	0.055	0.062
SC7	395L5470	0.019	0.035	0.038	0.045	0.047
SC8	95R5435	0.048	0.086	0.097	0.109	0.131
SC9	155L5410	0.025	0.044	0.049	0.056	0.058
SC10	485R5370	0.020	0.037	0.043	0.055	0.069
SC11	235R5345	0.018	0.030	0.033	0.039	0.040
SC12	165R5330	0.036	0.065	0.074	0.082	0.087

1 Probability of exceedance by a single tow.
2 Cellid shows this inlet is at River Mile 555.5 on the right side of the river looking downstream.

Table 8
Drawdown Versus Probability of Exceedance for Backwaters and Secondary Channels in Pool 96 (Pool 26 above confluence of IWW) for June

Backwater/ Secondary Channel	Cellid	Drawdown, meters				
		$P_e = 0.5$[1]	$P_e = 0.1$	$P_e = 0.05$	$P_e = 0.02$	$P_e = 0.01$
BW1	415R2350[2]	0.012	0.023	0.025	0.031	0.031
BW1	395R2390	0.010	0.019	0.024	0.027	0.027
BW2	245L2350	0.016	0.030	0.036	0.045	0.045
BW2	415L2360	0.014	0.026	0.033	0.036	0.036
BW6	285R2270	0.022	0.043	0.053	0.067	0.067
BW6	475R2285	0.009	0.017	0.020	0.023	0.025
BW7	725R2210	0.008	0.017	0.020	0.025	0.026
SC1	315R2345	0.018	0.033	0.040	0.047	0.047
SC2	205L2325	0.024	0.043	0.060	0.065	0.073
SC3	235R2225	0.024	0.055	0.069	0.089	0.089
SC3	135R2250	0.044	0.100	0.139	0.172	0.172
SC10	305L2255	0.018	0.040	0.050	0.064	0.064

1 Probability of exceedance by a single tow.
2 Cellid shows this inlet is at River Mile 235.0 on the right side of the river looking downstream.

Table 9
Drawdown Versus Probability of Exceedance for Backwaters and Secondary Channels in Pool 26 for June

Backwater/Secondary Channel	Cellid	Drawdown, meters				
		$P_e = 0.5$[1]	$P_e = 0.1$	$P_e = 0.05$	$P_e = 0.02$	$P_e = 0.01$
BW8	585R2160[2]	0.007	0.014	0.016	0.019	0.021
BW9	685R2145	0.006	0.011	0.013	0.016	0.016
BW11	405R2090	0.010	0.017	0.019	0.025	0.025
SC7	595R2160	0.007	0.014	0.016	0.018	0.021
SC8	355R2140	0.012	0.022	0.025	0.032	0.034
SC9	315L2105	0.011	0.021	0.024	0.029	0.029

[1] Probability of exceedance by a single tow.
[2] Cellid shows this inlet is at River Mile 216.0 on the right side of the river looking downstream.

Table 10
Drawdown Versus Probability of Exceedance for Backwaters and Secondary Channels in Pool 31 (LaGrange Pool) for June

Backwater/ Secondary Channel	Cellid	Drawdown, m				
		$P_e = 0.5$[1]	$P_e = 0.1$	$P_e = 0.05$	$P_e = 0.02$	$P_e = 0.01$
BW1	75L1240[2]	0.027	0.088	0.099	0.121	0.133
BW2	75L1230	0.030	0.088	0.099	0.120	0.132
BW3	85L1150	0.025	0.068	0.079	0.092	0.106
BW4	65L1130	0.033	0.090	0.105	0.123	0.147
BW5	105L0920	0.032	0.088	0.116	0.137	0.152
BW5	65L0960	0.038	0.106	0.131	0.155	0.163
BW5	105L0980	0.032	0.087	0.105	0.125	0.130
BW6	65L0950	0.041	0.112	0.140	0.173	0.182
BW8	65L0830	0.030	0.083	0.092	0.112	0.117
SC1	55L1220	0.028	0.084	0.097	0.114	0.127
SC2	175L0870	0.028	0.076	0.091	0.113	0.116
SC3	95L1400	0.024	0.061	0.077	0.087	0.093
SC5	75L1360	0.026	0.069	0.080	0.090	0.103
SC6	255L0860	0.020	0.056	0.069	0.083	0.083
SC7	105R1430	0.023	0.064	0.074	0.085	0.098
SC8	115R1490	0.031	0.089	0.108	0.119	0.142

[1] Probability of exceedance by a single tow.
[2] Cellid shows this inlet is at River Mile 124.0 on the left side of the river looking downstream.

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14. ABSTRACT

Field data were collected on the decay of tow-induced drawdown along backwaters and compared to predictions from the UNET model. Drawdown from tows was measured along 10 backwaters on the Illinois Waterway. At the longest channel, Bath Chute, drawdown could be clearly detected at 11.6 km (7.2 miles) from the point of origin although the magnitude was significantly reduced. The UNET model predictions of drawdown ranged from 10 percent overprediction to 30 percent underprediction for all backwaters except Bath Chute. At Bath Chute, UNET predictions overpredicted drawdown by 40 percent or more, particularly at the three gages located about 7 miles above the mouth of the backwater where drawdown magnitude was about 0.015 m (0.05 ft). Drawdown for various probabilities of exceedance was determined for the entrances of backwaters and secondary channels used in the UMR-IWW study. Based on the data and model comparisons presented herein, the UNET model is appropriate for determining drawdown decay along backwaters.

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