

# Estimating Monthly Water Withdrawals, Return Flow, and Consumptive Use in the Great Lakes Basin





## **Estimating Annual Water Withdrawals**

he study area, the time period, water-data esources, the data stream (how data are ompiled and stored), and what data are eeded (groundwater, surface water, wateruse categories, threshold data, locational data). To understand data reliability, waterresource managers, planners, and modelers

1. their study area and water-use data needs,

2. available data resources, and

. data gaps and methods to estimate da Optimally, water-withdrawal, return-flow and consumptive-use data that are reported by facilities themselves, or estimated data for similar types of facilities, are preferred over general estimates based on ancillary non-water data that may be related to a particular water-use category or groups of

water-use categories. Withdrawal and return-flow data are available from many State and Federal agencies. Below are some sources of withdrawal information and data that were used

in Shaffer (2009) and can serve as a starting point for managers, planners, and modelers. • State water-use data-collection programs

#### **Case Studies**

One method that is commonly employed uses metered data from public-supplied facilities by region to estimate withdraw- to estimate how much water is withdrawn a coefficient and the permitted pumpage for of the United States industrial freshwaals from self-supplied facilities (Horn and to operate facilities. Horn also developed others, 2008). Horn also estimated self- water-demand coefficients for specific supplied industrial withdrawals as a function types of commercial activities by using of the number of employees. Sometimes withdrawal and delivery data from the state data for 6 years and tiered median water withdrawals, 7 percent of self-supplied the amount of a product produced is used to water-use database and metered delivery withdrawals by water-use category (table 1) domestic withdrawals, and 5 percent estimate water-use needs, and other datasets data from community water systems. to better understand water demand. Ohio of public-supply withdrawals (Shaffer, such as wastewater releases (stored in the Buchwald and others (in press) estimated and Indiana have similar water-use registra- 2009). U.S. Environmental Protection Agency Per- commercial and industrial withdrawals by tion programs, thus making it possible to

and Indiana have similar data-collection programs. The National Academy Press (2002) describes each State Water-Us *Data Collection Program*; for more recent program changes, check with each State program

The USGS water-use program estimates water use every 5 years (years ending in 0 and 5) at three levels: county, Stat nd national datasets (Kenny and others, 2009). Some States collect data by references, and State contact names are available at *http://water.usgs.go* watuse/. While these data may not be sufficient for a detailed study, they can help prioritize areas or types of data Also, USGS State contacts may have a list of references that may be helpful

• The United States Department of Agriulture (USDA) National Agricultur Statistics Service estimates water used for irrigation every 5 years (years endi in 2 and 7) (United States Departmen Agriculture – National Agricultural Sta istics Service, 2002). The USDA also produces the Farm and Ranch Irrigation may collect withdrawal data (and occa-Survey (2007); estimates can be plotted

> mit Compliance Database, PCS) are com- using a default withdrawal (based on the combine and compare data. Combined, bined with consumptive-use information water-use purpose) and multiplying that by Ohio and Indiana comprised 17 percent

by State and (or) county. While these lata may not be sufficient for a detaile study, they can help prioritize areas types of data. An interactive statistial mapping application is available a http://www.agcensus.usda.gov/Publications/2002/SVG/index.asp

Thermoelectric power waterdata were collected by the U ment of Energy Energy Information Administration (EIA) on form EIA767 J.S. Department of Energy, 2005) Data were collected from 1996 to 2005 or more information, see *http://*1

egression model to estimate domestic domestic water-delivery data metered by community water systems and census data. Combining the public supply service areas with the regression equation provided estimates of self-supplied withdrawal. Combining sewered areas, the regression equation, and estimates of onsumptive use provided estimates of domestic return flow. This methodology may be used for other studies to estimate domestic water use.

Wisconsin. This method also could be used ter withdrawals in 2005, 12 percent of to estimate annual water withdrawals. mining freshwater withdrawals, 10 per-Shaffer (2009) used Ohio and Indiana cent of thermoelectric power freshwater

### **Estimating Consumptive Use and Return Flow**

Consumptive use is important because it is a way to estimate return flow when return-flow data are not available, and it is an important component of a water budget

for water-resources planning and management. Consumptive use often is computed by using a consumptive-use coefficient; more detailed discussions on consumptive

use and consumptive-use coefficients are contained in the following references: • Pebbles (2003a, b) presented annotated bibliographies and discussions on con-

sumptive-use coefficients. • Shaffer and Runkle (2007) lists consumptive-use coefficients by water-use and 9, respectively). Monthly consumptive

category for the Great Lakes Basin and use coefficients, the number of records, and climatically similar areas as well as selected statistics, an annotated bibliography, and an appendix with detailed consumptive-use coefficients. • Shaffer (2009) analyzes data from Oh

sumptive-use coefficients: the return flow and withdrawal method, the winter base-rate method and the standard industrial classifi-

the IQR for Ohio are listed in table 4 and were used to estimate consumptive use and return flow for the Great Lakes Basin for 2006 (table 5 and fig.3). Thermoelectric power consumptive-use coefficients varied by type of cooling, but average coefficients tended to be higher in the summer months. Industrial average consumptive-use coefficients were steady for the year. Commercial and public supply consumptive-use coeffi-



Fig. 3. Consumptive-use was highest for thermoelectric power. Irrigation, public supply, and self-supplied domestic consumptive use was highest during June to September.

and Indiana for consumptive-use coefficients. Shaffer (2009) used three methods to compute annual, monthly and seasonal con-

cation (findings are listed in tables 31, 32

cients were higher in the summer months.



- Some return-flow data are available the National Pollutant Discharge imination System Permit Compliand System. These data may be available through State Environmental Protection
- If annual withdrawal data are not availabl water withdrawals may be estimated by (t using an annual withdrawal rate base on water-use categories, groups, or Standard Industrial Classification (SIC codes or using median daily-withdrawa rates based on water-use categories groups, or SIC codes and multiplying the median water-withdrawal rate by 365 days to obtain an estimated annual
- water demand by census block based on using satellite data, weather data, and crop-irrigation needs and irrigationsystem types and efficiencies to estimate crop withdrawals, applications, and ET
  - using historical data or data available for another year; and

using ancillary non-water data that may

- be related to a particular water-use category or groups of water-use categories such as number of employees or gross product to estimate water use.

3rd to 66th percentiles; "large" is from the 66th to 90th percentiles; "very large" is from the 90th to 98th percentiles; and "extra large" s greater than the 98th percentile; Mgal/d, million gallons per day; N, number of records; <, less than; the sum of "Percent of total with lrawals" may not equal 100 owing to rounding.]								
Water-use category	Facility size	N	Median withdrawal (Mgal/year)	Percent of total withdrawals by water-use categor				
Public supply	Small	2,157	25.6	1				
	Medium	2,160	102	5				
	Large	1,570	464	18				
	Very large	524	1,940	27				
	Extra large	131	14,700	49				
Industrial	Small	1,078	1.46	<1				
	Medium	1,078	32.8	1				
	Large	784	237	4				
	Very large	261	1,990	11				
	Extra large	66	47,400	84				
Thermoelectric power	Small	161	54.8	<1				
	Medium	160	8,940	6				
	Large	116	110,000	44				
	Very large	39	284,000	36				
	Extra large	10	449,000	14				
Irrigation, golf	Small	1,354	2.19	4				
	Medium	1,356	11.0	19				
	Large	918	25.6	33				
	Very large	327	51.1	24				
	Extra large	82	113	19				
Irrigation, nursery	Small	260	3.65	2				
	Medium	258	11.0	12				
	Large	188	40.2	29				
	Very large	63	153	38				
	Extra large	16	296	20				
Irrigation, crop	Small	2,822	3.65	5				
	Medium	2,037	18.2	18				
	Large	682	36.5	28				
	Very large	171	87.6	24				
	Extra large	171	270	24				
Commercial	Small	858	0.73	<1				
	Medium	855	3.65	2				
	Large	624	21.9	11				
	Very large	206	172	28				
	Extra large	51	1,330	59				
Mining <sup>1</sup>	Small	496	7.3	1				
	Medium	495	142	14				
	Large	360	409	33				
	Very large	120	1,190	30				
	Extra large	21	2 440	22				





e range (distance between the 75<sup>th</sup> and 25<sup>th</sup> percentile)] Water-use category Jan. Feb. March April May June July Aug. Sep. Oct. Nov. Dec 2 6 14 20 19 14 5 2 1—8 9—19 12—27 10—24 7—19 0—8 11 12 11 11 12 12 12 11 11 12 0-37 0-37 0-39 0-40 0-37 0-39 0-40 0-40 0-41 0-40 0-37 0-3 
 58
 66
 77
 80
 79
 83
 80
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 70
 80
 1—99 42—98 65—98 67—95 68—98 68—99 37—98 0—94 IQR, golf course IQR, crop and nursery 67-93 68-91 65-90 68-90 66-93 60-92 56-90 37-84 4 3 7 8 5 9 5 5 6 3 2 20 24 11 27 28 27 23 34 33 32 26 24 0-44 0-50 0-50 0-55 0-56 0-56 0-50 0-73 0-78 0-48 0-23 24 21 15 18 18 19 19 19 19 19 16 iblic-supply water withdrawals are delivered domestic, commercial, industrial, thermoelectric power users. Consumptive-use will depend on the amount delivered and what the water is used for. During the winter, consumptive use will be limited by processes including: humidifiers, indoor swimming pools, incorporation into products, cooking, and any processes that loses water to make steam. As hese coefficients are for a region where outdoor water use is limited in the winter, the spring coefficient of 2 percent is used November to April. <sup>2</sup> Industrial and thermoelectric-power consumptive-use coefficients were fairly steady for the year. The average consumptive-use coefficient computed by Shaffer (2009) was used for industrial. A number between the median and average consumptive-use coefficients was used for thermoelectric. <sup>3</sup> All irrigation monthly consumptive-use coefficients are the median record monthly consumptive-use coefficients excluding any records that had no withdrawals and records that had returns but no <sup>4</sup> Shaffer (2009) found an annual median consumptive-use coefficient of 76 percent based on 18 records. As no other data is available and livestock is less than 1 percent of Great Lakes Basin withdrawals, '6 percent was used. There were not enough records to determine a IQR. <sup>5</sup> The average consumptive-use coefficient was used for aquaculture. There were not enough records to determine a IQR. <sup>6</sup> Shaffer (2009) found that the monthly median consumptive-use coefficients (based on percent) for Commercial and Mining water-use categories were different than the average (based on withdrawals).

fumbers are in percent of withdrawals; all irrigation is the combination of golf-course and crop, nursery, and turf grass irrigation in Ohio; Range; monthly min and max found for 1999–2004; IQR, Interquar-

 Table 4.
 Consumptive-use percentage of withdrawals for Ohio, 1999–2004.

Averages based on percentages were computed for these categories and listed above.

<sup>1</sup> Mining numbers may include dewatering



# **Estimating Monthly Water Withdrawals**

Monthly data are of great value for underareas where there is the potential for seastress on aquatic life. These shortages and along with annual-withdrawal estimates early fall when water temperatures are at water levels are at their lowest. Summer months and early fall (June, July, August and September) also are when water withat their highest. Monthly or seasonal water-

able instead of annual withdrawal data.

category	Jan.	Feb.	March	April	May	June
					Public Supply	
onthly percent	8.1	8.2	7.8	7.8	8.2	8.8
diana IQR	7.4—8.7	6.7—8.0	7.2—8.4	7.3—8.4	8.0—9.1	8.3—9
hio IQR	7.6—8.6	6.8—7.9	7.5—8.5	7.4—8.3	8.2—9.0	8.3—9
					Indu	Istrial
onthly percent	8.0	8.0	7.8	7.9	8.2	8.5
diana IQR	3.1-8.5	3.4—8.3	5.3—8.9	6.4—9.1	7.2—9.8	7.7—1
hio IQR	6.0-8.8	5.8-8.3	7.0—9.2	7.3—8.9	7.9—9.6	8.0—1
					Thermo	oelectric
Ionthly percent <sup>1</sup>	7.6	7.4	7.3	7.4	8.2	9.5
diana IQR	4.9—8.8	4.8-8.3	4.9—8.6	4.4-8.3	6.2—9.4	8.2—1
hio IQR	6.7—9.1	5.8-8.1	6.7—9.0	6.5—8.5	7.6—9.4	8.1—1
					Irrigati	ion, golf
lonthly percent <sup>2</sup>	.5	.3	.7	3.8	8.3	16.2
diana IOR	0—0	0—0	0—0	0-4.5	2.2—11.6	11.0—2
hio IOR	0—0	0—0	0—0	0-3.4	0—11.8	10.5—2
					Irrigatio	on, other
onthly percent <sup>3</sup>	.3	.3	.8	1.8	3.7	15.3
diana IOR — nursery	0-0	0-0	0-6.2	0-9.4	0-12.8	9.3—1
hio IOR – nurserv	0-4	06	0-4.0	0-8.1	5-13.1	11.2—
diana IOR — crop	0-0	0-0	0-0	0-0	0-0	0-24
hio IOR — crop	0-1	0-1	0-6	0-45	0-94	4 5-2
are exercised and provide a second					Irrigat	tion, all
onthly percent	.3	.3	.8	2.2	4.6	15.5
JT					Live	stock
onthly percent	7.0	8.1	7.5	7.6	7.8	9.0
diana IOR	1 4-8 3	5 2-8 3	4 8-8 3	2.9-8.3	7 0-8 7	7 99
hio IOR	74-85	7 2-8 3	76-85	7 7-8 3	83-87	8 2 - 8
	, 0.0	7.2 0.0	1.0 0.0	,., 0.0	Aqua	culture
onthly percent <sup>4</sup>	8.2	6.9	8.9	10.9	8.5	10.3
J. J. J. F. L. L.					Comn	nercial
onthly percent <sup>5</sup>	5.4	5.9	6.6	7.6	8.7	9.8
diana IOR	.9—8.7	.8-8.4	2.2-8.8	4.1-9.1	6.6—10.6	5.4—1
hio IOR	0-8.5	0-8.3	.2—8.3	3.0-8.6	7.3—10.9	7.4—1
					Ot	her
onthly percent <sup>6</sup>	5.9	6.1	6.9	8.1	8.7	9.9
	•				Mi	nina
onthly percent	5.2	6.0	7.6	9.5	9.4	9.7
diana IOR	0-79	0-78	54-94	7 7—11 1	8 3—12 0	8 2-1
hio IOR	0-83	0-8.2	4.6-9.1	8.0-10.9	8.3-11.5	8 2 - 1
	0.5	0.2		0.0 10.7	0.0 11.0	J.2 1







egory for Indiana and Ohio. Monthly perto estimate monthly water withdrawal by ties may vary from 0 to 100 percent and 5<sup>th</sup> percentile or interguartile range) may

annual water withdrawals by water-use cat- able. Shaffer (2009) graphs the distribution occurred mostly in April through October. of monthly water withdrawals for individual while nursery irrigation tended to be March sonal water shortages and (or) water-quality centages of annual withdrawals may be used records and the 25<sup>th</sup> and 75<sup>th</sup> percentiles by to November. Crop irrigation for Indiana water-use category for Ohio and Indiana. The interquartile range (IQR; the distance ber and was almost seven times of that for water-use category when monthly data are between the 25<sup>th</sup> and 75<sup>th</sup> percentiles) and the Ohio. Public-supply withdrawals in Ohio unavailable. While the average for irrigation number of records are listed on figures in were more than two times the public-suppl may be 21 percent in July, individual facili- Shaffer (2009) for Ohio and Indiana and are withdrawals in Indiana while industrial withdrawals withdrawals in Indiana while industrial withdrawals withdrawals in Indiana while industrial withdrawals with listed in table 2 for each water-use category drawals in Indiana had were more than two half of the facilities (between the 25<sup>th</sup> and and month. For commercial, public supply, times that of Ohio. The monthly percentindustrial mining, and thermoelectric power, ages of annual water withdrawals for Oh vary from 10 to 40 percent for that month the IQR tended to be a lower range in the and Indiana (table 2) were used to compu withdrawal data should be used when avail- depending on local conditions and water- winter months than in the summer months. monthly water-withdrawal estimates (tab use activities. This method is to provide a For example, the Ohio thermoelectric power fig. 2a and 2b) for the Great Lakes Basin general estimate (and should be used with IQR was 4.9 to 8.8 percent in January and 9.1 (United States and Canada).

caution) when monthly data are not avail- to 12.4 percent in July. Golf course irrigation was concentrated during June to Septem-





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