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Illinois State Water Survey
Urbana, Illinois
1979

Illinois Institute of Natural Resources

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CONTENTS

SUMMARY

The major effects of increased diversion on groundwater along the Illinois Waterway occur below De Pue (mile 213). Above De Pue, the river valley is narrow, agricultural activity primarily is on the uplands, and only scattered sand and gravel deposits are present. From De Pue to the confluence of the Illinois and Mississippi Rivers extensive deposits of sand and gravel occupy the bottomland portion of the Waterway. Wells tapping these deposits range in depth from 30 to 165 feet. An estimated 30.2 billion gallons were withdrawn from wells during 1977. Water obtained from these wells ranges in hardness from 172 to 639 mg/1 and averages 419 mg/1. Total dissolved minerals range from 211 to 896 mg/1 and average 545 mg/1.

A literature search for models relating river stages and groundwater levels revealed that a model developed by Prickett and Lonnquist (1971) best suits the purposes of this study. A lack of adequate historical groundwater level data prohibited accurate calibration of the model and presentation of specific results. Recommendations for establishing a monitoring network to provide input data for model calibration are made.

Analysis of data obtained for 15 Drainage and Levee Districts along the Illinois Waterway indicates that increases in pumping costs for these districts may range from 20 to 50 percent with 10,000 cfs diversion. At 6,600 cfs diversion increases may range from about 2 to 30 percent.

The effect of increased diversion on groundwater resources along the waterway can be only discussed in general terms. Maintaining higher river

stages during periods of low flow will result in higher water levels in the bottomland deposits. Where groundwater pumpage occurs near the river and river water is induced to move through the river bed to the pumping center, the higher groundwater level and river stage will maintain more available drawdown in the wells and allow increased water to be induced from the river. Adequate data is not available to speculate on the effect on the quality of groundwater in the bottomlands.

INTRODUCTION

A 5-year study and demonstration program to determine the effects of increased Lake Michigan diversion on water quality of the Illinois Waterway and on the susceptibility of the Illinois Waterway to additional flooding is authorized in Section 166 of the Water Resources Development Act of 1976 (P.L. 94-587). It is planned during the 5-year demonstration program to increase Lake Michigan diversion from the presently authorized 3200 cfs to a maximum of 10,000 cfs.

The 5-year study and demonstration program will include determining the effects of increased diversion on groundwater along the Illinois Waterway. Main interest is focused on the impact of increased diversion on groundwater in the vicinity of the LaGrange and Peoria Pools. Of particular interest is the impact of increased diversion on agricultural drainage.

The main purposes of this study are to: 1) discuss the existing groundwater conditions along the Illinois Waterway; 2) conduct a literature search of pertinent articles on analytical techniques for relating river stages and groundwater levels; 3) develop a predictive model relating river stages and groundwater levels; and 4) design a groundwater level monitoring network to assess the effects of river stages on groundwater levels. A general estimate of the increased cost of pumping by drainage districts along the Waterway also is made.

The Illinois Waterway extends from Lake Michigan at Chicago to the Mississippi River at Grafton, Illinois (see figure 1). On leaving Lake Michigan, the Waterway follows the south branch of the Chicago River and crosses

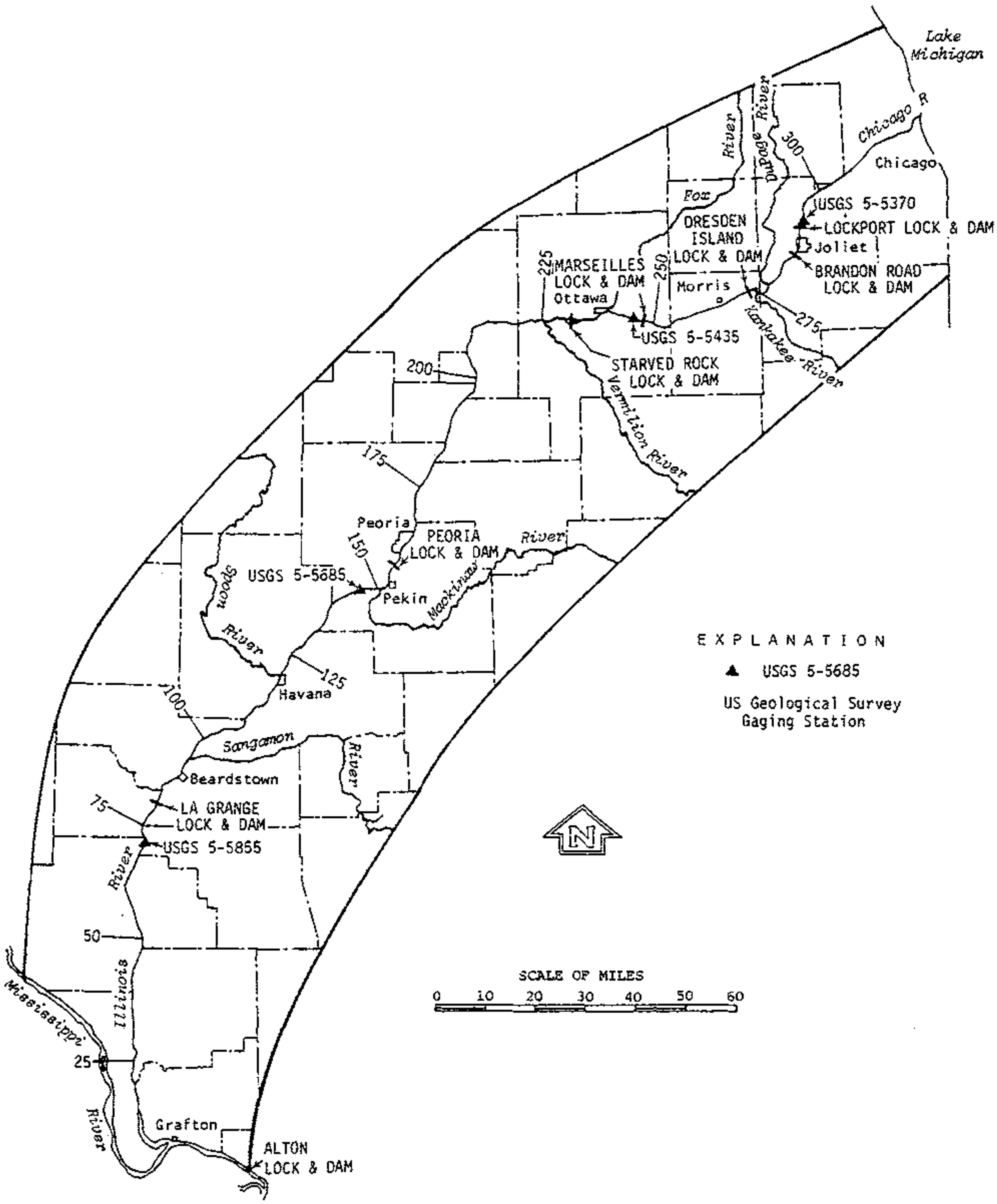


Figure 1. Illinois Waterway Location Map.

a low divide into the Chicago Sanitary and Ship Canal, which extends to a dam at Lockport. (mile 291). Just below Lockport, the Waterway coincides with the Des Plaines River until the mouth of the Kankakee River (mile 274) where the Illinois River begins. The Illinois River and Waterway are the same to Grafton except at Marseilles, where the Waterway bypasses a rapids in the river by a canal about two miles long.

Water levels along the Waterway are controlled by 7 lock and dams on the Waterway and one, the Alton Lock and Dam on the Mississippi River. Five dams, Lockport, Brandon Road, Dresden Island, Marseilles, and Starved Rock, maintain nearly contiguous pools in the 95 miles from Lake Michigan to Starved Rock. In this segment the water level drops about 135 feet (from 580 to 445 feet above mean sea level) resulting in an average slope of 1.42 feet per mile. In the 320 miles from Starved Rock to the Mississippi River, the water level drops only 25 feet (from 445 to 420 feet above mean sea level) resulting in an average slope of only .11 feet per mile. This segment has two dams, one at Peoria and one at La Grange. The lower few miles of the Waterway are controlled by the Alton River Dam on the Mississippi River.

Acknowledgments

The authors wish to thank W.E. Mueller, Customer Services Supervisor, Central Illinois Public Service Company, Beardstown, for providing water consumption data for Drainage and Levee Districts serviced by C.I.P.S. Simulated river water levels were provided by the U.S. Army Corps of Engineers. The tabulation of well records was compiled by Ken Smith, Hydrology Assistant.

The project was conducted under the general supervision of William C. Ackermann, Chief, Illinois State Water Survey. The art work was prepared by William Motherway and John Brother. The draft and final manuscripts were typed by Betty Dowling and Ginny Johnson.

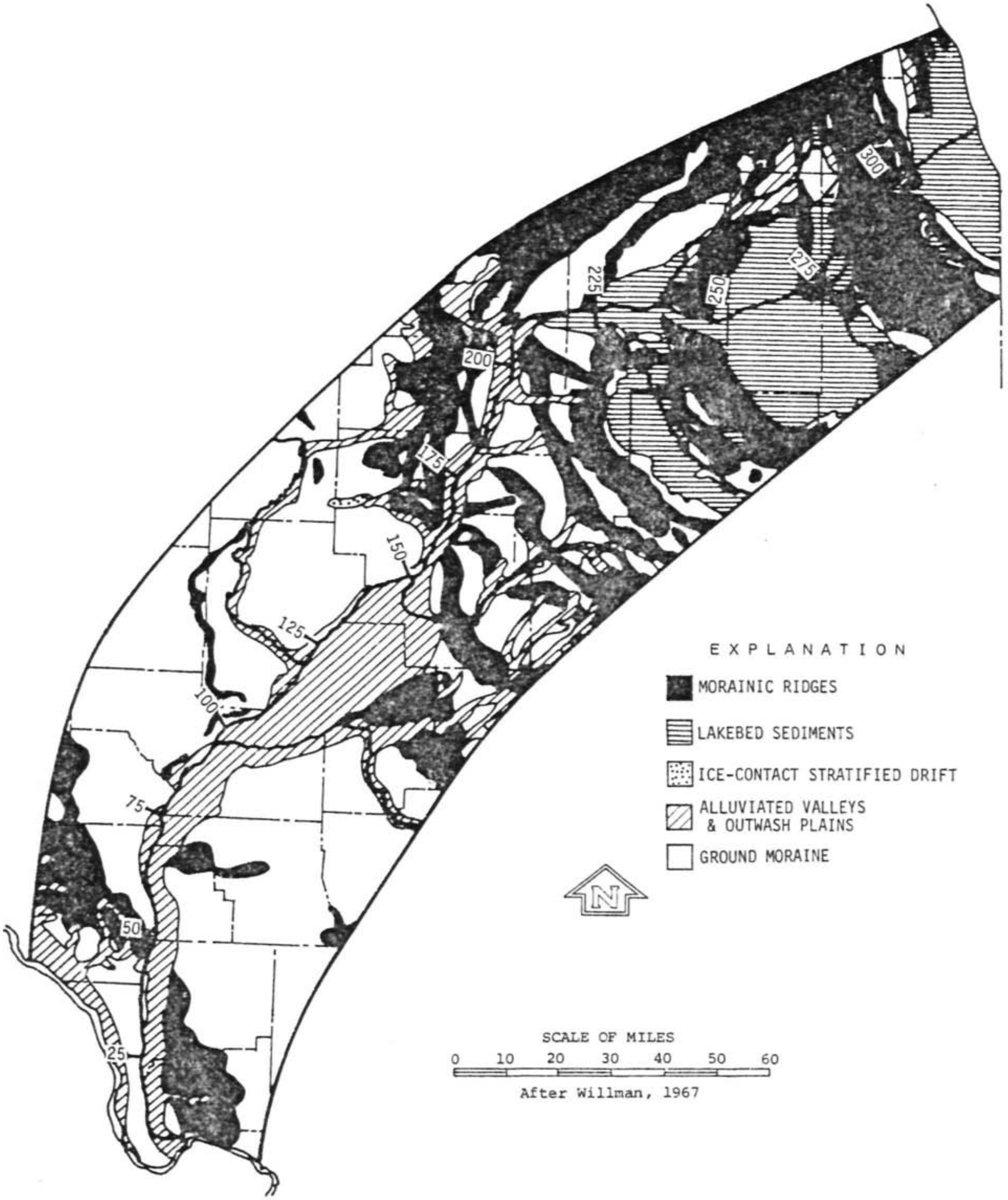
GEOLOGY

The Geology of the Illinois Waterway is described in detail in Cooperative Reports 1 and 3 by the State Water Survey and State Geological Survey, in Report of Investigations 47, 55, 59, and 61 by the State Water Survey, and in Circulars 222, 248, and 478 by the State Geological Surveys. These publications are included in the list of reference. The following discussion is taken largely from these publications and focuses mainly on the geology of the immediate valley portion of the Waterway.

The unconsolidated materials along the Illinois Waterway consist of gravel, sand, silt, clay, peat, marl, and distinctive variations having special names such as till, loess, alluvium, and colluvium. Most are deposits of streams, rivers, glaciers, lakes, and winds. Figure 2 illustrates the types of unconsolidated deposits present in the general area of the Waterway. The thickness of these deposits are shown in general ?'n Figure 3.

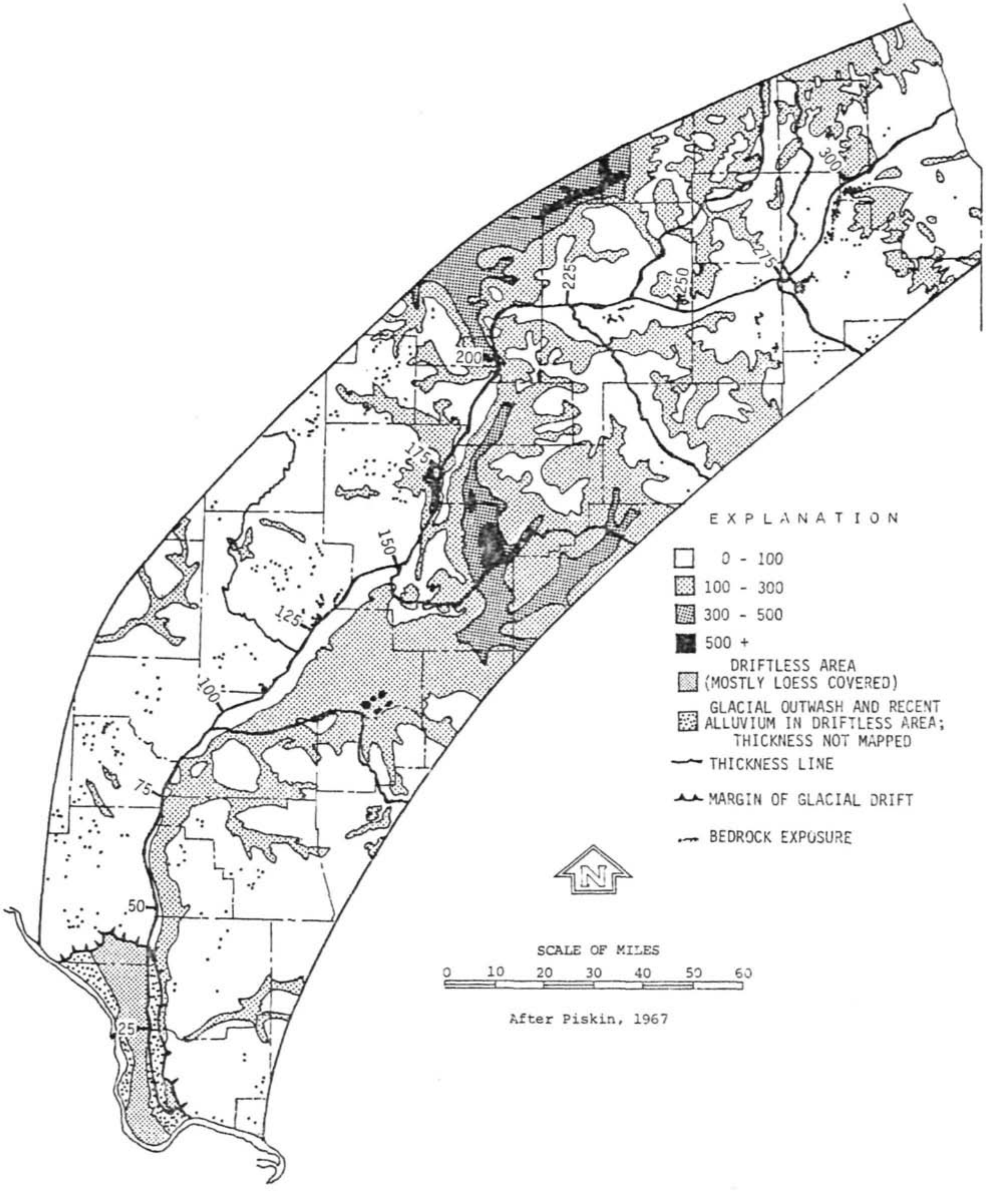
From Lake Michigan to La Salle (mile 223), the unconsolidated materials range in thickness from 0 to less than 50 feet in the immediate valley areas and from 0 to about 300 feet on the upland portions. Most of the unconsolidated materials along this reach of the Waterway are fine grained lake sediments and morainal deposits of silt, clay, and till interspersed with some gravel. In the immediate Waterway valley relatively thin alluvium and gravel terraces are encountered. No significant groundwater developments are recorded from the unconsolidated materials along this segment of the Waterway.

From La Salle (mile 223) to De Pue (mile 213), where the Waterway turns south and joins the preglacial Mississippi River valley, the unconsol-



After Willman, 1967

Figure 2. Glacial map of the Illinois Waterway.



After Piskin, 1967

Figure 3. Thickness of unconsolidated materials along the Illinois Waterway.

idated materials range in thickness from less than 50 to about 150 feet in the valley and from about 50 to over 300 feet in the upland areas. In the valley the unconsolidated materials predominately are alluvial outwash of sands and gravels covered by relatively thin (5 to 30 feet) loess deposits. Municipal and industrial wells ranging in depth from about 40 to 160 feet have been developed in the sand and gravel deposits in the valley portion of the Waterway.

From De Pue (mile 213) to Pekin (mile 153), the unconsolidated materials range in thickness from less than 50 to about 150 feet in the valley and from 0 to over 500 feet in the upland areas. The valley fill materials predominately are alluvial sand and gravel overlain by thin (0 to 20 feet) loess deposits. Municipal and industrial wells ranging in depth from about 50 to 150 feet have been developed in the sand and gravel deposits in the valley portions of the Waterway.

From Pekin (mile 153) to Beardstown (mile 88), the unconsolidated materials range in depth from about 50 to 150 feet in the valley and are generally less than 50 feet thick in the uplands west of the river. East of the river, in the Havana lowland area, these deposits range in thickness from about 100 to over 300 feet. This reach of the Waterway was formed by the confluence of the Illinois River and the ancient preglacial Mahomet River. The unconsolidated materials consist principally of alluvial and outwash sand and gravel from land surface to the underlying bedrock forming the most productive glacial aquifer along the Waterway. Muncipal, industrial, and irrigation wells ranging in depth from 90 to 150 feet have been constructed throughout this area.

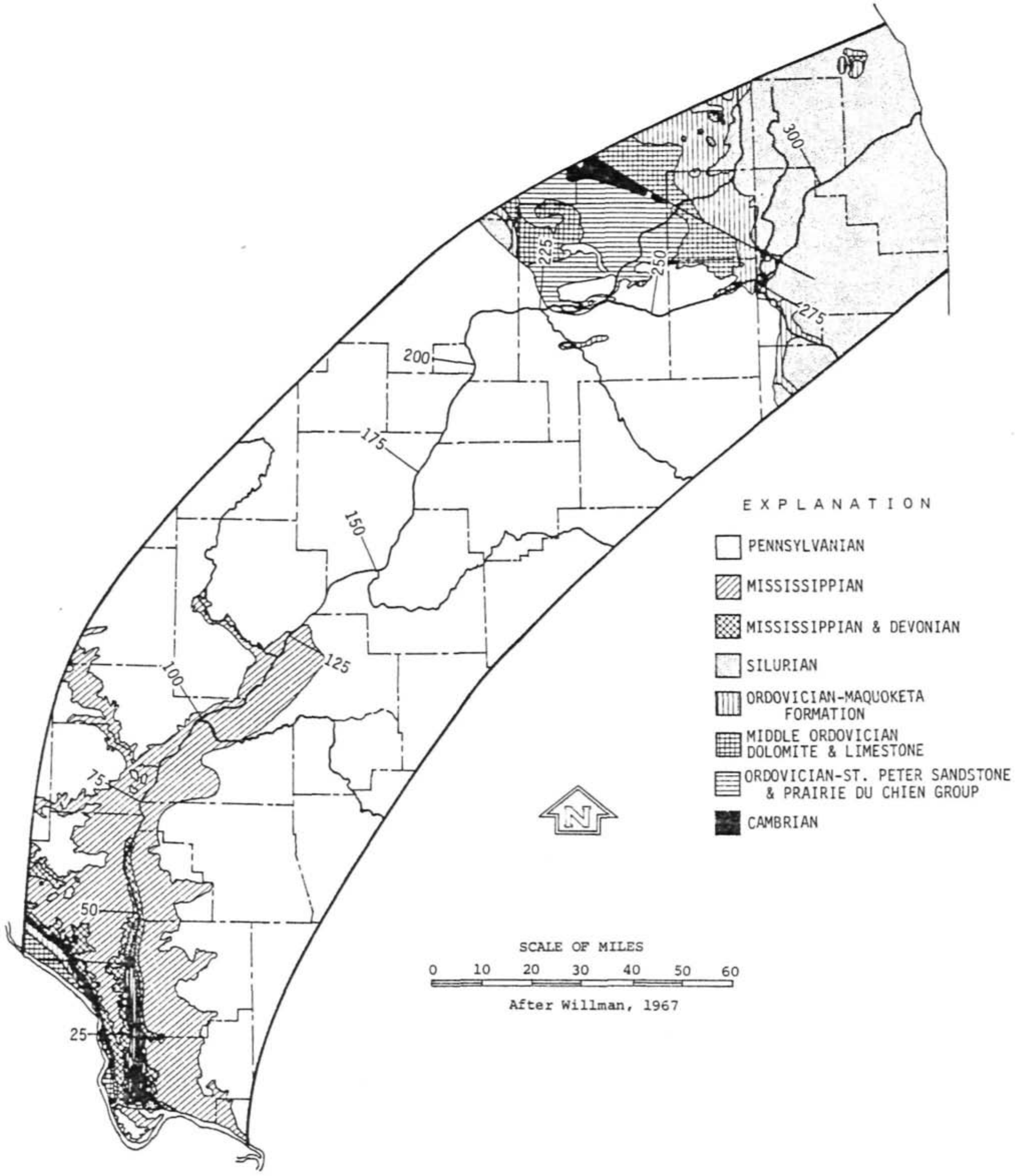
From Beardstown (mile 88) to Grafton, the unconsolidated materials range in thickness from about 100 feet in the valley and from 0 to about 150 feet in the upland areas. The valley fill materials principally consist of alluvial sand and gravel overlain by thin (generally less than 20 feet) wind blown loess. Several municipal water supplies have been developed from wells tapping the sand and gravel materials at depths from about 50 to 100 feet.

The bedrock units underlying the Illinois Waterway consist of sandstones, limestones, dolomites, and shales of Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian ages. During long intervals of erosion prior to the Pleistocene Epoch, or Glacial Period, all rock units except the Cambrian formations were exposed to form the present bedrock surface. Figure 4 illustrates the distribution of rock units beneath the glacial materials along the Waterway.

From Lake Michigan to Morris (mile 264) , Silurian and Ordovician age dolomites form the upper bedrock surface. Moderate to large quantities (10 to 500 gpm) of groundwater have been developed from these units in Cook, DuPage, and Will Counties. In some areas, these rocks units are hydraulically interconnected with overlying sand and gravel units and are capable of yielding larger quantities of water.

From Morris (mile 264) to Ottawa (mile 240), the surficial bedrock units consist of Pennsylvanian age shales, limestones, and sandstones. These rocks provide only very limited water for farm and domestic uses.

Between Ottawa (mile 240) and La Salle (mile 223), Ordovician age St. Peter Sandstone forms the upper bedrock surface and locally is exposed along



After Willman, 1967

Figure 4. Bedrock map of the Illinois Waterway.

the valley wall. This rock unit is widely used as an aquifer for municipal, industrial, and domestic supplies in the area. The unit also contributes moderate quantities of water to wells tapping deeper aquifers when left uncased.

Between LaSalle (mile 223) and mile 130 (about 10 miles north of Havana), Pennsylvanian age shales, sandstones, and limestones form the bedrock surface beneath the glacial materials. The Pennsylvanian rocks of this area contain little or no usable water and seldom are considered for even domestic water supply purposes.

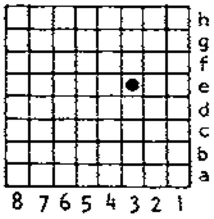
Between mile 130 and mile 52, southwest of Winchester ,Mississippian and Devonian age limestones and shales form the upper bedrock surface. Several limestone formations of the Mississippian rocks have been used as a source of small to moderate (5 to 20 gpm) quantities of groundwater in the upland areas along this portion of the river.

Below mile 52 to the confluence with the Mississippi River,Devonian, Silurian, and Ordovician age shales, dolomites, and limestones form the upper bedrock surface. These rocks generally are considered as a source of groundwater for domestic and small municipal supplies.

WELL RECORDS

Table 1 is a tabulation of well records from the Water Survey basic files for sand and gravel wells located in the valley bottomlands of the Illinois Waterway. These include municipal, industrial, and irrigation wells. Domestic sand and gravel wells or wells tapping the underlying bedrock units were not tabulated.

The well numbering system used in table 1 is based on the location of the well, and uses the township, range, and section for identification. The well number consists of five parts: county name or abbreviation, township (T), range (R), section, and coordinate within the section. Sections are divided into rows of 1/8 - mile squares. Each 1/8 - mile square contains 10 acres and corresponds to a quarter of a quarter of a quarter section. A normal section of 1 square mile contains 8 rows of 1/8 - mile squares; an odd-sized section contains more or fewer rows. Rows are numbered from east to west and lettered from south to north as shown in the diagram.



The number of the well shown is CSS 17N 13W - 11 .3e. Where there is more than one well in a ten acre square they are identified by arabic numbers of the lower case letter in the well number. Any number assigned to the well by the owner is shown in parentheses after the location well number.

Table 1. Sand and gravel wells along the Illinois Waterway.

Well number	Owner	Use*	Depth of well (feet)	Diameter of well (in)	Screen Length (feet)	Screen Diameter (in)
Bureau						
15N11E						
2.7g	Spring Valley (8)	P	46	16		
2.7g	Spring Valley (9)	P	50	12		
16N10E						
35.7a	New Jersey Zinc	I	77			
36.3h	New Jersey Zinc	I	30	6	4	6
Calhoun						
10S2W						
27.le	Hardin	P	70	8	15	8
27.le	Hardin	P	64	8	15	8
12S2W						
11.4c	Batchtown	P	87	6	10	6
11.4c	Batchtown	P	86	8	10	8
13S1W						
7.4a	Brussells	P	78	8	10	8
Cass						
17N12W						
1	Curls	A	96	18		
10.8c	Don Large	A	76	16	40	16
33	Burrus Bros Seed Farm	A	90	8	20	8
17N13W						
27.8a	Meredosia Farm Club	A	65	8	10	8
18N12W						
14.3a	Beardstown (13)	P	86	16	46	16
14.3a	Beardstown (14)	P	83	16	20	16
14.3a	Beardstown (16)	P	82	16	25	16
14.4a	Beardstown (15)	P	80	16	20	16
14.8f	Beardstown (12)	P	92	16	27	16
	Beardstown (5)	P	78	27	40	
	Beardstown (7)	P	86	16	25	16
	Beardstown (8)	P	89	16	20	16
24.6b	Oscar Meyer (3)	I	95	20	40	20
24.7b	Oscar Meyer (1)	I	97	20	40	20
24.7b	Oscar Meyer (2)	I	101	20	40	20
24.7h	Beardstown (11)	P	92	16	20	12
Fulton						
3N3E						
10.6c	Hille Building Serv.	A	56	15	20	12
4N4E						
16.2h	Norris Farms	A	38	8	10	8

* P=Public, I=Industrial, A=Irrigation.

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen	
					Length (feet)	Diameter (in)
Greene						
10N13W						
5.2g	Herschberger Ag Farms	A	70	16	40	16
28.7e	Eldred (1)	P	52	8	10	8
28.7e	Eldred (2)	P	56	8	10	8
12N13W						
17.7b	Beam Bros.	A	75	16	40	16
20.4e	Robert Wear	A	75	16	40	16
20.6f	John Vinyard	A	92	16	40	16
28.1b	Hillview	P	70	8	10	6
Jersey						
6N12W						
16	Grafton (1)	P	42	10		
16	Grafton (2)	P	56	16	15	16
6N13W						
4.4e	Pere Marquette St Pk (4)	P	79			
9.4a	Pere Marquette St Pk (2)	P	75	8	20	8
16.4h	Pere Marquette St Pk (3)	P	76	8	20	8
7N13W						
5.7e	Jerseyville (1)	P	96	16	50	16
5.7e	Jerseyville (2)	P	99	16	50	16
LaSalle						
33N1E						
14.7a	LaSalle (3)	P	38	16'		
14.7a	LaSalle (4)	P	58	12'		
14.7a	LaSalle (5)	P	60	12'		
14.7a	LaSalle (6)	P	56	36	15	36
14.7a	LaSalle (7)	P	49	36	15	36
16.1a	Western Clock Co.	I	56			
Marshall						
12N9E						
14.5f	Sparland (2)	P	30	10		
14.5f	Sparland (3)	P	34	12	4	12
34.1a	Hopewell Estates (4)	P				
13N10E						
3	B.F. Goodrich (9)	1	97	16	20	16
3.3a	B.F. Goodrich (3)	I	104	16	20	16
3.3b	B.F. Goodrich (2)	I	108	10	20	10
3.3b	B.F. Goodrich (4)	I	107	10	20	10
3.4a	B.F. Goodrich (7)	I	106	16	25	16
3.4b	B.F. Goodrich (1)	I	89	4	20	4
3.4c	B.F. Goodrich (5)	I	102	16	26	16
3.6a	B.F. Goodrich (8)	I	106	16	20	16
3.6b	B.F. Goodrich (10)	I	100	8	15	8
9.1d	Henry (5)	P	135	16	25	16
10.5d	Grace Chemical Co. (1)	I.	78	12		
10.5d	Grace Chemical Co. (2)	I	80	12	11	12
16.2c	Henry (3)	P	62	12	14	12
16.2c	Henry (4)	P	75	12	14	12

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen Length (feet)	Screen Diameter (in)
Marshall (Cont.)						
30N3W						
26.1b	Lacon (1)	P	39	10	12	10
26.1b	Lacon (2)	P	51	10	10	10
26.1b	Lacon (3)	P	51	10	10	10
Mason						
19N10W						
1.4g	John Fletcher	A	92	18	40	18
4.6c	Wm. Felber	A	67	18	40	18
13.8b	Laura Lane	A	84	18	40	18
15.7c	Morris Seraff	A	101	12	20	12
16.8a	Spud Farms	A	92	15	20	12
18.1g	James Sarth	A	73	16	40	16
18.8d	Rigby Roskelly	A	78	16	40	16
19.4e	Staley Bros.	A	81	16	36	16
20.7h	Spud Farms	A	101	12	20	12
21.4b	Spud Farms	A	91	15	20	12
23.2b	Mrs. Brown	A	73	18	40	18
25.6f	USAC0E	A	89	30	27	30
30.1d	USAC0E	A	63	30	27	30
30.2g	USACOE	A	62	30	27	30
30.4g	A. Staley, Jr.	A	66	18	40	18
30.8c	USACOE	A	69	30	27	30
20N9W						
1.7c	Howard Ermling	A	126	15	20	12
2.3c	Howard Ermling	A	125	15	20	12
3.2g	Ralph Vanderveen	A	101	18	40	18
9.2c	Everett Kiethly	A	90	15	20	12
10.1d	Vernon Heye	A	111	15	20	12
12.1b	Jack Schulte	A	120	12	11	11
17.7a	Homer Lascelles	A	100	18	40	18
19.2d	Marvin Lascelles	A	101	10	30	10
19.7b	Marvin Lascelles	A	96	18	40	18
20.2g	Spud Farms	A	92	12	20	11
21.5e	Spud Farms	A	92	12	20	11
21.7c	Donald Hogson	A	121	15	20	12
22.7a	Donald Flaherty	A	120	15	20	12
24.3b	Keest Estate	A	75	18	40	18
27.1e	Donald Friend	A	93	15	20	12
27.4f	Leo Pfeiffer	A	120	15	30	12
28.2b	Leo Pfeiffer	A	94	12		
28	Willard Brown	A	110	18	40	18
28.5g	Willard Brown	A	93	18	36	18
28.7b	Willard Brown	A	97	18	36	18
31	Homer Lascelles	A	87	18	40	18
32.5f	Spud Farms	A	100	15	20	12
33.2g	Fon Pfeiffer	A	120	12	19	11
34.1g	Donald Friend	A	103	15	20	12
35.2g	Cliff Friend	A	110	12	20	12

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen	
					Length (feet)	Diameter (in)
Mason (Cont.)						
20N10W						
2A.lc	Everett Keithley	A	88	15	20	12
25.2f	Richard Smith	A	78	16	40	16
25.2g	Richard Smith	A	92	12	20	11
36.5d	John Fletcher	A	99	16	40	16
36.6g	Howard Herring	A	93	15	20	12
21N8W						
1	Mrs. Herman Esselman	A	96	18	40	18
1	Robert Henninger	A	86	18	23	18
2	Delbert Hackman	A	85	18	40	
2	Delbert Hackman	A	114	18	40	18
2	Harry Spocketer	A	105	18		18
2.2b	Trevor Jones	A	96	18	40	18
3	Delbert Hackman	A	99	18	40	18
4	Rudy Shilling	A	85	18	40	18
5.7g	Havana Nat. Bank	A	83	18	44	18
6.8e	Havana (5)	P	96	12	50	12
9.6c	Trevor Jones	A	106	12	12	10
11	Alvin Hickman	A	88	18	36	18
11	David Larson	A	96	18	40	18
12	Douglas Budke	A	100	18	40	18
15	John Roat	A	105	18	40	18
15	Carl Steging	A	86	18	40	18
15.8h	Charles Roat	A	99	18	40	18
17.7g	Fred Vanderreen	A	94	15	22	12
18	Louis Busch, Jr.	A	72	18	40	18
21	Marvin Roat	A	105	18	44	18
21	Julius Stelter	A	104	18	40	18
22.2h	Bonnett, Inc.	A	60	6	3	5
23	Wilhelmina Hahn	A	115	18	40	18
23.2b	Bonnett, Inc.	A	40	5	3	5
24	John Kaupple	A	95	18	40	18
24	Howard Ermeling	A	106	18	40	18
24.5c	Mrs. Wade Friedrick	A	100	15	20	12
25.2g	George Glick	A	104	18	40	18
25.7g	John Knupple	A	105	18	40	18
27.2c	John Ermeling	A	120	15	20	12
28	Alvin Popmeyer	A	105	18	40	18
30.8g	Elmer Frye	A	87	18	40	18
33	Paul Friend	A	115	18	40	18
34.7g	John Ermeling	A	97	18	40	18
36.3c	Jesse Johnson	A	100	18	40	18
36.7b	Jesse Johnson	A	106	18	40	18
21N9W						
1.1f	Havana (2)	P	85	12	15	12
1.1f	Havana (3)	P	78	12	20	12
11	Illinois Power	I	83	18	20	18
11	Illinois Power	I	79	18	20	18
11	Illinois Power	I	82	18	20	18
11	Illinois Power	I	84	18	20	18
11.2c	Illinois Power	I	83	18	20	16
13.6d	Gerald Bonnett	A	91	18	40	18

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen	
					Length (feet)	Diameter (in)
Mason (Cont.)						
14	Gerald Bonnett	A	94	18	40	18
24	Gerald Bonnett	A	93	18	40	18
24	Raymond Maston	A	87	18	40	18
22N8W						
1.6b	Loren Thomas	A	80	12	31	10
13	Franklin Behrends	A	97	18	40	18
13.8a	Terry Johnson	A	107	14	20	14
14.6C	Francis Atwater	A	108	16	40	16
20.7b	Daryl Fornoff	A	72	15	20	12
21.6b	Don Rollo	A	111	12	20	11
23	Doyle Walker	A	103	18	40	18
24	Kenneth Ringhouse	A	84	18	40	18
24	Ringhouse Bros.	A	102	18	40	18
25	Mrs. Esselman	A	96	18	40	18
25.2g	Rick Horner	A	99	15	20	12
26.2g	Natalie Ganson	A	95	16	40	16
27	Chas. Walker	A	88	18	36	18
28	Niederer Estate	A	88	18	40	18
28.6c	Raymond Marker	A	92	18	40	18
28.8a	Ralph Vanderveen	A	92	15	20	12
29	Harry Fornoff	A	79	18	40	18
32.8h	Harry Fornoff	A	78	15	20	12
33.2d	Delbert Bonnett	A	85	.18	40	18
33.4e	Delbert Bonnett	A	104	18	40	18
33.7e	Dierker	A	110	15	20	12
36.2c	Clinton O'Bryant	A	93	12	16	9
23N7W						
32	Pauline Mitchell	A	95	18	40	18
Morgan						
15N13W						
31.2d	South Jacksonville (1)	P	79	10	20	10
31.2d	South Jacksonville (2)	P	76	10	20	10
15N14W						
12.4f	Jacksonville	P	90	13'	2	
16N13W						
21	Central Illinois Public Service (6)	I	103	12	25	12
21.1c	Central Illinois Public Service	I	109			
21.1c	Central Illinois Public Service (5)	I	106	12	25	12
21.1d	Central Illinois Public Service	I	105			
22.5g	Meredosia (2)	P	60	8	20	8
22.5g	Meredosia (3)	P	84	8	14	8
22.5g	Meredosia (4)	P	87	8	14	8
27.8f	Nat. Starch a. Chemical Corp. (1)	I	95	12	20	
27.3h	Nat. Starch & Chemical Corp. (10)	I	90	16	25	16

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen	
					Length (feet)	Diameter (in)
Morgan (Cont.)						
16N13W						
28	Swift Chem Co.	I	77	14		14
28.1h	W.R. Grace Co.	I	90	12	26	12
28.2f	Nat. Starch & Chemical Corp. (7)	I	96	8	16	8
28.2h	Nat. Starch & Chemical Corp. (2A)	I	92	12	20	
28.5g	Nat. Starch & Chemical Corp. (4)	I	98	12	20	12
28.5g	Nat. Starch & Chemical Corp. (6)	I	90	12	25	10
28.5g	Nat. Starch & Chemical Corp. (8)	I	95	12	25	12
28.5g	Nat. Starch & Chemical Corp. (9)	I	62	8	10	8
Peoria						
7N7E						
29.1d	Ashland Chem (7)	I	83	16	25	16
29.2d	Ashland Chem (1)	I	73	16	21	16
29.2d	Ashland Chem (2)	I	77	16	21	16
29.2d	Ashland Chem (3)	I	75	16		
29.2d	Ashland Chem (4)	I	73	16		
29.2d	Ashland Chem (5)	I	85			
29.2d	Ashland Chem (6)	I	89	16	25	16
8N8E						
7.5a	Peoria Water Works Co.(1)	P	165	27	72	27
7.5a	Griswald (2)	P	162	18	50	18
9.5c	Rozell Dairy	I	70	10	20	10
9.5c	Rozell Dairy	I	70	8	3	8
9.6a	L. Erie Mining Co.	I	61	10		
9.8a	Peoria Service Co.	I	93	10	8	10
9.8a	Peoria Service Co.	I	94	25	36	25
9.8a	Peoria Service Co.	I	94	12		
16	Pabst	I	47	8	8	8
16.7f	Pabst	I	47	10		
16.7f	Pabst	I	50	12	12	12
17.1e	Hiram Walker (1)	I	57	26	20	26
17.1f	Hiram Walker (2)	1	53	26	20	26
17.1f	Hiram Walker (8)	I	59			
17.1g	Hiram Walker (3)	I	56	26	20	26
17.2e	Hiram Walker (4)	I	54	26	20	26
17.2f	Hiram Walker (5)	I	67			
17.2g	Pabst	I	60	12	10	12
17.3d	Wilson Provision Co.	I	70	3		(5 wells)
17.3e	Hiram Walker (7)	I	69			
17.3e	Hiram Walker (9)	I	73			
17.4d	Union Stockyards	I	68	12	10	
17.5d	Peoria Service Co.	I	90	10		
17.5d	Peoria Service Co.	I	90	10		
17.7b	Peoria Water Works Co. (1)	P	119	17	44	17
17.7b	Dodge (2)	P	113	17	36	17
17.7b	Dodge (3)	P	124	17	40	17
17.7b	Dodge (4)	P	122	17		

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen Length (feet)	Screen Diameter (in)	
Peoria (Cont.)							
8N8E							
19.1g	Nat. Distiller's Products	I	60	14	20	14	3 wells
19.3d	Celetex (2)	I	103	25	35	25	
19.3d	Celetex (3)	I	105	25	39	25	
19.3d	Celetex (4)	I	119	26	20	26	
19.3e	Hiram Walker Plant #2 (1)	I	105	12	42	12	
19.4d	Hiram Walker Plant #2 (3)	I	69	20	40	12	
19.4d	Hiram Walker Plant #2 (4)	I	95	18	41	14	
19.5d	Peoria Creamery Co.	I	72	6	10	6	
19.5d	Peoria Creamery Co.	I	66	6	10		
20.7f	Peoria Sanitary Dist.	I	104	12	5		
31.7g	Keystone Steel & Wire (1)	I	178	12			
31.7g	Keystone Steel & Wire (2)	I	166	12			
9N8E							
15.1c	Peoria Heights (9)	P	103	16	20	16	
15.1d	Peoria Water Works (7)	P	92	60	24	84	
15.1d	Sankoty (8)	P	88	60	24	84	
15.1d	Sankoty (9)	P	95	25	26	25	
15.1e	Sankoty (10)	P	93	25	24	25	
15.2d	Peoria Heights (5)	P	135	18	20	18	
15.2d	Peoria Heights (6)	P	122	16	20	16	
15.2d	Peoria Heights (7)	P	129	16	20	16	
15.2d	Peoria Heights (8)	P	123	16	20	16	
15.2e	Peoria Water Works Co. (15)	P	124	20	29	20	
15.3e	Sankoty (12)	P	140	25	39	25	
15.3f	Sankoty (14)	P	130	10	30	10	
15.6g	Peoria Heights (10)	P	131	16	20	16	
26.3a	Peoria Water Works Co. (Main)	P	43	34'	5	24'	
26.3a	Peoria Water Works Co. (Reserve)	P	56	12'	22	12'	
35	Wabco	t	40	12	7	12	
35.4d	Bemis Bros. Bag Co.	I	65	25	31	25	
35.4d	Bemis Bros. Bag Co.	I	63	26	10	26	
10N8E							
10.4a	Caterpillar (8)	I	96	16	25	16	
14.8c	Caterpillar (BB6)	I	101	14	24	10	
15.4f	Caterpillar (7)	I	90	16	21	16	
15.4g	Caterpillar (5)	I	90	16	21	16	
15.4g	Caterpillar (6)	I	90	16	25	16	
15.4h	Caterpillar (4)	I	67	16	20	16	
23.7a	McDougal-Hartman Const.	I	61	6	11	6	
23.7a	McDougal-Hartman Const.	I	63	8	15	8	
23.7h	Caterpillar (2)	I	71	16	20	16	
23.7h	Caterpillar (3)	I	66	16	20	16	
23.8h	Caterpillar (1)	I	82	16	20	16	
11N9E							
9	Donald E. McMillin	A	39	18	20		
9	Donald E. McMillin	A	55	18			
20.4g	Chilicothe (6)	P	105	8	14	8	
20.5b	Chilicothe (3)	P	123	12	27	12	
20.5c	Chilicothe (2)	P	127	12	20	12	

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diatn-eter of well (in)	Screen	
					Length (feet)	Diam-eter (in)
Peoria (Cont.)						
11N9E						
20.7g	Chilicothe (7)	P	100	10	15	10
21.1f	Chilicothe (1)	P	80	12	17	12
21.8h	Chilicothe Sand & Gravel	I	92	10	15	
29.8e	Chilicothe (4)	P	143	4	5	4
29.8e	Chilicothe (5)	P	143	4	5	4
Pike						
3S2W						
1.2h	Brandt Chemical	I	60	8	12	8
7S2W						
15	Western Ill. Power Coop	I	85	8	25	8
Putnam						
32N2W						
4.1a	Hennepin Public Water Dist. (5)	P	135	18	25	18
4.1d	Jones & Laughlin Steel	I	131	8	20	8
4.3c	Jones & Laughlin Steel	I	80	8	20	8
9.2a	Hennepin Public Water Dist. (4)	P	107	8	10	8
9.3b	Hennepin Public Water Dist. (3)	P	100	8	10	8
10.7h	Jones & Laughlin Steel	I	141	6	10	6
26.5h	Illinois Power Co. (4)	I	114	18	30	18
Schuyler						
1N1W						
35	Robert Krouck (1)	A	54	18	28	18
36	Robert Krouck (2)	A	65	18		18
Scott						
15N13W						
16	Wabash Railroad (E)	I	64	12	10	8
16	Wabash Railroad (W)	I	64	12	10	8
16.2h	Bluffs (2)	P	57	8	12	8
16.2h	Bluffs (3)	P	59	12	15	12
Tazewell						
24N5W						
3.2h	Pekin (1)	P	91	25	54	25
3.2h	Pekin (3)	P	100	25	52	25
3.2h	Pekin (4)	P	119	25	56	25
3.3h	Pekin (2)	P	92	25		
3.5c	Pekin (7)	P	121	20	30	20
3.6d	CPC (9)	I	107	26	20	26
3.7b	CPC (2)	I	98	26	20	26
3.7c	CPC (3)	I	98	26	20	26
3.7c	CPC (5)	I	99	26	20	26

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen Length (feet)	Screen Diameter (in)
Tazewell (Cont.)						
24N5W						
3.8a	CPC (1)	I	97	26		26
3.8b	CPC (4)	I	91	26	20	26
3.8d	CPC (10)	I	113	26	20	26
4.1b	CPC (6)	I	92	26	20	26
4.1c	CPC (7)	I				
4.2b	American Distilling Co. (1)	I	104	26	17	26
4.2b	American Distilling Co. (7)	I	100	26	20	26
4.3a	American Distilling Co. (5)	I	86	26	20	26
4.3b	American Distilling Co. (2)	I	85	24	20	24
4.3b	American Distilling Co. (6)	I	93	26	20	26
8	Commonwealth Edison (12)	I	61	18	20	18
8	Commonwealth Edison (13)	I	59	22	16	22
8	Commonwealth Edison (14)	I	63	18	20	18
9.5a	Bird Provision Co.	I	75			
9.6a	Commonwealth Edison (8)	I	63	26		
9.7a	Commonwealth Edison (11)	I	72	26		
9.7c	Commonwealth Edison (1)	I	76	24		
9.8a	Commonwealth (9)	I	64	25		
9.8b	Commonwealth (6a)	I	58	25		
9.8b	Commonwealth Edison (7a)	I	67	25		
9.8b	Commonwealth Edison (10)	I	64	25		
9.8c	Commonwealth Edison (3a)	I	56	25		
9.8c	Commonwealth Edison (4a)	I	59	25		
9.8c	Commonwealth Edison (5a)	I	61	25		
10.7h	Quaker Oats (5)	I	90	18	20	18
10.8h	Quaker Oats (4)	I	79	17		
10.8h	Quaker Oats (4)	1	87	18	20	18
24N7W						
36.2a	John Vale	A	93	15	20	12
25N5W						
12.5d	Creve Coeur (1)	P	91	15	20	15
12.5d	Creve Coeur (3)	P	78	16	20	16
12.5d	Creve Coeur (4)	P	81	12	20	12
13.7g	North Pekin (1)	P	81	10	12	10
24.6h	North Pekin (2)	P	104	12	26	12
32.1f	Caterpillar (13)	I	55	12	15	12
32.2e	Caterpillar (14)	I	60	12	15	12
32.2g	Caterpillar (10)	I	69	12	15	12
32.3d	Caterpillar (15)	I	51	12	15	12
32.3f	Caterpillar (9)	I	66	12	15	12
32.3g	Caterpillar (7)	I	51	12	15	12
32.4h	Caterpillar (11)	I	54	12	15	12
32.4h	Caterpillar (12)	I	79	12	15	12
32.6g	Caterpillar (5)	I	62	12	15	12
32.7h	Caterpillar (6)	I	62	12	15	12
35.4d	Pekin (5)	P	146	26	48	26
35.4d	Pekin (6)	P	138	28	40	28
26N4W						
23.8b	East Peoria-Main (2)	P	100	12	23	12
23.8c	East Peoria-Main (1)	P	104	12	22	12

Table 1. (continued)

Well number	Owner	Use	Depth of well (feet)	Diameter of well (in)	Screen Length (feet)	Screen Diameter (in)
Tazewell (Cont.)						
26N4W						
29.3a	Altorfer Bros.	I	80	12	15	12
29.4f	Central Illinois Light Co.	I	56	20		
31	TP&W RR (4)	I	47	8		
32	R. Herschel Mfg. Co.	I	63	12	12	12
33.4e	East Peoria-Main (9)	P	44	12	17	12
34.2f	TP&W RR	I	42	8		
34.4e	East Peoria-Catherine	P	60	12	27	12
34.5e	East Peoria-Main (8)	P	66	16	18	14
34.6e	East Peoria-Allison (2)	P	46	10	20	10
34.7e	TP&W RR	I	49	8		
35.5b	East Peoria-Allison (1)	P	51	10	20	10
35.5b	East Peoria-Meadow (1)	P	113	12	30	12
35.5b	East Peoria-Meadow (2)	P	115	12	30	12
35.6d	Peoria Concrete Const.	I	82	12	19	

GROUNDWATER PUMPAGE

Groundwater pumpage from sand and gravel wells along the Illinois Waterway can be divided into three categories, municipal, industrial, and irrigation. Groundwater withdrawals from private wells for domestic pumpage is not considered. Table 2 summarizes the pumpage by category and county.

A total of about 39 mgd was pumped for municipal uses in 1977 with the major pumpage in the Peoria-Pekin area (Peoria and Tazewell Counties). Individual municipal pumpages are presented in Table 3.

Industrial pumpage totaled about 29.6 mgd in 1977 with the major pumpage again in the Peoria-Pekin area.

Irrigation pumpage in 1977 was estimated to be about 5.1 billion gallons. The number of acres irrigated and estimated pumpage for each county is presented in Table 4. Mason County accounts for about 80 percent of the total pumpage along the Waterway. It should be emphasized that the Mason County irrigation pumpage is for a 6 mile wide strip of land bordering the Illinois River. Total irrigation pumpage for the entire county would be much larger.

Due to the concentration of municipal and industrial pumpage in the Peoria-Pekin area it seems appropriate to look at this area in more detail. Previous studies by Marino and Schicht (1969) have presented historical pumpage data for this area. For comparison purposes the distribution of pumpage in the Peoria-Pekin area for the years 1944, 1966, and 1977 are presented in Figures 5 a, b, and c, respectively.

Pumpage has increased in 2 pumping centers, the Mossville area and the Peoria Lock and Dam area during the past 33 years. The increase in the Moss-

Table 2. Pumpage from Sand and Gravel Wells Along the Illinois Waterway During 1977.

County	Municipal Pumpage (mgd)	Industrial Pumpage (mgd)	Total Municipal & Industrial (mgd)	Total Annual Irrigation Pumpage (mil gal)
Bureau	-	1.000	1.000	-
Calhoun	0.275	-	0.275	-
Cass	1.100	1.130	2.230	147
Greene	0.042	-	0.042	226
Grundy	-	-	-	33
Jersey	0.680	-	0.680	-
. La Salle	3.200	-	3.200	-
Marshall	0.752	0.165	0.917	8
Mason	0.810	2.106	2.916	4470
Morgan	3.901	4.262	8.163	-
Peoria	19.781	8.818	28.599	-
Pike	-	0.059	0.059	-
Putnam	0.152	0.100	0.252	-
Schuyler	-	-	-	16
Scott	0.084	-	0.084	6
Tazewell	8.233	11.918	20.151	217
Totals	39.010	29.558	68.568	5,123

Table 3. Muncipal Pumpage from Sand and Gravel Wells Along the Illinois Waterway During 1977.

County	Municipality	Number of Wells		Pumpage (mgd)
Bureau	Spring Valley	2		standby
Calhoun	Batchtown	2		0.015
	Brussells	1		0.039
	Hardin	2		0.221
			Total	0.275
Cass	Beardstown	4		1.1
Greene	Eldred	2		0.025
	Hillview	1		0.017
			Total	0.042
Jersey	Grafton	2		0.080
	Jerseyville	2		0.600
			Total	0.680
La Salle	La Salle	5		3.200
Marshall	Henry	3		0.396
	Hopewell Estates	1		0.021
	Lacon	3		0.275
	Sparland	2		0.060
			Total	0.752
Mason	Havana	3		0.810
Morgan	Jacksonville	1		3.5
	Meredosia	3		0.129
	South Jacksonville	2		0.272
			Total	3.901
Peoria	Chilicothe	7		0.75
	Peoria Heights (Sankoty)	6		3.5
	Peoria Water Works Co.			15.531
	Sankoty	9		(5.650)
	North	2		(1.529)
	Central	6		(8.353)
			Total	19.781
Putnam	Hennepin	3		0.152
Scott	Bluffs	2		0.084
Tazewell	Creve Couer	3		0.850
	East Peoria	10		2.6
	Marquette Hgths. Water Company	3		0.297
	North Pekin	2		0.179
	Pekin	7		4.307
			Total	8.233

Table 4. Irrigation Pumpage from Sand and Gravel Wells Along the Illinois Waterway during 1977

County	Irrigated Acreage	Total Annual Irrigation Pumpage (mil gal)
Cass	900	147
Greene	1200	226
Grundy	200	33
Marshall	50	8
Mason	16900	4470
Schuyler	100	16
Scott	550	6
Tazewell	1000	217

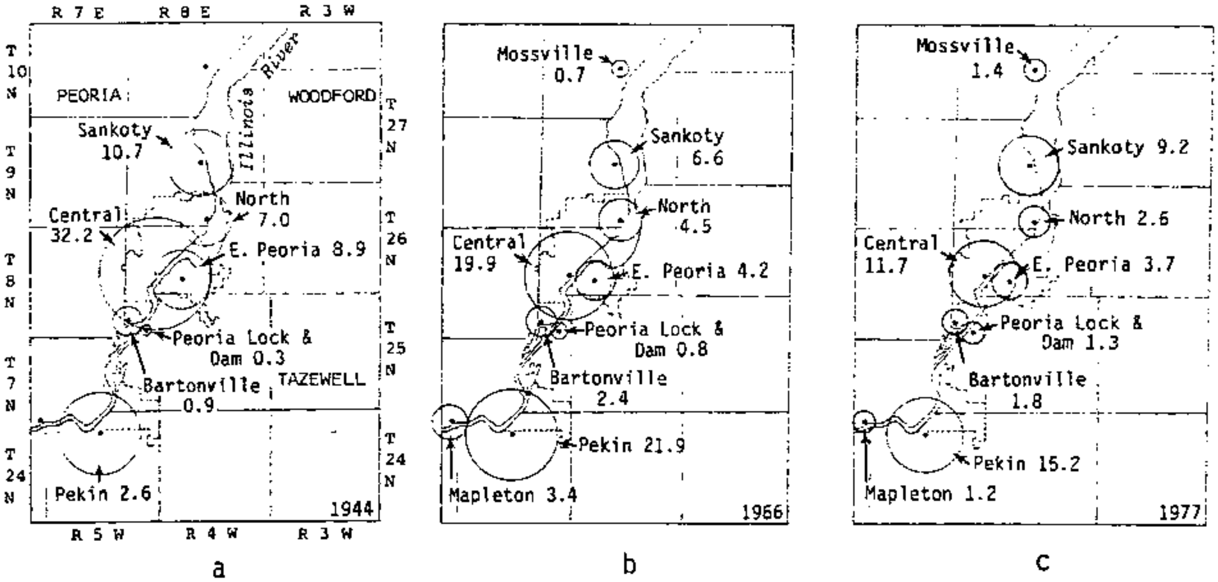


Figure 5. Distribution of estimated pumpage for the Peoria-Pekin area during a) 1944, b) 1966, and c) 1977.

ville area is due to increased industrial pumpage. The increased pumpage in the Peoria Lock and Dam area is due to increased pumpage by municipalities of Creve Coeur, Marquette Heights, and North Pekin.

Pumpage in 4 pumping centers, the North Well Field area, the Central Well Field area, the East Peoria area, and the Mapleton area has declined during the period of interest. The declines in all areas is partially the result of efforts by industry to conserve water. In the North and Central Well Field Areas reduced groundwater pumpage by the Peoria Water Works in response to increased use of river water also is a factor. In the Sankoty Well Field Area and the Pekin Area no definite trends are apparent.

WATER QUALITY

The chemical quality of water obtained from sand and gravel wells along the Illinois Waterway is extremely variable. Selected results of analyses of water from 35 municipal wells are presented in Table 5.

Available chemical and hydrological data suggests that the variation in chemical constituents in water from the Illinois Waterway valley deposits generally can be explained by the period of time the water has been in contact with soil particles from which mineral constituents are dissolved. Relatively low mineralized water, indicating a short period of residence, usually is found in areas of recharge and shallower deposits. More highly mineralized waters, suggesting longer periods of contact, generally are associated with discharge areas and deeper deposits.

Throughout the Waterway, the general areas of recharge are near the valley walls and the areas of discharge along the river. The relative positions of wells, their depth, and the hydraulic character of the aquifer all influence the chemical quality of water obtained. Wells in close proximity to the river also may induce infiltration of river water during pumping altering the quality of water pumped.

In general, water obtained from sand and gravel wells along the Waterway is more highly mineralized than Illinois River water. The range of hardness for the selected data is from 172 to 639 mg/1 and averages 419 mg/1. The range of total dissolved minerals is from 211 to 896 mg/1 and averages 545 mg/1.

Table 6 shows the ranges and median values of hardness and total dis-

Table 5. Selected water quality data from sand and gravel wells along the Illinois Waterway.

Well II	Owner	Depth (ft)	Lab.#'s	Iron Fe	Manganese Mn	Sodium Na	Calcium Ca	Magnesium Mg	Silica S10$_2$	Fluoride F	Nitrate NO$_3$	Chloride C1	Sulfate SO4	Alkalinity (as Ca CO3)	Hardness	Total Dissolved Minerals
Bureau																
15N 11E-2.7g	Spring Valley(8)	46	0164294	0.3	0.80	65.0	135.2	63.7	12.0	0.1	3.4	60.	344.	300.	600.	896.
Calhoun																
10S 2W-27.1e	Hardln(2)	64	B0024545	0.1	0.64	21.8	J02.0	45.2	21.6	0.3	8.4	32.	65.	344.	444.	524.
12S 2W-11.4c	Batchtown(2)	86	196976	3.8	0.27	7.3	97.6	36.6	26.0	0.2	1.3	7.	62.7	332.	394.	439.
13S 1W-7.4g	Brussels(1)	78	B111276	4.4	0.20	7.0	87.0	38.0	28.0	0.3	0.9	3.	21.	384.	373.	419.
Cass																
18N 12W-14.3a	Beardstown(14)	83	B049072	1.1	0.19	46.0	55.	19.0	15.0	0.2	1.7	72.	52.	172.	216.	367.
Greene																
ION 13W-28.7e	Eldred(1)	52	B101664	0.1	0.20	18.0	122.	37.0	23.0	0.1	24.0	23.	115.	346.	457.	571.
12N 13W-28.1b	Hlllview(1)	70	B102611	1.7	0.30	25.0	100.	48.0	18.0	0.2	0.4	26.	76.	380.	447.	524.
Jersey																
6N 12W-16.	Grafton(2)	56	A22509	1.1	0.27	80.0	103.	33.0	18.0	0.2	0.4	135.	76.	300.	395.	680.
7N 13W-5.7e	Jerseyville(2)	99	A21615	0.9	1.05	12.0	91.	39.0	23.0	0.2	0.4	16.	30.	370.	388.	460.
LaSalle																
33N 1E-14.7a	LaSalle(6)	60	B105348	0.2	0.37	41.0	164.0	56.0	18.0	0.3	0.9	53.	240.	440.	639.	859.
Marshall																
12N 9E-14.5f	Sparland(3)	34	B01733	0.0	0.00	24.0	120.0	59.0	11.0	0.3	9.2	27.	240.	287.	549.	698.
12N 9E-34.1a	Hopewell Est.(4)	40	B16596	0.1	0.01	11.0	120.0	50.0	13.4	0.1	2.2	6.	190.	310.	505.	615.
13N 10E-16.2c	Henry(4)	75	C000057	0.0	0.00	18.0	83.0	36.0	17.0	0.2	35.6	28.	58.	280.	355.	600.
30N 3W-26.1b	Lacon(3)	50	C006517	0.0	0.00	12.0	86.0	37.0	18.0	0.2	20.2	19.	51.	288.	367.	536.
Mason																
21N 9W-1.1f	Havana(5)	96	B47351	0.2	0.13	4.0	44.0	15.0	12.0	0.1	10.1	5.	35.	141.	172.	211.
Morgan																
15N 13W-22.5g	S. Jacksonville (#2)	76	A17401	0.8	0.22	7.5	64.0	26.0	15.0	0.2	23.8	8	50	208	270	350
15N 14W-12.4f	Jacksonville (Ranney)	30	A17169	3.0	0.35	21.0	78.0	26.0	16.0	0.2	4.0	30.	65.	240.	304.	400.
16N 13W-22.5g	Meredosia (04)	87	A18545	0.7	0.18	10.0	66.0	28.0	13.0	0.1	14.1	22.	50.	240.	299.	380.

Peoria																
8N 8E-7.5a	Peoria (Grlswold St. #2)	162	187419	0.2	---	21.2	126.4	46.7	---	0.9	---	22.	---	342.	508.	640.
-17.7b	Peoria (Dodge St. #4)	122	B107766	0.0	0.00	42.5	155.0	56.0	21.0	0.1	16.0	60.	215.	384.	---	752.
9N 8E-15.1d	Peoria (Sankoty #7)	92	B120110	1.8	0.50	20.0	79.0	40.0	22.0	0.2	0.4	17.	22.	367.	---	460.
-15.1d	Peoria (Sankoty #9)	95	B35999	1.4	0.49	19.0	88.0	43.0	19.0	0.3	0.4	20.	34.	380.	---	395.
-15.2d	Peoria Heights (//8)	123	B53840	0.1	0.47	40.0	92.0	47.0	20.0	0.5	1.3	28.	45.	416.	418.	520.
-15.3f	Peoria (Sankoty #14)	130	B107765	0.8	0.36	93.0	63.0	30.0	16.0	0.1	0.0	22.	18.	438.	---	484.
-15.6g	Peoria Heights (#10)	131	B33978	0.4	0.35	44.0	87.0	49.0	19.0	0.4	1.3	32.	40.	417.	421.	538.
-26.3a	Peoria (Main Well)	43	B107764	0.0	0.00	26.0	86.0	30.5	9.0	0.5	17.0	43.	105.	216.	---	484.
11N 9E-20.5c	Chilicothe (#2)	127	B45162	0.0	0.00	10.0	61.0	35.0	16.0	0.3	11.0	15.	60.	219.	294.	357.
Putnam																
32N 2W-4.1a	Hennepin (#5)	135	B16572	0.0	0.38	27.0	80.0	35.0	16.0	0.4	4.4	47.	49.	275.	354.	451.
Scott																
15N 13W-16.2h	Bluffs(#3)	59	A5626	1.6	0.20	19.0	112.5	52.5	15.0	0.2	0.4	10.	170.	J60.	500.	596.
Tazewell																
25N 5W-12.5d	Creve Coeur(#4)	81	B 03826	0.0	0.01	43.0	108.0	55.0	19.0	0.2	37.0	55.	129.	349.	504.	675.
-24.6h	N. Pekin(#2)	104	B 17007	0.0	0.01	10.0	100.0	45.0	17.0	0.2	34.0	17.	85.	300.	448.	509.
-35.4d	Pekin(#6)	138	B 46683	0.0	0.00	49.0	130.0	57.0	17.0	0.7	25.0	96.	170.	337.	538.	769.
26N 4W-23.8b	E. Peoria (N. #1)	104	B 39522	4.2	0.22	14.0	89.0	39.0	16.0	0.1	0.0	5.	8.	416.	383.	440.
-33.4e	E. Peoria (#9)	44	202911	0.1	0.00	---	---	---	---	0.2	62.0	112.	---	416.	610.	864.
-34.5e	E. Peoria(#B)	66	201800	0.4	0.14	---	---	---	---	0.1	15.4	52.	---	298.	424.	549.
-25.51.	E. Peoria (Allison St. #1)	51	B 39527	0.0	0.01	58.0	102.0	39.0	11.0	0.1	38.0	72.	98.	319.	428.	607.
	mean values	83		0.82	0.24	28.4	96.4	40.9	17.3	0.3	12.1	31.	93.	323.	419.	545.

solved minerals of Illinois River water for 2 sampling points and 3 periods of record. More detailed chemical data for the Illinois River is presented by Harmeson (1969, 1973). Data presented in those reports indicates an increase in the total dissolved solids during periods of low flow when most of the water is base flow. During higher flows a greater proportion of surface runoff causes the river to be less highly mineralized. The slight increase in mineralization with time shown in Table 6 is likely the result of man's activities and cannot be related to flow conditions.

Table 6. Illinois River Water Quality Summary.

	Hardness (mg/1)		Total dissolved minerals (mg/1)	
Peoria	Range	Mean	Range	Mean
1957 - 1960	139-332	265	218-477	380
1961 - 1965	202-400	260	269-569	410
1966 - 1971	136-400	282	306-603	419
Meredosia				
1955 - 1960	136-300	245	206-449	360
1961 - 1965	184-386	255	236-531	380
1966 - 1971	220-368	274	304-580	413

WATER LEVELS IN WELLS

Water level data for sand and gravel wells along the Illinois Waterway is limited to data for wells in the Peoria-Pekin area with the exception of a well near Beardstown in Cass County. Groundwater resources in the Peoria-Pekin area have been studied extensively by the Water Survey previously. Data presented in this section is primarily an update of State Water Survey Report on Investigation 61 (Marino and Schicht, 1969).

The Water Survey has maintained a program of water level observations in the Peoria-Pekin area for the last 30 years. Wells currently being observed are shown in figure 6 and described in Table 7. For the purposes of this report, data from the last 25 years of record (1953-1977) is used to establish long term trend information. Three water years, 1971, 1973, and 1977 were selected for presentation to compare with years of low, high, and average river stages, respectively.

Water levels in the Peoria-Pekin area generally recede in late spring, summer, and fall when evapotranspiration losses and pumpage from the groundwater reservoir are greater than recharge from precipitation and induced infiltration of water from the river. Discharge of groundwater to the river also occurs during this period in areas remote from pumping centers when groundwater levels are above river stages. Water levels generally begin to recover in the early winter months when conditions are favorable for groundwater recharge. The recovery of water levels is most pronounced during the spring months. Maximum and minimum annual water levels are recorded at different times from year to year. However, the highest water levels frequently are recorded in May and the lowest in December, depending on

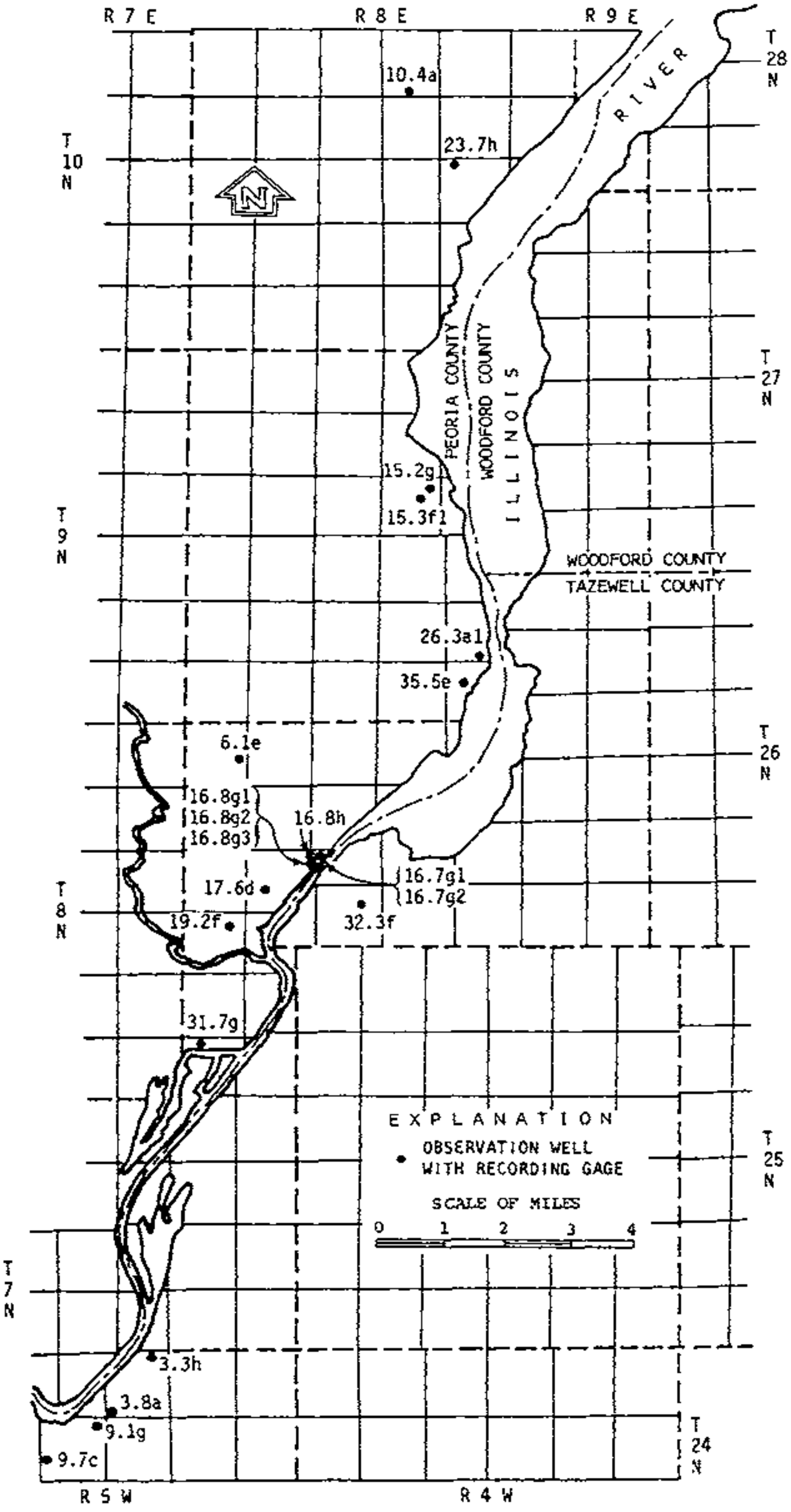


Figure 6. Location of observation wells in the Peoria-Pekin area.

Table 7. Observation Wells Along the Illinois Waterway.

Location	Owner	Use*	Well		Screen		Yr. of
			Depth (ft)	Diameter (in)	Length (ft)	Diameter (in)	Record
Peoria							
8N8E							
6.1e	State Water Survey (8)	N	162	6	9	6	1942-Present
16.7gl	State Water Survey (22)	N	46	6	5	6	1955-Present
16.7g2	State Water Survey (27)	N	53	12	10	12	1963-Present
16.8gl	Hiram Walker (TH19)	N	53	6	7	6	1952-Present
16.8g2	State Water Survey (20)	N	66	6	5	6	1951-Present
16.8g3	Pabst	N	49	16	8		1941-76
16.8h	State Water Survey (24)	N	71	6	5	6	1953-Present
17.6d	Hiram Walker Cooperage	I	85	6	6	6	1958-72
19.2f	Commercial Solvents (6)	N	79	26	21	26	1936-68
31.7g	Keystone Steel & Wire (W)	N	166	12	18	12	1944-Present
9N8E							
15.2g	Peoria Water Works Co. (7)	P	92				1941-Present
15.3fl	Peoria Water Works Co. (13)	N	116	6			1941-Present
26.3a	Peoria Water Works Co. (3)	P	60		22		1945-Present
35.5e	Bemis Co. (2)	I	62	26	10	26	1941-Present
10N8E							
10.4a	Caterpillar Tech. Center(20)	N	99	6	3	6	1963-Present
23.7h	Caterpillar Engine Plant(13)	N		6		6	1963-Present
Tazewell							
24N5W							
3.3h	Pekin Water Works (1)	P	90	32	53	37	1933-Present
3.8a	CPC International		80	6			1941-Present
9.1g	Standard Banks (2)		76	25			1941-71
9.7c	Commonwealth Edison (3)	N					1942-Present
26N4W							
32.f	Caterpillar (4)	N	63	12	15	12	1941-Present
Mason							
19N10W							
11.8b	Harold 3anks	N	42				1958-Present
Cass							
18N12W							
15.4g	U.S. Army Corps of Eng.	N	74				1957-68

*N - not used
I - industrial
p - public supply

climatic conditions, groundwater withdrawals, and river stage.

Water levels in well PEO 8N8E-6.1e illustrate the trend in water levels in the Peoria area from 1952 through 1977 (see figure 7) in areas remote from pumping centers and the effects of the Illinois River. The hydrograph of water levels in the well and graph of annual precipitation at Peoria illustrate the effects of below normal precipitation on water levels. Water levels were lowest during 1956 and 1957 as a result of three years of below normal precipitation (1953, 1955, and 1956). Prior to groundwater development in the Peoria-Pekin area, water levels in the sand and gravel deposits at most places along the river were at a higher elevation than the surface elevation of the Illinois River during low river stages. Water levels in well CSS 18N12W-15.4g, located only a few hundred feet from the Illinois River, in Beardstown (Cass County) about 75 miles southwest of Peoria, and corresponding Illinois River stages at Beardstown (figure 8) illustrate the effects of river stage on groundwater levels. During periods when the stage of the Illinois River was low, water levels in the well were from less than a foot to one foot higher than the river. During periods when the stage of the river rose above the water level in the well, water levels in the well rose correspondingly, reaching a peak a few days after the peak river stage. As the stage of the river declined, water levels in the well also declined but at a lesser rate.

Pumpage of groundwater has lowered water levels considerably along, the reach of the Illinois River from the Sankoty Well Field area to Pekin. As a result, groundwater levels along much of this reach are lower than the surface of the Illinois River. Water levels in the wells in the Sankoty, North, Cen-

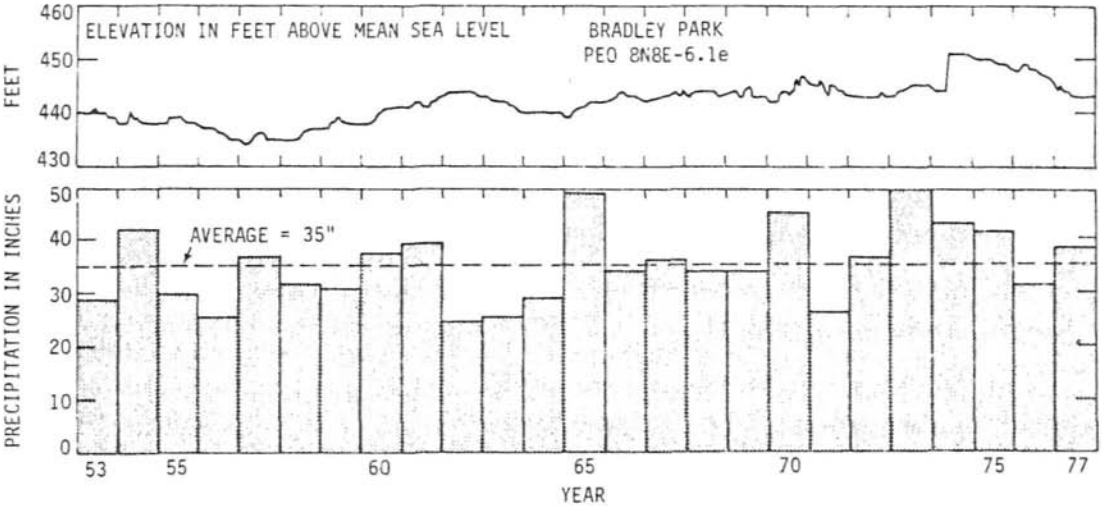


Figure 7. Water levels in well and annual precipitation at Peoria, 1953-1977.

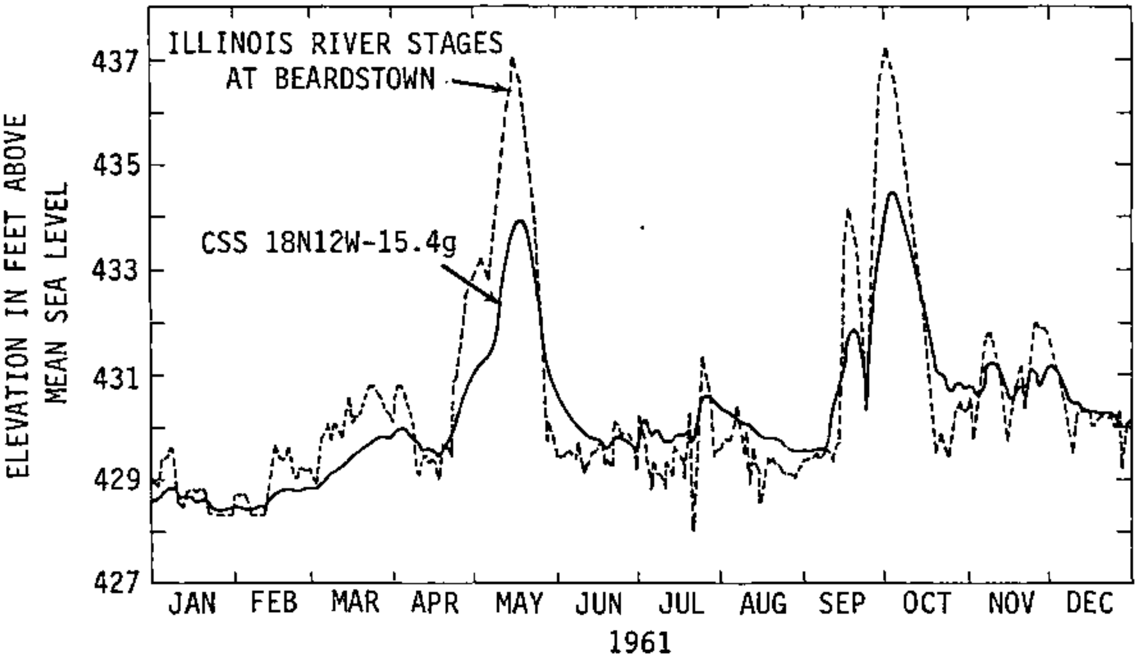


Figure 8. Water levels in well and Illinois River stages at Beardstown, 1961.

tral, East Peoria, and Pekin Well Field areas and corresponding Illinois River Stages for the water years 1971, 1973, and 1977 are shown in figures 9 thru 13. In all cases, except the Pekin Well Field (see figure 13), water levels in the wells were below river stages. The differences between water levels in wells and the river are functions of river stage, well field pumpage, and aquifer and river bed properties. In 1973 and 1977 (high and average years of river stage) the water levels in the Pekin Well Field wells were above river levels during the recession portions of the river hydrographs (see figure 13).

Twenty-five year hydrographs for wells in the six major well fields are shown in figure 14. These hydrographs show the long term effects of precipitation, pumpage, and river stages on the groundwater system.

The Sankoty Field hydrograph shows a period of slow recovery from 1953 to 1959 with the water level rising from an elevation of 410 feet above mean sea level (msl) to 416 feet as the groundwater withdrawals in the area were reduced. Recovery increased through 1961 with water levels rising to 427 feet due to more favorable groundwater recharge conditions. From 1962 to 1968 the water level dropped to 410 feet due to less favorable recharge conditions and increasing pumpage. The levels remained steady through 1974 as groundwater recharge balanced increasing withdrawals then dropped again to 400 feet from 1975 to 1977 due to less favorable recharge conditions.

Water levels in the North field show a slight increase during the period 1953 to 1958 from 418 feet to 425 feet then remained steady from 1958 to 1977 as artificial recharge was used to supplement recharge from precipitation and the river.

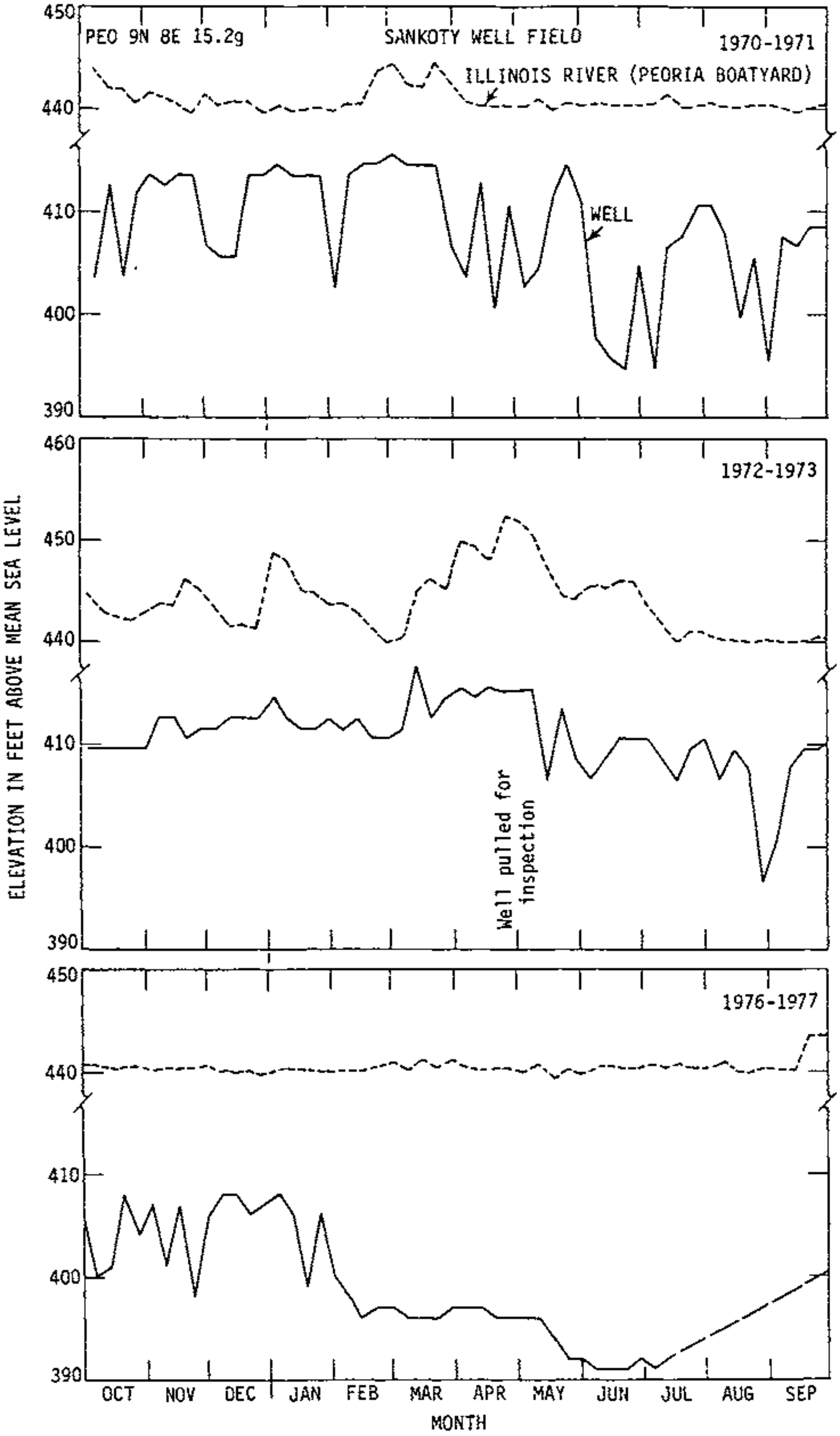


Figure 9. Water levels in well and Illinois River stages, Peoria Sankoty well field for water years 1971, 1973, and 1977.

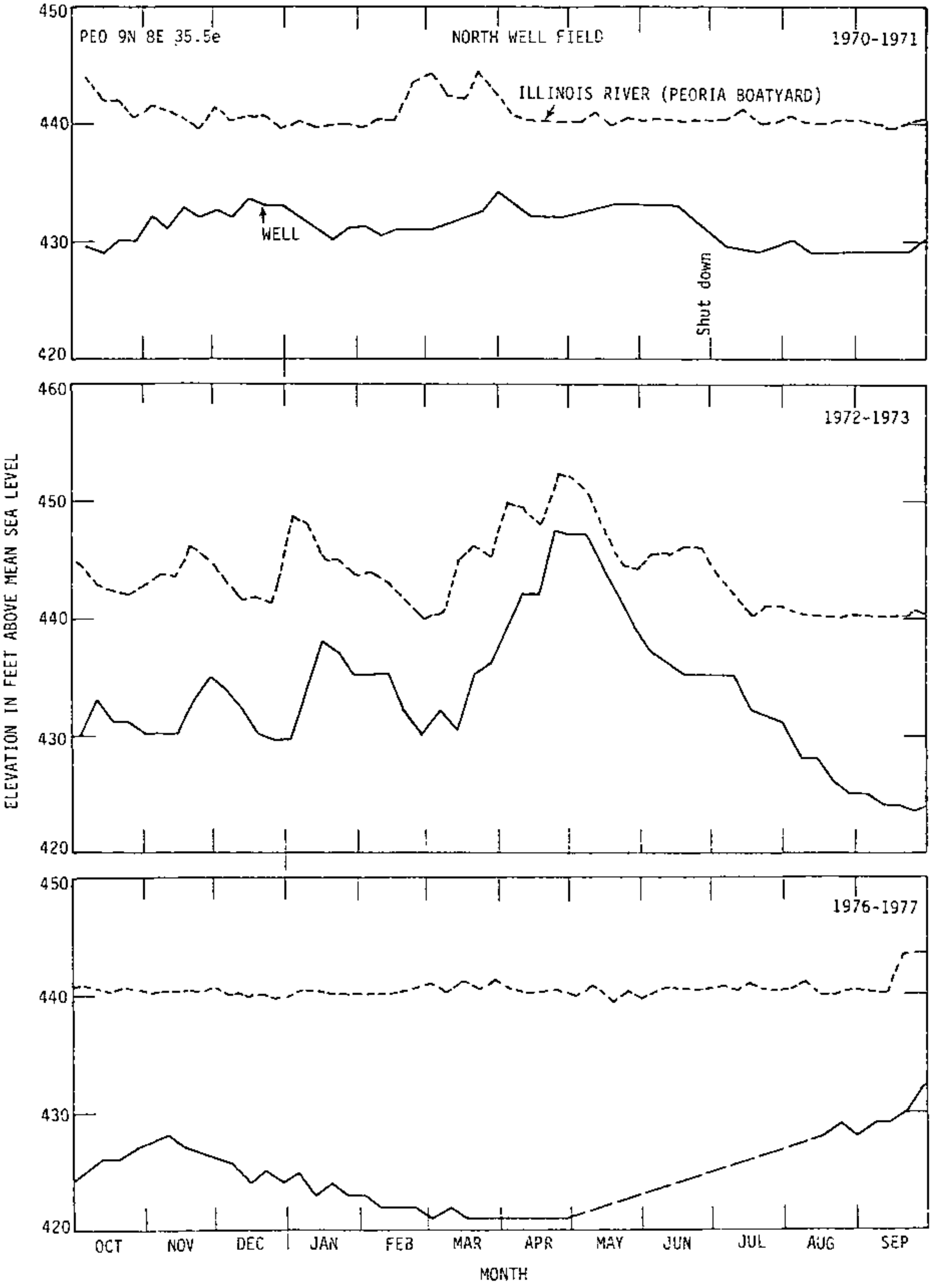


Figure 10. Water levels in well and Illinois River stages, Peoria North well field for water years 1971, 1973, and 1977.

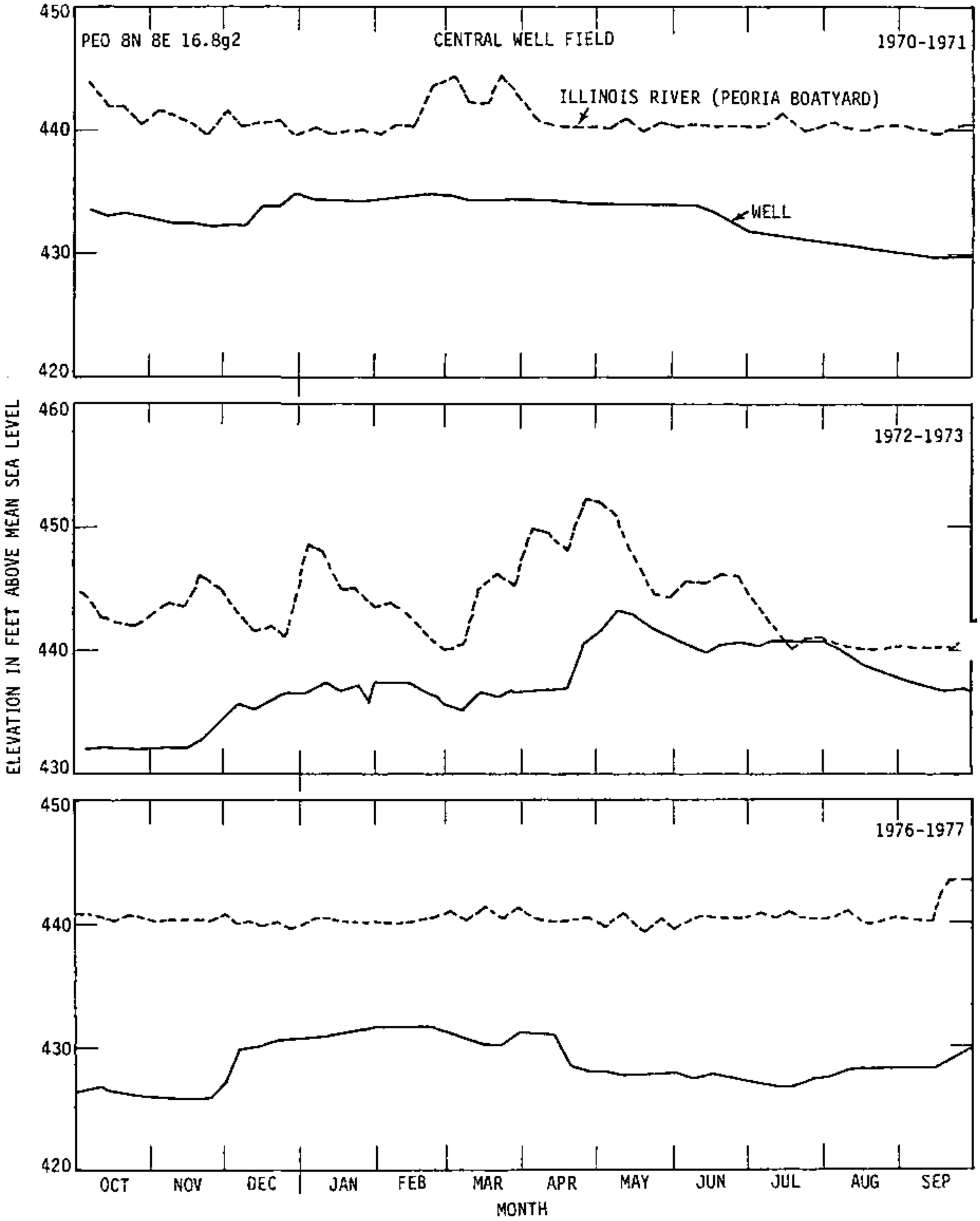


Figure 11. Water levels in well and Illinois River stages, Peoria Central well field for water years 1971, 1973, and 1977.

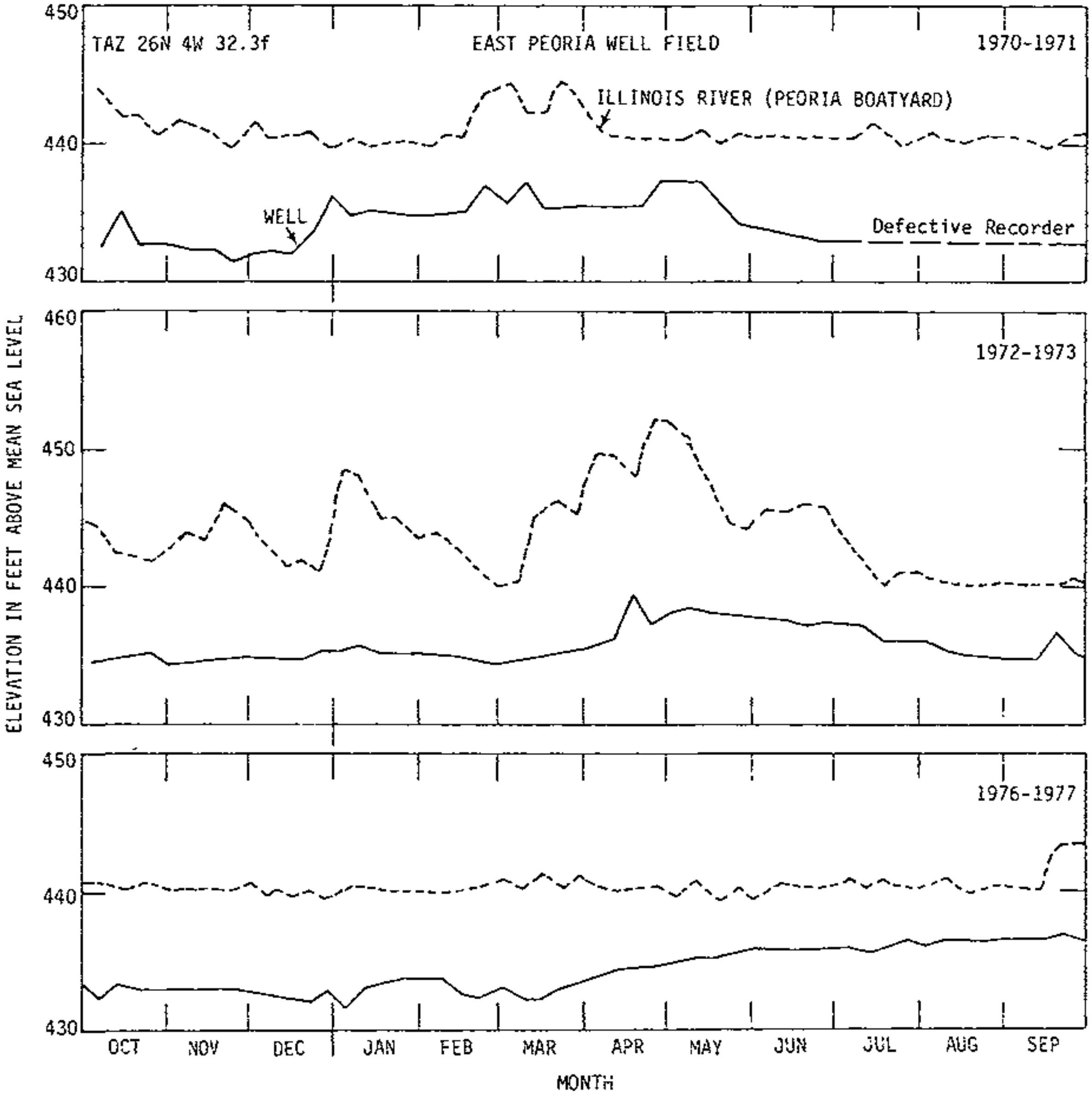


Figure 12. Water levels in well and Illinois River stages, East Peoria well field for water years 1971, 1973, and 1977.

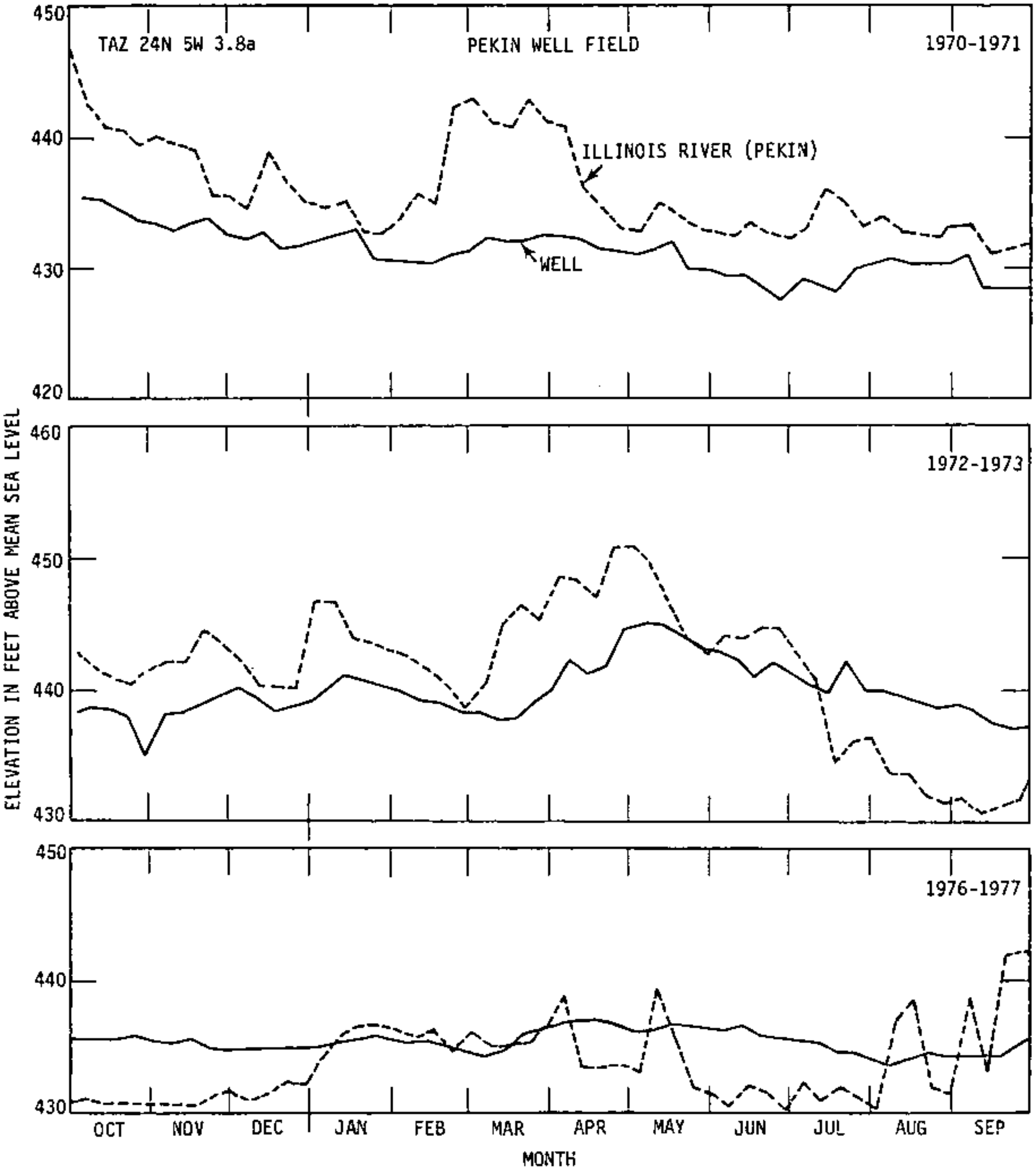


Figure 13. Water levels in well and Illinois River stages, Pekin well field for water years 1971, 1973, and 1977.

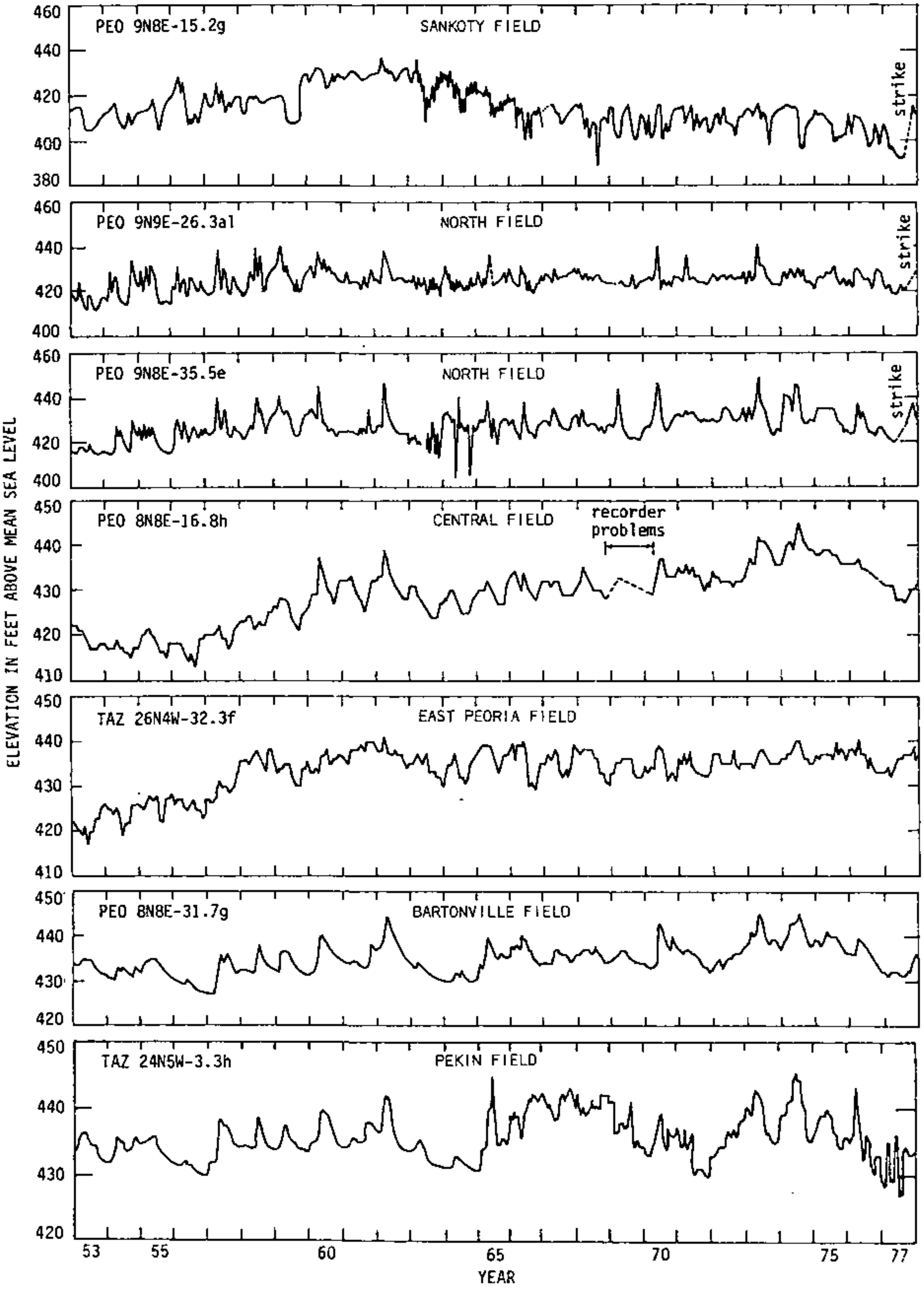


Figure 14. Long term water levels of wells in the Peoria-Pekin area.

The hydrograph for a well in the Central field shows water levels declining to an extreme low of 413 feet from 1953 to 1956 when recharge was low and withdrawals were increasing. From 1957 to 1961 the water level rose to 432 feet due to more normal recharge and reduced withdrawals. During the years 1962 to 1964 recharge was again lower than normal resulting in a decline in water levels. From 1965 to 1972 water levels remained steady at about 432 feet. In the years 1973 to 1975, due to favorable recharge conditions, water levels recovered to 430 feet in 1976.

Water levels in the East Peoria region were near 423 feet from 1953 to 1956 as below normal recharge resulted in low water levels despite decreasing pumpage. In 1957 and 1958 recharge conditions improved sufficiently to raise the levels to about 435 feet. From 1959 to 1977, water levels remained steady at about 435 feet as recharge balanced pumpage.

Water levels in the Bartonville area fell to 430 feet during periods of below normal recharge from 1953 to 1956 and from 1962 to 1964. High water levels of about 440 feet were experienced from 1973 to 1975 during years of above average recharge and otherwise remained steady at about 435 feet.

The water levels in the observation well shown for the Pekin area are influenced most heavily by the pumping rates in the North Pekin Well Field. This rate has increased steadily from 2.0 MGD in 1953 to 4.6 MGD in 1977. The effects of this increased pumping rate can be seen in the declining water levels from 1968 through 1970 and from 1974 through 1977 despite normal to above normal recharge.

HYDRAULIC PROPERTIES OF AQUIFERS

The yields of wells, quantity of water moving through an aquifer, and the magnitude of water-level fluctuations due to recharge and discharge of groundwater are largely dependent on the hydraulic properties of an aquifer. The principal hydraulic properties of an aquifer are its transmissivity, T, and hydraulic conductivity, P. Transmissivity is defined as the rate of flow of water in gallons per day through a vertical strip of the aquifer one foot wide and extending the full saturated thickness under a hydraulic gradient of 100 percent (one foot per foot). Hydraulic conductivity is defined as the rate of flow of water in gallons per day through a one-foot square cross-sectional area of the aquifer under a hydraulic gradient of 100 percent. The hydraulic properties of an aquifer may be determined by means of aquifer and well production tests. Table 8 presents results of aquifer and well production tests from the Water Survey files for wells located in the valley portion of the Illinois Waterway. Figure 15 presents selected results of hydraulic conductivities along the Waterway.

Based on the test results shown in Table 8, it is obvious that large variations in aquifer properties can be measured in wells located in the same general area. These variations may be due to actual changes in aquifer properties or the analysis of test data effected by improperly constructed and developed wells. The selected data shown in Figure 15 is intended to illustrate the relative yield capabilities of the sand and gravel aquifers associated with the Illinois River bottomlands. From De Pue (mile 213) south to Grafton, the hydraulic conductives generally range from 1,000 to

Table 8. Results of Aquifer and Well Productions Tests

Well Number	Owner	Depth of Well (ft)	Hon-Pumping Level (ft below land sfc.)	Pumping Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Transmissivity (gpd/ft)	Hydraulic Conductivity$_2$ (gpd/ft)	Land Surface Elevation (ft above msl)
Bureau								
T15N, R9E								
11.3f (1)	Lake Aspic Subd.	61	4.83	396	11	25,000	1,250	460
T15N, R11E								
2.7f1 (6)	Spring Valley (C)	35	5.70	135	13.62	155,000	19,400	460
2.7f2 (7)	Spring Valley (C)	30	4.4	165	21.7	90,000	11,200	460
2.7g	Spring Valley (C)	50	1	500	23.8	50,000	1,430	460
2.7g1 (5)	Spring Valley (C)	31	7	325	108.3	220,000	30,400	600
2.7g2 (8)	Spring Valley (C)	46	17.5	650	43.3	55,000	1,830	460
T16N, R11E								
34.7f1 (3)	Spring Valley (C)	33	23	50	33.3	44,000	4,400	600
34.7f2 (4)	Spring Valley (C)	39	29.5	29	19.3	37,000	6,170	600
Calhoun								
T9S R2W								
11.6d (1)	Kanpsville (V)	60	18.8	100	6.13	17.000	1,130	428
35.5h (1)	U.S. Corps of Engineers	67	11.54	20	42.6	95,000	4.750	425
T10S, R2W								
27.1e1 (1)	Hardin (V)	70	24.0	205	51.25	104,000	6,950	441
27.1e2 (2)	Hardin (V)	63	21.22	150	113.7	160,000	6,400	449
T13S, R1W								
7.4g	Brussels (V)	78	24.5	150	66.4	224,000	7,480	440
Cass								
T17N, R12W								
33.8a	Burris Bros. Seed Farm	90	13.75	320	36.4	220,000	2,820	460
T18N, R12W								
10.2a (K4)	Beardstovn (C)	67	10	750	78.3	110,000	2,320	440
14.1a (14)	3eardstown (C)	83	0.92	900	57.0	243,000	3,320	450
14.1a (16)	Beardstovn (C)	81.5	3.55	900	61.0	273,000	3,500	450
14.2a (15)	Beardstovn (C)	80	1.69	900	51.7	273,000	4,140	450
14.3a (TW)	Beardstovn (C)	86	8.92	821	76.9	134,000	1,820	450
14.7c (K1)	Beardstovn (C)	84	21.0	780	29.6	36,500	1,000	442
14.8d	Beardstovn (C)	87	20.0	725	41.4	88,000	1,780	442
14.8f1	Beardstovn (C)	89	17.95	690	122.0	281,000	3,960	442
14.8f2 (5)	Beardstovn (C)	92	17.30	980	55.1	253,000	3,290	440
14.8h (V2)	Beardstovn (C)	89	19.0	1000	60.6	97,000	4,850	440
15.2e1 (V1)	Beardstovn (C)	86	16	800	154	225,000	3,220	442
15.2e2 (K2)	Beardstovn (C)	78	9.30	1550	110.5	280,000	5,120	442
24.7b (1)	Oscar Meyer	105	15.5	210	32.3	105,000	1,270	460
24.7h (IWS-67)	Beardstovn (C)	92	12.45	710	71.7	600,000	7,060	445
T19N, R9W								
31.5a (2)	Chandlerville (V)	37	13.13	156	15.8	20,600	900	460
31.7b (T3)	Chandlerville (V)	34	9.75	53	12.0	20,000	800	460
31.7b2 (1)	Chandlerville (V)	32	11.5	154	19.5	27,000	1,080	460

(C) City well
(V) Village well

Table 8 (Continued)

Well Number	Owner	Depth of Well (ft)	Non-Pumping Level (ft below land sfc.)	Pumping Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Transmissivity (gpd/ft)	Hydraulic Conductivlty (gpd/ft^2)	Land Surface Elevation (ft above msl)
Greene								
T12N, R13W								
28.1b	(l)iHillview (V)	70	10.66	60	1.53	1,790	138	440
Jersey								
T6N, R13W								
9.4a	(2) Pere Marquette State Park	75	8	20	6.67	50,000	2,940	520
T7N, R13W								
5.3e	(W) Jerseyville (C)	99	8.3	753	144.8	330,000	3,890	425
5.7el	(T1-61) Jerseyville (C)	79	12.25	320	26.3	165,000	1,830	420
5.7e2	(E) Jerseyville (C)	96	10.35	750	90.9	220,000	2,590	420
LaSalle								
T33N, R1E								
14.7a	(T2) LaSalle (C)	50	14.5	100	11.1	16,500	472	460
14.7b	(T1) LaSalle (C)	50	12.75	102	13.6	16,700	477	460
Marshall								
T12N, R9E								
14.5f	(1) Sparland (V)	26	7.3	170	26.2	31,400	1,650	460
T13N, R10E								
3.4a	(7) B.F. Goodrich Co.	106	61	748	55.4	190,000	4,090	500
3.4b	B.F. Goodrich Co.	105	50	50	12.5	26,500	480	490
10.5d	(1) Grace Chemical Co.	78	45	222	15.8	21,000	640	487
16.2c	(2) Henry (C)	62	18	550	22.9	41,500	940	480
T30N, R3W								
26.1bl	(2) Lacon (C)	50	20	350	20.6	35,700	1,190	465
26.1b2	(3) Lacon (C)	50	19	350	26.9	40,200	1,300	465
Mason								
T19N, R9W								
7.3d	(1) Morris 3ell	86	6.5	600	92	195,000	2,440	472
8.2e	(1) Nelda Greb	86	14	200	96	200,000	2,360	478
T19N, R10W								
13.7c	(1) Laura Lane	84	11	300	144	400,000	4,000	467
23.2b	(1) Alice Daniel	73	16.5	1500	97	165,000	2,900	462
T19N, R11W								
14.2a	(1) Marty Marion	87	13	300	200	360,000	4,870	460
24.1b	(1) W.C. Barchausen	85	7	1000	109	230,000	2,950	435
24.8h	Albert Magnus	65	4	550	26.2	120,000	1,970	465
T20N, R8W								
2.3h	Ted Krause	60	4.5	60	35.3	170,000	3,150	498
3.4a	(3) Paul Friend	115	10.67	300	181	720,000	4,230	498
4.2h	(1) Ron Friend	74	7.33	200	59	610,000	3,700	501
11.8d	(1) Floyd Koke	96	15.25	500	222	900,000	5,300	500
21.2g	(4) Paul Friend	106	13	200	171	560,000	4,000	498
26.1b	(1) C.H. Venetten	104	13	300	138	430,000	3,070	498

Table 8 (Continued)

Hell Number		Owner	Depth of Well (ft)	Non-Pump-ing Level (ft below land sfc.)	Pump-ing Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Trans-missivity (gpd/ft)	Hydraulic Conduc-tlvlty (gpd/ft^2)	Land Surface Elevation (ft above msl)
Mason (Cont.)									
T20N, R9W									
3.2g	(1)	R. Vanderveen	101	8.67	500	177	570,000	4,380	478
17.6a	(1)	H. Lascelles	100	13	300	256	776,000	7,700	470
28.6b	(2)	Willard Brown	97	12.67	400	253	768,000	7,680	484
28.7g	(1)	Willard Brown	110	13	300	150	470,000	3,620	482
30.3b		Homer Lascelles	104	12	750	102.7	500,000	5,450	472
31.2g	(2)	H. Lascelles	87	17.5	300	200	650,000	5,410	480
T20N, R10W									
34.	(1)	Snlcarte Gun Club	45	8	300	200	800,000	6,670	445
T21N, R6W									
4.3g	(2)	Louis C. Pfelffer	102	14	700	58.3	340,000	2,120	520
T21N, R7W									
4.5b	(1)	W. Moldenhauer	80	5	400	267	1,100,000	6,470	497
5.7b	(1)	Ray Carpenter	113	16	1480	120.0	460,000	2,790	495
5.7f	(2)	Ray Carpenter	128	16	1480	120.0	550,000	3,240	502
7.6a	(1)	Kenneth Krause	47	18	100	40.0	660,000	4,120	502
15.2b	(1)	Clarence Pfelffer	108	8	300	95	300,000	2,000	497
15.7e	(2)	Burnett Stienhauer	112	6.7	650	175.7	620,000	4,130	500
17.3e	(1)	v. Williams	107	8	300	256	860,000	5,200	504
22.2g	(3)	Louis Pfelffer	112	10.33	600	106	320,000	2,130	500
25.6a		Easton Fire Dept.	150	13.48	60		275,000	2,200	510
25.7al	(1)	Easton (V)	135	15.5	60	30.45	310,000	2,500	510
25.7a2	(2)	Easton (V)	138	13.16	150	38.4	237,000	2,060	510
30.3f		F. C. Ringhouse	105	10	110	31.4	130,000	1,300	498
T21N, R8W									
1.2f		H. Esselman	96	12.5	300	240	1,000,000	6,670	495
1.8c		Fred Kruse	114	10	1310	65.5	150,000	1,360	495
1.8f		R. Henniger	86	16	1580	176	560,000	3,370	494
2.2b	(1)	Trevor Jones	96	11	300	300	1,200,000	8,000	498
2.3g	(2)	Delbert Hackman	85	18	200	200	800,000	5,330	492
2.4c	(1)	Harry Specketer	105	13	500	426	1,700,000	11,300	496
2.8g	(3)	Delbert Hackman	114	13.67	300	362	1,400,000	9,330	494
3.2f	(1)	Delbert Hackman	98	12.58	250	176	560,000	4,310	493
4.1c	(1)	Rudy Schilling	85	18	150	120	370,000	3,360	490
5.6g	(1)	Havana Natl. Bank	83	11	1000	71.5	150,000	1,670	472
7.4e		National Standard Co.	98	12	851	85.1	340,000	3,780	470
11.2a	(1)	Alvin Hackman	88	13	300	240	1,000,000	6,250	502
11.2f	(1)	David Larson	96	14.17	500	214	840,000	5,250	495
12.2c	(1)	Douglas Budke	100	8	500	115	440,000	2,750	497
15.4b	(1)	John Roat	105	12	300	278	1,100,000	7,340	501
15.8f	(1)	carl Steging	86	11	400	160	470,000	2,940	500
15.8h	(1)	Charles Roat	99	9	750	111	420,000	2,620	500
16.1b	(1)	Mervin Roat	108	7	850	66.4	450.000	4,160	490
21.2f	(3)	Julius Stelter	103	5	300	300	1,250,000	7,580	490
21.4c	(2)	Marvin Roat	105	4.7	400	400	930,000	9,020	487
21.4e	(3)	Louis Stelter	99	3.75	600	58.57	260,000	1.580	487
23.8g	(1)	W. Hohn	115	8	250	214	850,000	5,000	499

Table 8 (Continued)

Well Number		Owner	Depth of Well (ft)	Non-Pumping Level (ft below land sfc.)	Pumping Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Transmissivity (gpd/ft)	Hydraulic Conductivity (gpd/ft^2)	Land Surface Elevation (ft above msl)
Mason T21N, R8W (Cont.)									
25.2f	(1)	George Glick	104	6	500	143	560,000	3,290	502
25.6f	(1)	John Knupple	105	5	300	164	640,000	3,770	498
28.1g	(2)	Julius Stelter	122	13	1000	232.6	820,000	5,000	495
33.7h	(1)	Paul Friend	115	7	300	200	800,000	4,700	490
36.3c	(2)	Jesse Johnson	100	5.8	1000	98.0	335,000	3,420	497
36.7b	(1)	Jesse Johnson	106	6	1150	115.0	515,000	3,030	498
T21N, R9W									
1.1f1	(2)	Havana (C)	85	22	950	135.7	530,000	6,400	490
1.1f2	(4)	Havana (C)	78	24	1000	38.5	124,000	1,590	431
1.2f	(3)	Havana (C)	125		635	29.5	100,000	1,330	432
11.2cl	(2)	Ill. Power Co.	83	17.6	410	41.0	260,000	3,140	441
11.2c2	(2)	Ill. Power Co.	83	17.6	410	41.0	150,000	1,670	465
11.2c3	(4)	Ill. Power Co.	83	30	500	50.0	239,000	2,880	455
11.2c4	(4)	Ill. Power Co.	8z	30	500	50.0	220,000	2.440	465
13.6d	(2)	Gerald Bonnett	91	11	300	200	520,000	5,200	468
14.2d	(3)	Gerald Bonnett	74	12	200	171	380,000	4,230	468
24.2g	(1)	Gerald Bonnett	93	16.83	300	211	620,000	4,770	480
24.4g	(1)	Raymond Masten	87	6.17	400	185	580,000	4,450	472
T22N, R6W									
2.6c	(1)	Earl Graff	105	27	1200	75.0	160,000	1,690	515
18.2b	(2)	Norman White	81	13	300	200.0	650,000	5,410	498
21.4c	(1)	Norman White	110	8	300	150	470,000	3,920	502
28.2b	(1)	John Dozier	112	13	800	252	800,000	5,330	505
32.1f	(1)	Henry Alberts	129	15.75	300	211.0	650,000	5.750	504
33.7b		Earl Pfeiffer	105	8	750	119.0	870,000	5,270	503
T22N, R7W									
11.3a	(1)	Otto Dierker	95	13.75	300	240	760.000	4,750	500
11.6c	(1)	Clarence Foster	67	14	250	158	490,000	4,080	497
17.4f	(1)	Paul Behrends	96	12	300	150	460,000	3,540	498
17.5c	(1)	Raymond Messman	98	27.67	1660	179	560,000	4,300	490
18.6f	(1)	Russell Friedrich	94	17	300	278	880,000	7,330	498
23.2d		Theodore Kramer	80	13	1735	144.6	560,000	4,000	495
24.5g	(2)	Alvin Pfeiffer	113	11.2	600	157.9	640,000	5,660	495
24.7b	(1)	Alvin Busch	105	7	600	115.4	470,000	4,480	495
24.7h	(2)	Mable Kramer	95	5.1	1200	99.2	315,000	3,320	495
24.8f	(1)	Ralph Kramer	120	18	300	278	880,000	5,870	495
25.1f	(1)	Paul Knupple	85	6	300	200	620,000	4,140	501
27.2c	(2)	Glenn Sturbe	125	14.6	1200	98.4	720,000	4,200	485
31.6d	(1)	Bernice McNutt .	87	24	300	256	810,000	5,400	497
32.4d	(1)	John Cunningham	96	18.67	300	181	583,000	3,640	497
33.2b	(1)	Ralph Heinhorst	102	33.33	400	200	630,000	3,710	498
33.8h		State Tree Nursery	136	28	210	9.1	155,000	1,000	492
34.2bl		t. McClure	102	7.17	725	94.6	290,000	1,760	498

Table 8 (Continued)

Well Number	Owner	Depth of Well (ft)	Non-Pumping Level (ft below land sfc.)	Pumping Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Transmissivity (gpd/ft)	Hydraulic Conductivity (gpd/ft^2)	Land Surface Elevation (ft above msl)
Mason T22N, R7W (Cont.)								
34.6c (1)	Glenn Strube	127	13	1225	94.2	400,000	2,350	498
34.7e (1)	Howard Ermeling	82	5	600	116	350,000	2,060	495
35. (3)	Glenn Strube	104	11	300	180	580,000	3,620	490
T22N, R8W								
9.2A	Wildfowl Refuge	70	6	50	7.1	86,000	1,230	460
18.6d (1)	Eugene Ringhouse	101	28	1300	130	270,000	3,700	450
23.3d (1)	Doyle Walker	103	29.17	300	164	355,000	3,550	485
24.3c (1)	Ringhouse Brothers	102	23	400	200	510,000	4,630	488
25.2b (2)	Herman Easelman	96	23	300	300	1,000,000	7,700	470
27.7f (1)	C. D. Walker	88	13.08	300	240	630,000	6,300	475
28.2f (1)	R. E. Niederer	87	12.17	500	201	470,000	5,230	465
28.6c (1)	Raymond Markert	92	19	150	128	270,000	3,000	473
33.3e (1)	Delbert Bonnett	85	40	200	133	290,000	3,220	490
33.4d (2)	Delbert Bonnett	104	22	200	133	290,000	3,000	473
T23N, R6W								
21.3d1 (1)	Manito (V)	81	33	120	60.0	800,000	8,900	507
21.3d2 (2)	Manito (V)	93	37	152	30.4	650,000	7,220	501
21.4b (3)	Manito (V)	100	19.04	369	65.5	230,000	2,840	491
T23N, R7E								
26.6f	111. Dept of Conservation	110	26.0	1064	36.7	284,000	2,000	500
T23N, R7W								
22.8h (1)	Bart Nelson	100	46	200	185	410,000	5,130	515
28.8e (1)	Schissler Seed Co.	91	37.58	1000	126	220,000	4,230	498
Morgan								
T16N, R13W								
21.2c (6)	Central Illinois Pub. Serv. Co.	103	23.0	500	89.9	100,000	1,200	445
22.5g1 (1)	Meredosia (V)	40	21.9	71	10.6	11,200	620	455
22.5g2 (2)	Meredosia (V)	40	17.3	120	11.9	16,000	700	455
28.2h1 (2)	Natl. Starch Prod.	92	25	500	66.7	395,000	5,890	440
Peoria								
T7N, R7E								
21.2a (1)	Olin Matheison Ind.	54	5.4	220	169.2	400,000	16,000	445
21.2b	T. P. S W. Railroad	48	8	550	550.0	880,000	44,000	442
23.6e1	T. P. & W. Railroad	67	5.25	430	136.5	500,000	15,000	447
29.2d (16-1-60)	Arch, Dan, Mid. Co.	73	4.97	980	48.4	182,000	9,100	435
30.2b1 (T28)	T. P. & W. Railroad	45	9.3	290	24.2	55,000	1,830	445
30.2b2	T. P. & W. Railroad	56	8	425	28.3	67,000	2,230	445
T8N, R8E								
7.5a1 (G1)	Peoria Water Works Co.	166	87.75	1430	164.9	245,000	3,110	510
7.5a2 (G2)	Peoria Water Works Co.	162	91	1470	183.8	320,000	4,520	510

Table 8 (Continued)

Well Number		Owner	Depth of Well (ft)	Non-Pumping Level (ft below land sfc.)	Pumping Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Transmissivity (gpd/ft)	Hydraulic Conductivlty (gpd/ft^2)	Land Surface Elevation (ft above msl)
Peoria T8N, R8E (Cont.)									
9.3f		Block & Kuhl Co.	59	33	1300	325.0	740,000	28,400	455
17.1f	(1)	Hiram Walker & Sons	57	29	3700	528.6	700,000	25,900	456
17.1f1	(2)	Hiram Walker & Sons	53	30	1327	884.7	1,150,000	50,000	469
17.1f2	(3)	Hiram Walker & Sons	56	30	2500	625	1,100,000	52,400	469
17.2e	(4)	Hiram Walker & Sons	53	27	3000	375.0	560,000	20,800	465
17.7bl	(D1)	Peoria Water Works Co.	118	63.25	1030	3120	5,100,000	86,500	474
17.7b2	(D2)	Peoria Water Works Co.	113	62	1390	5560	9,000,000	147,000	474
17.7b3	(D3)	Peoria Water Works Co.	124	57.87	1600	800.0	1,530,000	23,200	474
20.7f		Peoria Sanitary Dist	104		500	400.0	2,100,000	29,200	454
20.8e	(4)	Com. Sol. Corp.	94	35.86	1800	236.8	400,000	6,900	450
15.2dl	(6)	Peoria Heights	122	73	1007	167.8	520,000	9,640	500
15.2d2	(7)	Peoria Heights(V)	129	80	1270	- 181	650,000	13,830	495
15.2el	(1)	Peoria Water Works Company	125	62.75	1810	124.8	300,000	6,980	480
15.2f	(13)	Peoria Water Works Company	110	61.2	1250	59.8	125,000	4,810	480
15.2h	(9)	Peoria Water Works Company	94		2100	210.0	400,000	10,000	460
15.3e2	(12)	Peoria Water Works Company	140	76	1700	118.6	385,000	5,140	495
15.3f	(14)	Peoria Water Works Company	130	68.33	1000	150	300,000	6,980	492
23.8h1	(1)	Peoria Heights	102	55	550	55.0	100,000	2,130	537
23.8h2	(2)	Peoria Heights	130	83	550	55.0	100,000	2,130	537
35.5e	(2)	Bemis Company,Inc.	57	33.85	2000	117.6	245,000	8,450	461
35.5f	(3)	Bemis Company,Inc.	63	48	1800	360.0	670,000	44,600	461
T10N, R8E									
10.4a	(8)	Cat. Tractor Co.	96	52.62	1600	107	731,000	16,860	510
14.4d	(TW4-70)	Cat. Tractor Co.	96	41.86	345	10.1	555,000	10,300	498
14.8c	(BB-6)	Cat. Tractor Co.	101	42.67	507	55.6	150,000	2,590	497
15.4f	(7)	Cat. Tractor Co.	90	53.40	771	98.8	329,000	7,480	509
15.4gl	(5)	Cat. Tractor Co.	90	52.82	1040	239.6	480,000	11,400	511
15.4g2	(6)	Cat. Tractor Co.	90	52.97	1040	110.3	270,000	5,520	511
15.4h	(4)	Cat. Tractor Co.	87	50.5	1120	172.3	300,000	7,150	511
23.7h	(3)	Cat. Tractor Co.	66	25	530	33.1	50,000	1,220	474
23.8h	(1)	Cat. Tractor Co.	82	31	620	56.4	100,000	1,960	480
T11N, R9E									
20.4g	(1)	N. Chillicothe	105	70.5	270	24.5	59,000	1,710	523
20.5b	(3)	Chillicothe (C)	123	79	310	62.0	100,000	2,280	525
20.5c	(2)	Chillicothe (C)	124	77.5	425	39.7	64,000	1,380	525
20.7g	(2)	N. Chillcothe (V)	100	61.6	293	48.8	100,000	7,600	529
21.8b	(1)	Chillocothe (C)	80	47	300	17.6	32,000	970	491
Pike									
T3S, R2W									
33.8h	(5)	Griggsville (V)	84	5.61	220	13.49	66,000	1,320	430
33.8h	(2)	Griggsville (V)	70.9	6.98	140	7.28	74,000	1,680	430

Table 8 (Continued)

Well Number		Owner	Depth of Well (ft)	Non-Pumping Level (ft below land sfc.)	Pumping Rate (gpm)	Observed Specific Capacity (gpm/ft)	Aquifer Transmissivity (gpd/ft)	Hydraulic Conductivity (gpd/ft^2)	Land Surface Elevatio (ft above msl)
Pike (Cont.)									
T7S, R2W									
15.2d	(1)	W. Ill. Water Coop	85	22.25	310	106.5	248,000	6,050	425
Putnam									
T32N, R2W									
4.3c	(T2)	J. & J. Steel Corp.	80	37.23	402	25.1	100,000	2,130	475
4.4a	(T1)	J. & J. Steel Corp.	131	45.38	402	19.0	80,000	1,030	480
9.3b	(1-55)	Hennepin (V)	100	60.72	151	104.9	235,000	6,030	505
10.8b	(1)	Hennepin (V)	115	77.3	125	7.5	38,000	1,030	505
T33N, R2W									
26.5h	(4)	Illinois Power Co.	114	13.33	1571	79.9	270,000	2,700	460
Scott									
T15N, R13W									
16.2h1	(1)	Bluffs (V)	58	15.5	170	27.4	50,000	1,660	460
16.2h2	(2)	Bluffs (V)	57	17	90	12.5	28,000	1,270	460
16.2h3	(3)	Bluffs (V)	59	19.41	159	29.0	31,700	1,130	460
31.2d1	(3)	S. Jacksonville (V)	80	17.40	412	30.5	154,000	2,370	439
31.2d2	(4)	S. Jacksonville (V)	77	14.29	495	34.6	195,000	3,900	438
Tazewell									
T22N, R4W									
16.8b	(1)	Hiram Walker Dis. Co.	209	39	2250	97.8	298,000	1,770	560
T23N, R5W									
5.6b		Robert Fredrick	83	27	1150	100.0	232,000	2,900	520
26.8a	(1)	Green Valley (V)	115	33.5	38.5	11.0	200,000	2,100	538
T24N, R5W									
3.1c	(7)	Pekin (C)	120	39.0	1750	109.2	430,000	5,300	480
3.2h1	(1)	Pekin (C)	90	35	700	700.0	1,180,000	21,400	475
3.2h2	(3)	Pekin (C)	100	36.5	3300	264.0	650,000	10,200	475
3.3h3	(2)	Pekin (C)	91	37.5	2100	350.0	630,000	11.700	475
4.2b	(7)	American Dis. Co.	100	28	1905	126.9	640.000	8,900	455
4.3a2	(6)	American Dis. Co.	93	28.5	1705	135	680,000	10.500	460
9.1g	(1)	Quaker Oats Co.	50	19	400	25.0	420,000	9.500	470
9.1h1	(1)	Standard Brands, Inc.	76	20	450	150.0	335,000	8,350	455
9.1h2	(2)	Quaker Oats Co.	78	18	600	109.1	235,000	6,910	455
9.2e		Standard Brands, Inc.	95	46	2426	220.5	560,000	11,400	460
9.2g	(4)	Standard Brands, Inc.	70	25	1890	103.6	175,000	3,890	460
9.8b1	(7)	Commonwealth Ed. Co.	66	28.75	510	47.4	240,000	7,300	460
9.8b2		Commonwealth Ed. Co.	99		1000	148	300,000	9,000	460
10.8h2	(4)	Quaker Oats Co.	87	40	869	86.9	230,000	4,900	465
10.8h3	(5)	Quaker Oats Co.	90	41	1056	81.2	200,000	4,090	465
34.5h	(2)	S. Pekin (V)	70	3	350	175.0	480,000	7,170	510
T26N, R4W									
29.7a		Herschel Mfg. Co.	64	12	600	75.0	140,000	2,700	445
34.5e	(8)	East Peoria (C)	66	12.42	608	41.8	60,000	1.260	490

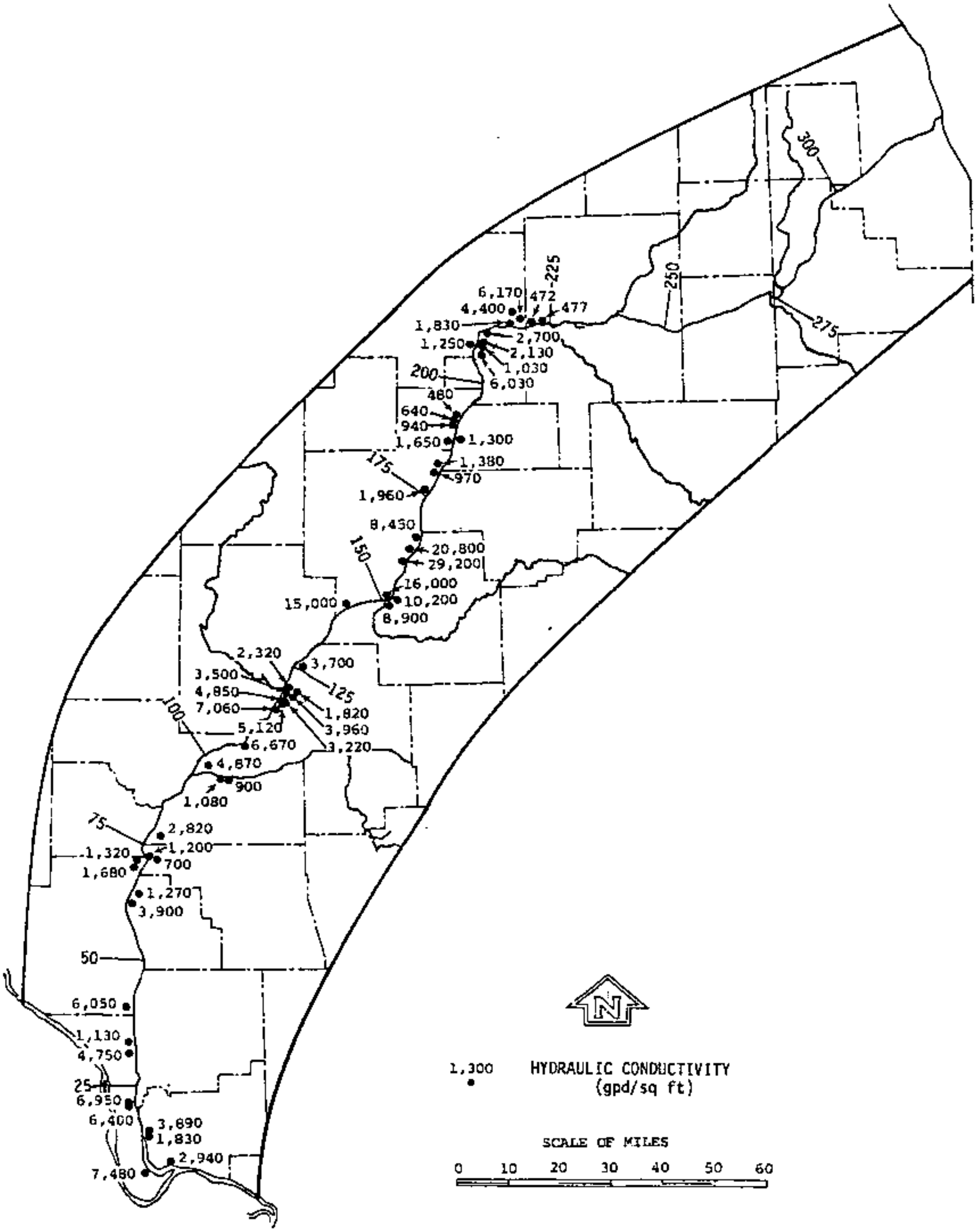


Figure 15. Hydraulic conductivities of sand and gravel aquifers along the Illinois Waterway.

7,000 gpd/sq ft with the exception of an area from Peoria (mile 167) to Pekin (mile 150) where they range from about 8,500 to 29,000 gpd/sq ft.

RIVER-AQUIFER MODEL DEVELOPMENT

Literature Search

Techniques for the evaluation of groundwater resources have been under investigation for many years. The subject of groundwater-surface water interrelationship, although not new, has received significantly more attention over the past ten to fifteen years both from the standpoints of water quality and quantity. Typical approaches to groundwater analysis, such as deterministic and stochastic mathematical analysis, electric analog modeling, and digital simulation models, have been employed in many ways in attempts to demonstrate the effects of the hydraulic connection of aquifers to surface water bodies. In the selection of pertinent papers on the topic, abstracts received from the Water Resources Scientific Information Center and work referred to by other investigators were used as a guide.

Flow net analysis (Walton, 1962) has been a much used method for the analysis of stream-aquifer systems. In its earlier forms, it was developed using the principle of superposition with drawdown and build-up represented by a system of image wells. By utilizing various configurations of point sources and sinks, complex situations involving barrier boundaries, recharge boundaries, and drilled wells can be modeled. In more recent applications, the flow net has been replaced by more complex equations of flow using either uniform or non-uniformly spaced grid networks.

The low flow conditions on many rivers are sustained by discharge from the aquifers that they intersect. Over the years, this interaction has been forecast for several reasons, such as determinations of firm capacity and firm power for proposed impoundments and for the determination of a stream's navigability. These studies have encompassed a variety of objectives and methods of analysis, such as the direct computation of groundwater out-flow by electric analog and mathematical processes (Rorabaugh, et al, 1962), comparison of groundwater levels with both downstream flow records and differences between surface inflow and outflow, dependable flow methods, and extrapolation of base-flow recession curves. The use of long-term records for surface water flow and groundwater levels (Rorabaugh and Simons, 1966) has allowed the long-range forecast of low flows by statistical methods.

By treating a river as a fully penetrating line source, Longenbaugh (1967) utilized a non-linear partial difference equation derived from the mass-continuity equation and Darcy's Law to model two dimensional flow through a saturated porous medium. The equation has no general solution, but numerical solution by computer can be accomplished by finite difference approximation. The model can handle variable transmissivity in the aquifer, non-steady state flow in two dimensions, and physiographic features such as impermeable, semipermeable, and hydraulic boundaries without over-idealization of the system.

The most common assumptions included in the formulation of analytical methodologies are, in the case of a surface water body which is hydraulically connected to an aquifer, the lake or stream bed was as permeable as the aquifer and that the stream was fully penetrating. These assumptions were empirically modified (Hantush, 1970) to approximate the conditions found when a stream is partially penetrating and has a semi-pervious bed. The modifications are based on the assumption that the resistance to flow induced by both constraints can be approximated by the insertion of an additional length of aquifer, having the same properties as the main aquifer, between the stream and the aquifer. The effect of neglecting the semiperviousness of the streambed will be an underestimate of the drawdown distributions of nearby wells and thus an overestimate of the total volume and rate of the stream's discharge to the aquifer. When using this technique, however, one must be careful that the retardation coefficient of the semipervious streambed not become excessively large compared to the distance from the stream to the point of interest, or the additional storage represented by the modification can no longer be neglected.

The majority of recent groundwater flow analyses are based on the deterministic solution of partial differential equations. At best, the discretized time series which represents the natural variability of a hydrologic system, such as temporal variations of recharge or water levels in adjacent bodies and spatial fluctuations in hydraulic conductivity or recharge, are dealt with in terms of average values. By utilizing this natural variability, aquifer properties and management strategies may be analyzed in such a way as to significantly increase the confidence in their derivation. Gelhar (1974) demonstrated the use of linear reservoir, Dupuit, and Laplace aquifer models for determining the various frequency domains for phreatic aquifers receiving variable recharge from a hydraulically connected stream.

Linear systems analysis also has been shown to be an effective tool in evaluating groundwater resources (Bathala et al., 1977). The use of both linear deterministic and linear stochastic models has shown good results in prediction applications. The stochastic models used are of the autoregressive type, using a large range of lag times.

Steady state analyses of the four basic conditions involving streams which are hydraulically connected to phreatic aquifers, flow to and from the aquifer for both finite and semi-infinite aquifers, were dealt with by Marino (1973). In his treatment of the various systems, the formulae are expressed in terms of the head averaged over the depth of saturation, and are applicable only when the change in the water table elevation is smaller than 50 percent of the initial depth of saturation.

By eliminating the steady-state condition on the above cases, Marino (1975) changed the analysis from a boundary value problem to one where an arbitrarily varying flood pulse in the stream is used to analyze the aquifer response to stream stage. The streambed was considered semi-pervious and the aquifer as unconfined. This work showed that the water level fluctuation in the aquifer was sensitive to the initial saturated depth, in that all things held constant, the higher the initial level of saturation, the larger the fluctuation in water level due to the in-stream flood pulse.

Tests on the sensitivity of aquifer response to aquifer diffusivity for the cases of both finite and semi-infinite aquifers with semi-pervious banks (Hall and Moench, 1972), showed a relative insensitivity of head relationships to the assigned value of aquifer diffusivity. Convolution relations based on unit step response and unit impulse response were used to 1) simplify the mathematics of stream-aquifer interaction, 2) permit greater generality by allowing for flood pulses of arbitrary shape, and 3) evaluate quantitatively the flux into or out of the aquifer. The study concluded that less time should be spent on evaluating transmissivity from diffusivity and more attention be given to groundwater contributions to streamflow.

One approach now commonly used to obtain approximate solutions to the partial differential equation for nonsteady-state, two dimensional flow is the method of finite differences. This is accomplished by discretizing the flow equation so that a series of equations may be solved sequentially by various digital computer techniques. One technique is the iterative alternating direction implicit method (Prickett and Lonnquist, 1971), where the flow of groundwater in an artesian, non-homogeneous and isotropic aquifer is approximated by superposing a grid network over the aquifer, and manipulating the finite difference equations in such a way that a series of equations in one unknown results, which are then solved by columns and by rows. The direction of the solution along each column and row is reversed at the start of each iteration. The models of this type allow different aquifer properties to be assigned at each node, thus representing spatial variation in aquifer characteristics such as permeability and bottom slope. The model is capable of handling such situations as groundwater evapotranspiration, recharge from precipitation, barrier boundaries, wells, watertable or confined aquifers, semi-infinite or finite aquifers, variable pumping rates, non-uniform grids, and semi-pervious streambeds.

Three other methods have been tested with the alternating direction method (Lin, 1970). The relaxation method, where iterative approximations are employed to eliminate the residual at each node in a systematic process, has been found to give good solutions for Laplacian steady-state problems. The explicit solution method solves the finite difference equation in such a way that there is only one unknown for each node equation, the head of that node at the current time. The implicit method also results in only one unknown per node equation, the head at the node during the previous time increment. Both the explicit and implicit methods require that the time increment chosen be small compared to the square of the grid spacing in order to assume stability. The alternating direction method can implement either of these iterative techniques. The advantage to using alternating directions is the reduction in the number of simultaneous equations to be solved by looking at rows and columns separately.

Vol'ftsun (1975) derived a mass transfer equation for an aquifer system hydraulically connected to a reservoir, which could be expanded to hydraulic connection with a stream. The methodology utilized the Dupuit equation with the assumption of a lumped linear reservoir system.

In an attempt to get away from the use of a piecewise polonomial functions of two or three degrees, such as those which are the basis of finite difference methods, Yoon (1975) elected to use the Galerkin Principle because of the flexibility in the choice of basic functions. Using this method, piecewise linear functions are integrated to produce systems of nonlinear ordinary differential equations which are contiguous in time. A matrix system, solved by Newton's method, results in a set of equations where the current head parameter is a function of conditions during the previous time step and current known parameters. The method has been shown to be readily applicable to situations associated with two dimmensional flow and complicated geometry.

The models mentioned above have been used as management tools and as instructional material. The "Basic Aquifer Simulation Model" of Prickett and Lonnquist (1971) was used by Karanjac (1977), with some alterations, as a part of a training course for Turkey's State Hydraulic Works. The course demonstrated the use of groundwater models for forecasting the results of aquifer management policies which include such factors as precipitation, evaporation, pumped wells, and recharge from hydraulically connected surface water bodies.

Bachmat et al. (1978) made a comparative study of available computer models which classifies the models of various investigators by capabilities and special applications.

Bennett (1976) has written a text for self-instruction in the use of various techniques, such as finite difference methods, Darcy's Law, non-equilibrium flows, and analog models, which mentions pertinent work using the various methodologies discussed.

RIVER-AQUIFER MODEL SELECTION

The various models which were reviewed in the literature search provided a great deal of information on what types of analytical techniques and models are available for stream-aquifer system studies and also gave a more than adequate amount of insight as to the "state of the art" at this time. Based on the models reviewed and the specific requirements of this study, the model presented by Prickett and Lonnquist (1971) was chosen to be the framework of the Illinois River Basin's aquifer model.

The choice of a model was made on two basic conditions; first, confidence in the technique utilized for solving a large number of simultaneous equations of several unknown variables; and, second, the flexibility and ease of application of the model for representing such aquifer characteristics as a partially penetrating stream, a semi-pervious streambed, phreatic conditions, variable aquifer thickness, semi-infinite extent, and the influence of both natural and artifical abstractions. The model chosen meets both of these conditions. The Iterative Alternating Direction Implicit method (IAPI) of systematic solution of simultaneous equations is used, in conjunction with user assigned limitations on allowable error and the number of iterations permitted to achieve that variance. The model also employs a head-predictor technique based on persistence in order to provide a reasonable "first guess" for the heads in the next time step, thus aiding in the reduction of the number of iterations per time step.

The flexibility of the model allows the transmissivity of the aquifer at any point to vary as the function of bottom depth and water table elevation with time, with few changes in program structure. The presence of a constant head boundary, the Illinois River, was accomodated with a few extra changes, allowing river stages to be read into the model and thus represent fluctuations in the river's stages and their effect on the aquifer's water table.

The following sections will discuss the method of application of the model runs, and discuss the conclusions which may be drawn from this study.

RIVER-AQUIFER MODEL IMPLEMENTATION

The model was set up to simulate an "ideal" aquifer along the Illinois River. This decision was made for several reasons, most notably the absence of data with which to calibrate the parameters which represent the aquifer's characteristics, such as hydraulic conductivity and the storage coefficient. Among the other reasons for making this choice was the geometric variability of the aquifer along the length of the river. Such properties as aquifer thickness, bedrock topography, and semi-infinite extent change considerably with change in location. The choice of an idealized aquifer model is not inconsistent with the goal of the study, which is not to show site-specific, but general effects on the adjacent water table aquifer induced by stream stage fluctuations.

The study is concentrated on the relative differences in water table elevation induced by increasing diversions from Lake Michigan into the Illinois River. With this purpose in mind, the effects of aquifer recharge due to precipitation, and depletion due to evapotranspiration and pumpage, are being neglected. The inclusion of this information, without data from observation wells with which to calibrate, would not be of any significance.

It is assumed that the Illinois River will not become a dry stream, and therefore the water table in the connected aquifer will not fall below the streambed. This assumption is justification for neglecting the partial penetration of the Illinois River in its adjacent aquifer.

Aquifer properties assigned to the ideal aquifer are considered as reasonable for the sand and gravel aquifers along the river. The hydraulic conductivity of the aquifer is assumed to be 2500 gallons per day per square foot, while that for the semi-pervious riverbed is assumed to be 0.5 gallons per day per square foot. The aquifer's storage coefficient is set to 0.1. The river is represented as a constant head boundary by setting the storage coefficient of the river to 10^{21}

The idealized aquifer has no slope component parallel to the river. The slope component normal and toward the river is 1 foot per 1700 feet. A default water table gradient of five feet per mile toward the river is assumed as a starting point for each model run.

The plan view of the aquifer is represented by a 31 by 31 matrix of nodes. For the purpose of this study, fluctuations in water table elevation will be noticeable along the rows, but not along the columns, which are parallel to the river. Therefore, the rows are equally spaced, one thousand feet apart, and the column spacing increases as you move away from the river.

The Illinois River is represented by column one. The spacing between columns one and two, one half foot, represents the streambed. Between columns two and eleven,the column spacing is two hundred and fifty feet and between columns eleven and twenty-one, the spacing is five hundred feet. Between the last ten columns, the spacing is one thousand feet. This matrix, illustrated in figure 16, represents an aquifer of semi-infinite extent.

The model reads first the default aquifer properties, and then the properties are read by node, so that spacial variation in the aquifer may be represented. The node properties which are read include the storage coefficient, water table elevation, bottom elevation, pumpage, and the hydraulic

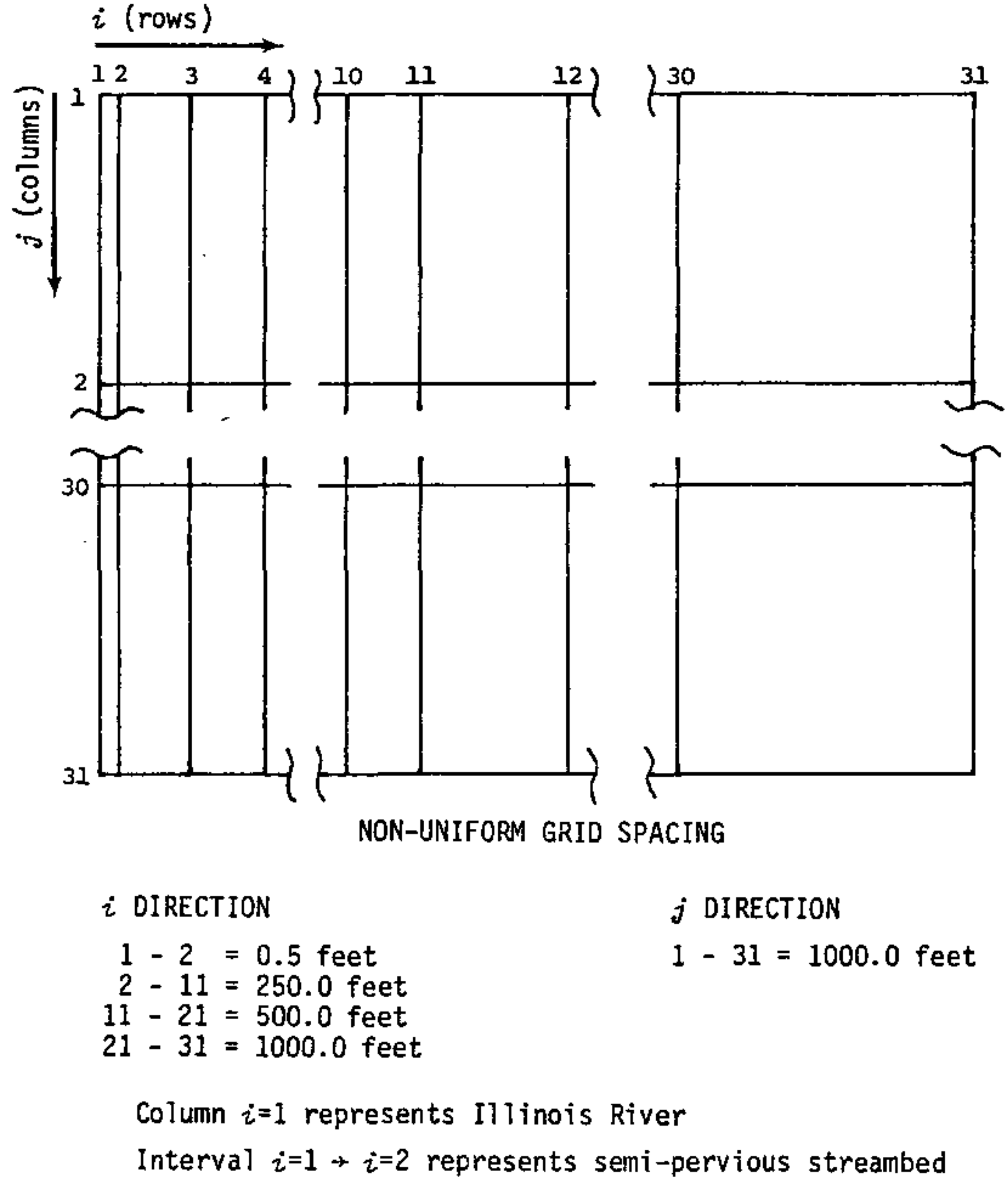


Figure 16. Finite difference grid for Illinois River - Aquifer Model.

conductivity both parallel and perpendicular to the stream.

Each model run was made utilizing weekly average stream stages for water years 1971, 1973, or 1977 with four weekly stages added to the beginning of the run in order to allow the water table to achieve a natural slope consistent with the aquifer properties by the beginning of a particular water year.

Three locations along the river were chosen to represent the river stages possible from increasing Lake Michigan diversion. The locations are the gages at Havanna, Beardstown, and Meredosia, Illinois. For each of these locations, the United States Army Corps of Engineers provided river stages for the three water years mentioned above. For water years 1971 and 1977, years of normal and below normal river stages respectively, river stages were provided for simulated base line (including 3200 cfs diversion), base line flow plus 6660 cfs diversion, and base line flow plus 10,000 cfs. For Water Year 1973, an above normal period, the baseline flow and base line flow plus 6600 cfs diversion were modeled.

The results of each model run were printed for row sixteen only, because of the repetitious nature of the fluctuations between rows. Along this row stages were printed for eight distances from the river, in feet. These distances are 0.0, 0.5, 1000.0, 2250.0, 4750.0, 7250.0, 12250.0, and 17250.0. A general discussion of the results is presented in the next section.

RIVER-AQUIFER MODEL RESULTS

Model run results are illustrated for Merdosia at a point 1000 feet from the river for 1971, 1973, and 1977 in figures 17, 18, and 19, respectively. The groundwater levels shown for the 3200 cfs diversion were computed from river stages based on present diversion practices (3200 cfs) and are referred to as simulated baseline groundwater levels. It should be noted that river stages based on present diversion practices are not actual stages, but were simulated with the U.S. Army Corps of Engineers river model.

As shown in figures 17, 18, and 19, the greatest increases in simulated groundwater levels due to increased diversion occur during periods when the simulated baseline groundwater levels are at low stage corresponding to low river stage (1971). Conversely the smallest increases occur during periods when simulated baseline groundwater levels are at high stage corresponding to high river stages (1973). This is to be expected because the increase in simulated river stages due to increased diversion are less at high river stages than at low river stages.

During 1971 at Meredosia (figure 17) a year of below normal river stage the maximum increase between baseline groundwater levels and groundwater levels based on 10,000 cfs diversion was almost 5 feet. During 1973 (figure 18) a year of above normal river stage there was little difference between baseline levels and levels simulated for a diversion of 6,600 cfs until baseline levels dropped below an elevation of 426 feet near the end of the period.

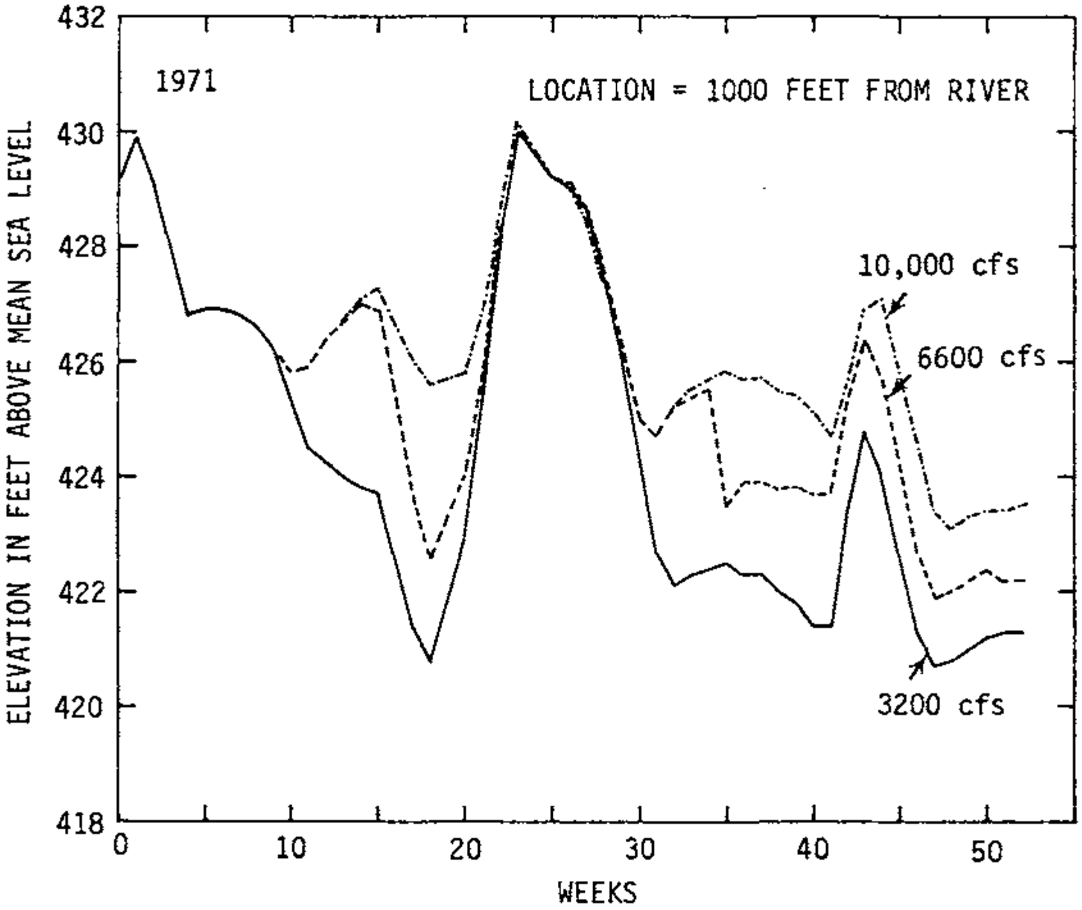


Figure 17. Effects of increased diversion on groundwater levels at Meredosia during 1971.

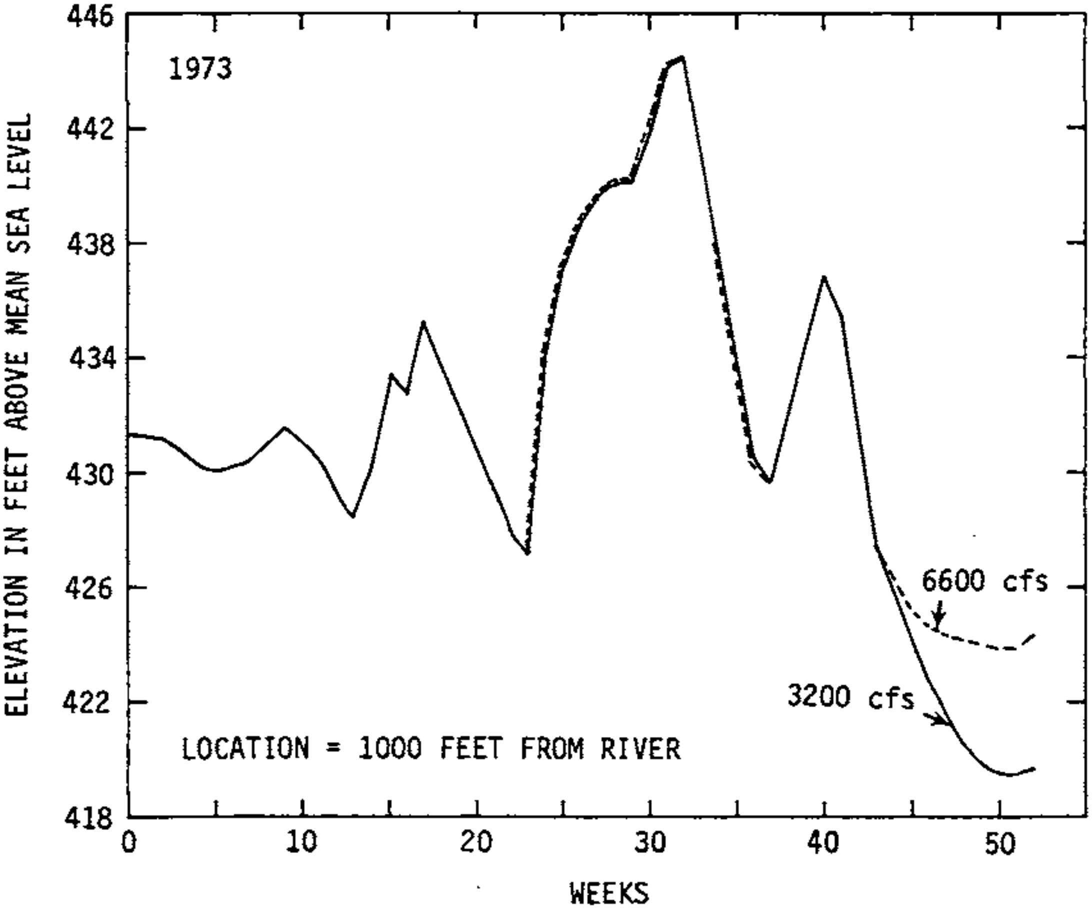


Figure 18. Effects of increased diversion on groundwater levels at Meredosia during 1973.

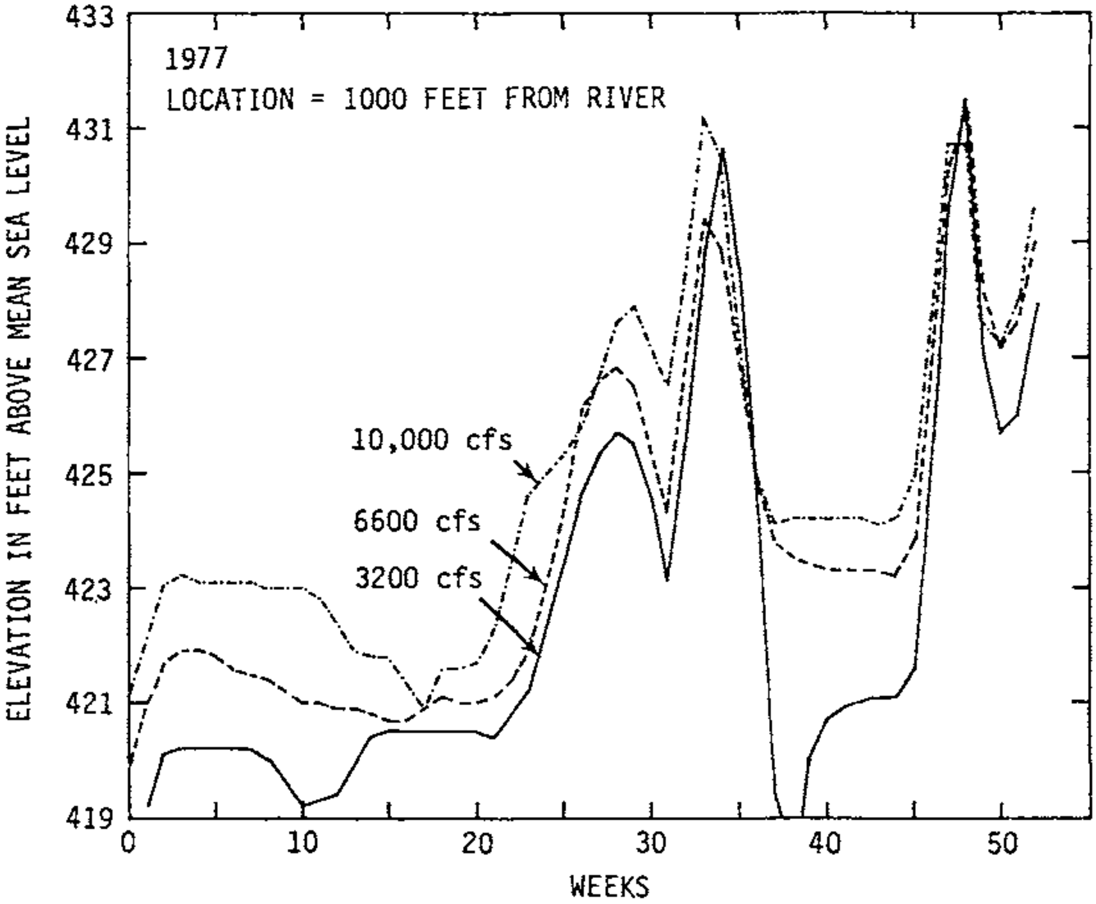


Figure 19. Effects of increased diversion on groundwater levels at Meredosia during 1977.

In conclusion, the model can give a good deal of insight as to the effects on the water table from increased diversions. Confidence in the model results could be bolstered by implementing a water level monitoring system and aquifer testing to collect data to calibrate the model. It should be noted that evaluation of any specific site would require a water level monitoring system and aquifer testing at that site to calibrate the model.

RECOMMENDED MONITORING NETWORK

To calibrate the developed model for a specific location two sets of data are required; 1) aquifer and streambed hydraulic properties; and 2) historical groundwater level and river stage data. The following recommendations and associated costs should provide the needed data sets for one reach or location along the river.

The hydraulic properties of the aquifer and streambed can be determined by conducting a controlled pumping test with properly located and constructed observation wells. For planning purposes, one 12-inch diameter test well about 100-feet deep should be constructed. The test well should be located about twice the aquifer thickness from the edge of the river. Three 4-inch diameter observation wells approximately 50 feet deep and located 100, 300, and 700 feet, respectively, on the land side of the test well in a line perpendicular to the river should be constructed. Four additional 2-inch diameter wells approximately 50-feet deep also are required. One should be located across the river 2 aquifer thicknesses from the river edge in line with the test well and 4-inch diameter observation wells. The other three should be located 100, 300, and 700 feet from the test well, respectively, in a line paralleling the river.

The estimated cost for constructing these wells and conducting a 30-hour pumping test at a pumping rate of 1,000 gallons per minute is estimated to be about $30,000 per site in 1978 dollars.

To obtain historical groundwater level and river stage data water level recorders need to be installed in the 4-inch diameter observation wells constructed for the pumping test. A stilling well and recorder also should be installed in the river immediately opposite the observation wells. Weekly servicing of these recorders for a period of two years would provide adequate data for model calibration.

The estimated cost for purchasing and servicing these recorders for a period of 2 years is about $52,000. If the wells were not constructed during the pumping test phase an additional $6,000 would be required.

In addition to obtaining data to calibrate the quantitative model, two probes, a conductivity and temperature probe, should be purchased to obtain quality data from the river and observation wells.

Weekly quality observations could be made when the recorders are being serviced. The estimated cost of these probes is about $5,500.

EFFECTS OF INCREASED DIVERSION ON DRAINAGE AND LEVEE DISTRICTS

The most apparent detrimental effects of increased diversion of Lake Michigan water down the Illinois Waterway are the problems associated with farming the lowland areas and increased costs of pumping to protect the lowland areas. These problems are most critical in the river lowland areas south of Peoria where the river slope is smaller. The adverse effects on farming the lowland areas is beyond the scope of this project but should be noted.

To determine the effects of increased diversion on the cost of pumping by Drainage and Levee Districts the following analysis was conducted. Pumpage data (monthly power usage in kilowatt-hours, (kwh) was obtained for the years 1967 through 1977 for 18 Drainage and Levee Districts located between river miles 30 and 140. Regression analyses using the method of least squares were performed on the data, relating monthly power consumption values to average monthly river stages at the nearest gage using the Beardstown, Havana, and Meredosia gages. Correlation and regression coefficients for 15 Drainage and Levee Districts are presented in Table 9. Poor correlation was obtained for Kelly Lake, Coon Run, and Eldred Districts due to missing power usage data. For the remaining 15 districts correlation coefficients range from .7121 to .9216 and average .8194.

To predict the effect of increased diversion on pumping costs or power consumption, simulated power usage for each district was determined using the developed regression equations and the simulated river stage data provided by the Corps for the water years 1971, 1973, and 1977. Regression analysis of 1977 costs versus 1977 power usage (kwh) for the districts of interest provided the cost function to applied to power usage. A correlation coefficient of .94 and the regression equation cost

$$(1977 \text{ dollars}) = 3623 + .0328 \ (\text{kwh})$$

were obtained. The results of these simulations are presented in Tables 10, 11, and 12, respectively.

For the simulated year of low flows, 1971, average percentage increases in power costs were 10.3 percent and 20.0 percent for 6,600 cfs and 10,000 cfs diversions respectively. It is interesting to note that the smaller percentage increases were for the drainage districts above the La Grange Lock and Dam.

For the simulated year of high flows, 1973, an average percentage increase in power costs of 3.5 percent was obtained at 6,600 cfs diversion. No river stage data was available for 10,000 cfs diversion. For the simulated year of average flows, 1977, average percentage increases in power costs of 23.9 percent and 42.7 percent were obtained for 6,600 cfs and 10,000 cfs diversions, respectively. Six of the 15 districts had percentage increases in power costs at 10,000 cfs diversion in excess of 50 percent.

Table 9. River Stage vs monthly power consumption: a + b (monthly average river stage)

	Levee and Drainage districts	River mile	Correlation Coefficient	Regression Coefficients	
				a	b
	Peoria Lock & Dam	158			
1)	Banner Special	140	.8029	-1,684,000	3,924.1
2)	Spring Lake	135	.8568	-5,152,000	12,042.0
3)	E. Liverpool	130	.8612	-1,322,200	3,074.3
4)	Liverpool West	127	.8681	-1,667,400	3,878.8
5)	Kerton Valley	123	.7260	- 381,560	887.1
6)	Sea Horn	118	.7121	- 420,380	976.3
7)	Norris Farms	116	.8233	- 452,940	1,051.1
8)	Lacy-Langlier Combined	115	.8260	-2,753,600	6,415.6
9)	Lost Creek	91	.9216	-2,258,600	5,259.2
10)	Coal Creek	86	.8436	-2,737,000	6,397.9
11)	S. Beardstown	81	.8771	-5,281,200	12,375.0
	LaGrange Lock and Dam	80			
12)	Meredosia Lake	7,5	.8293	-1,618,700	3,823,0
13)	Scott County	67	.7769	-2,262,000	5,386.3
14)	Hartwell	40	.7451	-1,875,500	4,466.3
15)	Keach	35	.8221	-1,698,300	4,051.5

Table 10. Simulated power consumption and cost for 1971.

	Simulated flow		6,600 cfs diversion		Percent	10,000 cfs diversion		Percent
District	kwh	cost	kwh	cost	cost Increase	kwh	cost	cost Increase
Peoria Lock & Dam								
1)	213,073	$11,352	271,947	$12,543	10.5	305,184	$13,633	20.1
2)	841,166	35,184	1,021,836	37,139	5.6	1,123,832	40,485	15.1
3)	132,590	8,457	178,714	9,485	12.2	204,754	10,339	22.3
4)	176,815	10,442	235,010	11,331	8.5	267,863	12,409	18.8
5)	37,899	5,092	51,209	5,303	4.1	58,723	5,549	9.0
6)	36,105	4,945	50,752	5,288	6.9	59,021	5,559	12.4
7)	34,851	4,903	50,616	5,283	7.8	59,519	5,575	13.7
8)	343,713	16,093	439,969	18,054	12.2	494,309	19,836	23.3
9)	61,277	5,633	81,143	6,284	11.6	96,378	6,784	20.4
10)	196,422	10,066	226,876	11,065	9.9	246,134	11,696	16.2
11)	535,027	21,172	593,932	23,104	9.1	631,181	24,326	14.9
LaGrange Lock & Dam								
12)	77,922	6,179	108,443	7,180	16.2	134,493	8,034	30.0
13)	291,798	13,194	367,332	15,671	18.8	413,205	17,176	30.2
14)	243,681	11,616	306,314	13,670	17.7	344,352	14,918	28.4
15)	257,645	12,074	314,461	13,937	15.4	348,966	15,069	24.8
Totals		$176,402		$195,337	10.3		$211,389	20.0

Table 11. Simulated power consumption and costs for 1973.

	Simulated flow		6,600 cfs diversion		Percent Cost
District	kwh	cost	kwh	cost	Increase
Peoria Lock & Dam					
1)	458,237	$18,65	486,255	$19,572	4.9
2)	1,597,182	56,010	1,683,162	58,831	5.0
3)	323,988	14,250	345,939	14,970	5.1
4)	418,486	17,349	446,181	18,258	5.2
5)	93,122	6,677	99,456	6,885	3.1
6)	96,790	6,798	103,738	7,026	3.4
7)	100,344	6,914	107,584	7,152	3.4
8)	744,447	28,04	790,255	29,543	5.4
9)	421, 99	17,458	429,426	17,708	1.4
10)	638,453	24,564	651,291	24,985	1.7
11)	1,390,016	49,216	1,414,849	50,030	1.7
LaGrange Lock & Dam					
12)	391,656	16,469	402,659	16,830	2.2
13)	760,586	28,570	791,000	29,568	3.5
14)	632,398	24,366	657,618	25,193	3.4
15)	610,261	23,640	633,138	24,390	3.2
Totals	$338,944		$350,941		3.5

Table 12. Simulated power consumption and costs for 1977.

	Simulated flow		6,600 cfs diversion		Percent cost Increase	10,000 cfs diversion		Percent cost Increase
District	kwh	cost	kwh	cost		kwh	cost	
Peoria Lock and Dam								
1)	140,333	8,225	210,012	$10,511	27.8	262,568	$12,235	48.8
2)	621,620	24,012	835,446	31,026	29.2	996,728	36,316	51.2
3)	76,004	6,116	129,518	7,871	28.7	170,693	9,222	50.8
4)	104,252	7,042	173,126	9,302	32.1	225,076	11,005	56.3
5)	21,645	4,332	37,006	4,837	11.6	48,887	5,226	20.6
6)	19,584	4,265	35,012	4,771	11.9	48,088	5,200	21.9
7)	18,556	4,232	33,590	4,725	11.7	47,668	5,187	22.6
8)	224,698	10,993	338,618	14,730	34.0	424,544	17,548	59.6
9)	31,928	4,670	51,109	5,299	13.5	70,255	5,927	26.9
10)	137,455	8,132	179,254	9,503	16.9	213,590	10,629	30.7
11)	420,971	17,431	501,821	20,083	15.2	568,234	22,261	27.7
LaGrange Lock and Dam								
12)	36,468	4,819	57,324	5,503	14.2	78,745	6,206	28.8
13)	157,579	8,792	240,521	11,512	30.9	307,006	13,693	55.7
14)	131,957	7,951	201,162	10,221	28.5	256,291	12,029	51.3
15)	154,697	8,697	219,075	10,809	24.3	269,084	12,449	43.1
Totals		$129,709		$160,703	23.9		$185,133	42.7

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