

# Measuring and Estimating Consumptive Use of the Great Lakes Water

GREAT LAKES COMMISSION

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# Measuring and Estimating Consumptive Use of the Great Lakes Water

*Prepared in cooperation with the Water Withdrawal and Use Technical Subcommittee of the Water Resources Management Decision Support System Project*

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## Background

This paper was prepared as background information in support of the Great Lakes Commission's Water Resources Management Decision Support System (WRMDSS) project as a product of the Water Withdrawal and Use Technical Subcommittee (TSC 3). Work was conducted in the in spring and summer of 2002. The purpose of this paper is to discuss the current state of knowledge of consumptive use of water in the Great Lakes basin. The discussion in this paper reflects findings from three primary information sources. First, a consumptive use bibliography was prepared by Victoria Pebbles of the Great Lakes Commission in support of the project. That bibliography is also included in the Appendix to the final report for the WRMDSS project. Research for this background paper involved a series of informal telephone interviews and email correspondence with various water resource management practitioners and other water policy experts in the Great Lakes region. Finally, the Great Lakes Commission conducted a survey among Great Lakes states and provinces in the spring of 2002 regarding consumptive use information and estimating methods.

This paper shows that consumptive use is calculated in the Great Lakes region either by subtracting return flows (and conveyance losses) from overall withdrawals or by multiplying withdrawal quantities by a coefficient – a generally agreed-upon number that reflects the percentage of overall withdrawals that makes up consumptive use. This very important aspect of water resources planning and management in the U.S. and the Great Lakes basin is influenced by:

- varying definitions of consumptive use and other related and relevant terms,
- estimates made in different ways by different groups (often changing with time and often with limited scientific or other validation), and
- differences in data collection and interpretation.

## What Is Consumptive Use?

The term “water use” as initially used in 1950 in the U.S. Geological Survey’s (USGS) water-use circulars meant withdrawals of water; in the report for 1960, the term was redefined to include consumptive use of water as well as withdrawals. With the beginning of the Survey’s National Water-Use Information Program (NWIP) in 1978, the term was again redefined to include return flow and offstream and instream uses. The NWIP established a method for reporting on U.S. water use and consumptive use every five years. The reports were issued in the form of USGS “circulars.” The first USGS National Water Use Report under the program was issued for 1980 and defined consumptive use as “water that is no longer available because it has been evaporated, transpired, incorporated into products or crops, consumed by man or livestock, or otherwise removed from the water environment.”<sup>1</sup> In the report for 1985, the term was redefined as “that part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.”<sup>2</sup> In the reports for 1990 and 1995, the definition remained the same. In the Great Lakes region, consumptive use has been defined since the late 1980s as “that portion of water withdrawn or withheld from the Great Lakes Basin and assumed to be lost or otherwise not returned to the Great Lakes Basin due to evapotranspiration, incorporation into products, or other processes.” This definition is noted in the first *Annual Report of the Great Lakes Regional Water Use Data Base Repository* representing 1987 data.<sup>3</sup> The same definition has been used since then for each reporting year. Compiled by the Great Lakes Commission, the annual reports of the Great Lakes Regional Water Use Database are based on data submitted by the eight Great Lakes states and two Great Lakes provinces. All jurisdictions use this definition of consumptive use except Minnesota, which defines consumptive use as “water that is taken from a source and not immediately returned to that source.” Under this regulatory

definition, any and all groundwater that is pumped out of an aquifer and not immediately returned to that aquifer is considered to be consumptively used. The annual database reports provide a centralized source of information on water withdrawals, diversions and consumptive uses throughout the entire Great Lakes-St. Lawrence basin. The Technical Subcommittee on Water Withdrawal and Use of the Great Lakes Commission's Water Resources Management Decision Support System project (2002) continues to use the regional database definition.

Various reports from the International Joint Commission (IJC) have slightly different definitions of consumptive use. The 1985 report, *Great Lakes Diversions and Consumptive Uses*, defines consumptive use as "that portion of water that has been withdrawn or withheld from the Great Lakes for various uses such as power generation, manufacturing and so on, and is either known or assumed to be lost due to evaporation during use, leakage, or incorporation into manufactured products, or for other reasons has not been returned."<sup>4</sup> The most recent IJC report addressing consumptive use, *Protection of the Waters of the Great Lakes*, offers as a definition: "that portion of water withdrawn which is evaporated, transpired from plants, incorporated into products, or otherwise lost, and thus is not available for further use in the basin."<sup>5</sup>

Not all the states and provinces have legal or regulatory definitions of consumptive use, and most use the generally accepted definition adopted by the Great Lakes Commission for the Great Lakes Regional Water Use Database. There is general support for this definition across jurisdictions because it was the result of a collaborative and iterative regional process. For the purposes of providing comparisons across the region, most state and provincial water resource managers believe a commonly-accepted definition and generally agreed-upon coefficients for calculating consumptive use will provide useful information where gaps in data and scientific studies exist to verify actual consumption. A common definition and generally-agreed upon coefficients allow water resource managers to make professional estimates, fostering greater regional cooperation and coordination on water resource policy.

*... most state and provincial water resource managers believe a commonly-accepted definition and generally agreed-upon coefficients for calculating consumptive use is the best possible solution in a world that has a paucity of real or reliable data, a lack of resources and commitment to data collection, and a lack of scientific studies to verify actual consumption.*

Although state and provincial water resource managers generally accept the regional database definition of consumptive use, this definition is not as widely accepted by all individual practitioners or water use experts in all sectors. Examples from the industrial and agricultural sectors illustrate this point.

Estimating or calculating consumptive use is possible from a technological, scientific and policy standpoint for sectors (i.e., water withdrawal categories) with point discharges. Many industries, for example, measure the amount of water coming into a particular facility and the amount of water leaving that facility. The difference between the two is considered consumptive use. This assumption is correct for the portion of the database definition that relates to "incorporation into products." However, there may be inadequate accounting for water that is incorporated into products for in-basin uses that provide return flows. Is bottled beer or water necessarily a consumptive use? Or is it only consumptive insofar as the bottles leave the basin? Why are "discharges" from facilities considered non-consumptive (i.e., if consumptive use is calculated as the difference between withdrawals and discharges/return flow) but human or animal "discharges" are not? If humans, like industrial plants, "export" or otherwise take the water out of the basin, is it only then a consumptive use? Notwithstanding the lack of answers to these questions, the inputs and outputs of water into specific facilities at specific locations can be measured, and a reasonable assessment of what is lost or consumed can be calculated.

The portion of the consumptive use definition that refers to water that is “lost or otherwise not returned to the Great Lakes basin” is even less clear. This definition includes water lost “due to evapotranspiration, incorporation into products, or *other processes*,” so it can be interpreted to refer to water that evaporates (e.g., through industrial processes or agriculture) and is then subject to climatological forces that may or may not return the water to the basin through wind, rain and snow. This type of consumptive use is very different in concept from incorporation into products and cannot be measured like facility consumptive use. The technical ability exists to measure the amount of water that becomes vapor (i.e., evaporates) from select industrial processes and power plants that have point source steam releases. Although never attempted, water could be colored so that steam releases would be spatially traceable. This process would be very expensive, and the results may not be worth the costs.<sup>6</sup> The same ability for measurement is not even possible for the agricultural sector (i.e., irrigation), which accounts for a very large percentage of Great Lakes water consumption. Thus comparable data would not be available for all of the water use categories.

In summary, the amount of vapor that remains in or leaves the Great Lakes basin is not measurable. Therefore, determination of basin-wide water loss or consumptive use is not truly feasible due to the size of the Great Lakes basin, the nature of the hydrologic cycle and the impracticality of monitoring vapor movement in and out of a basin. Tate (1999) describes the inherent contradictions in the application of the current consumptive use definition:

“Water consumption refers to water that is lost during use or in a production process. In other words, consumed water is not returned to its original source .... Water consumption is strictly a local concept, and refers to water not returned to the source of the abstraction *in the vicinity of the plant in question* (italics original). In the broader context, because of the earth’s hydrologic cycle, water is never really ‘consumed.’ For example, evaporated water falls back to the earth in the form of precipitation and is not lost to the environment as a whole.”<sup>7</sup>

Consumptive use was conceived as a balancing concept so that individual facilities and water resource managers could account for water used and returned at a particular location. The concept is often extrapolated to a watershed-wide or longer basin-wide scale. Although this expanded application has been beneficial to water resource managers and policymakers, it has resulted in contradictions because water lost to the basin cannot easily be measured or monitored. From a hydrologic perspective, water is neither created nor destroyed; based on the database definition, consumption only occurs when the water leaves the hydrologic basin.<sup>8</sup>

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Application of the current definition of consumptive use to the agricultural sector involves additional complexities. Irrigation experts and practitioners employ a separate concept of consumptive use from the definition that is accepted in policy circles. The irrigation concept of consumptive use is based on evapotranspiration (ET) rates, which is the use of water by a given crop. The amount of water that is reserved for the use of the plant itself in the transpiration process cannot be differentiated from the water that is released into the atmosphere through evaporation. Water released by plants to the surrounding air is not technically lost to the basin until other forces, such as wind and precipitation, relocate the water.

The different views of consumptive use may seem minor, but the lack of a consensus definition for consumptive use ultimately affects how Great Lakes jurisdictions individually and collectively address consumptive use in water resource management activities. Great Lakes policymakers may want to reexamine the definition of consumptive use to reconcile the difference between measuring losses at a single location and estimating overall losses to the hydrologic system.

## Methods for Estimating Consumptive Use

Two primary methods are used to calculate consumptive use in the Great Lakes region. First, it can be calculated by **subtracting return flows (and conveyance losses) from overall withdrawals**. Accounting for the influence, either positive or negative, of conveyance losses and leaks from withdrawals and discharges is critical to the accurate application of this approach. Second, consumptive use can be estimated by **multiplying withdrawal quantities by a coefficient – a generally agreed-upon number that reflects the percentage of overall withdrawals that makes up consumptive use**. Both methods are used in the Great Lakes basin, but the second is predominant. This paper discusses the application, advantages and disadvantages of each.

## Measuring Return Flows to Estimate Consumptive Use

In gathering measured data, the National Pollutant Discharge Elimination System (NPDES) permit program, which is an established federal/state program that requires reporting on discharges to U.S. surface waters under the Clean Water Act, could serve as an information source for some releases/return flows. However, the NPDES permit program does not cover all water withdrawal categories or even all users in those categories that are covered. Discharge data is available for facilities in the public supply, industrial and thermoelectric power categories, which are all subject to NPDES permits. Discharge data is not available for the livestock, irrigation and self-supply domestic categories since these activities currently do not require an NPDES permit. Animal feeding operations, however, have the potential to be regulated under the NPDES program.<sup>9</sup>

Another weakness of the NPDES data is that leaks and conveyance losses are not considered. As noted previously, quantifying positive or negative effects of conveyance losses and leaks is critical to the accurate application of a consumptive use formula that takes the difference between withdrawals and discharges.

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Aging infrastructure can allow groundwater or surface water to infiltrate or leave water supply and discharge systems, resulting in untracked losses or gains of water. Some cases, such as mining operations examined by Dr. Don Tate and others, produce a net gain in water that overshadows the consumptive loss. In this case, consumptive use was reported as zero because the consumptive use figure was negative due to groundwater infiltration.<sup>10</sup> This issue should be accounted for in consumptive use estimation procedures.

## Water Quality and Consumptive Use

One drawback of the withdrawal-minus-return flow method is that return flow is not always of the same quality as the water withdrawn, which can affect the water's reuse value. For example,

“irrigation return flow may be contaminated by pesticides and fertilizers, and, because of the relatively high consumptive use of water in irrigation, the mineral content of the return flow is often substantially greater than that of the water withdrawn/applied. Consequently, irrigation return flow frequently has little reuse potential. This is in significant contrast to the reuse potential of water discharged from thermoelectric plants, where the principal change in the water is an increase in temperature.”<sup>11</sup>

In both cases, however, the quality of the water is negatively affected. If water that is returned to the basin after use is so severely degraded that it is unusable, this water is essentially lost to the watershed. Changes in water quality may also affect a watershed's ecological integrity.

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## Coefficients

### USGS Coefficients

When the NWIP was established in the late 1970s, it was a new endeavor with no history, guidelines or set procedures. Because most states do not collect consumptive use data, the task for calculating or estimating consumptive use was extraordinary. Under the NWIP, the USGS attempted to guide its districts in gathering data for various categories of use, but the emphasis was largely on how to understand data already being collected. When data was nonexistent, the USGS was effectively forced to develop estimations from scratch, as occurred for public water supply sector.<sup>12</sup> Coefficients were developed to provide consistent consumptive use estimates in cases where information for calculating the difference between withdrawals and return flows was insufficient.

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In the first report on estimated use of water in the U.S. for 1980 (USGS Circular 1001), consumptive uses were estimated by subtracting return flow and conveyance losses from withdrawals; there is no mention of coefficients. In the NWIP water use report for 1985 (USGS Circular 1004), coefficients were used for the first time to estimate consumptive use for the U.S. In this report, the coefficients range from 0.1 to 0.5 for domestic; from 0.05 to 0.30 for commercial; from 0.8 to 1.0 for irrigation; from 0.1 to 1.0 for livestock; from 0.07 to 0.72 for industrial, depending on the type of industry; from 0.1 to 1.0 for mining, depending on the type of mining activity; and from 0.02 to 0.07 for thermoelectric, depending on the type of plant.

In the NWIP water use report for 1990 (USGS Circular 1081), consumptive use estimates are based on coefficients multiplied by withdrawals and deliveries. In this report, the coefficients range from 0.1 to 0.5 for domestic; from 0.05 to 0.30 for commercial; from 0.4 to 1.0 for irrigation (a change from 1985); from 0.1 to 1.0 for livestock; from 0.03 to 0.8 for industrial, depending on the type of industry (a change from 1985); from 0.1 to 1.0 for mining, depending on the type of mining activity; and from 0.02 to 0.07 for thermoelectric, depending on the type of plant.

In the NWIP water use report for 1995 (USGS Circular 1200), the most recent report, consumptive use estimates are also based on coefficients multiplied by withdrawals and deliveries. In this report, the coefficients range from 0.1 to 0.5 for domestic; from 0.05 to 0.30 for commercial; from 0.4 to 1.0 for irrigation; from 0.1 to 1.0 for livestock; from 0.1 to 0.4 for industrial, depending on the type of industry (a change from 1990); from 0.1 to 0.9 for mining (a change from 1990); and from 0.01 to 1.00 for thermoelectric, depending on the type of plant (a change from 1990). These coefficients are shown in Table 1.

**Table 1. USGS Consumptive Use Coefficients by Water Use Category**

<b>Year</b>	<b>Domest.</b>	<b>Comm.</b>	<b>Irrig.</b>	<b>Livest.</b>	<b>Indust.</b>	<b>Mining</b>	<b>Thermo.</b>
<b>1985</b>	0.1-0.5	0.05-0.30	0.8-1.0	0.1-1.0	0.07-0.72	0.1-1.0	0.02-0.07
<b>1990</b>	0.1-0.5	0.05-0.30	0.4-1.0	0.1-1.0	0.03-0.8	0.1-1.0	0.02-0.07
<b>1995</b>	0.1-0.5	0.05-0.30	0.4-1.0	0.1-1.0	0.1-0.4	0.1-0.9	0.01-1.00

The changes in the USGS's consumptive use coefficients are not explained in these reports, though there are brief discussions of how water withdrawals are calculated and why some of the figures can vary significantly within certain categories. Over the years, the USGS has tried to balance the national program with the reality that each district (state office) acquires most of its data from state agencies with differing procedures, definitions, minimum withdrawal levels that trigger data collection, etc. USGS staff involved in conducting research and information compilations on water withdrawals and consumptive use for over a decade remark that "documentation of consumptive use coefficients is extremely sparse and most it is not even referenced." When the NWIP came under intense review in the late 1990s, the lack of consumptive use data and documentation on the authenticity or origin of consumptive use coefficients became apparent and consumptive use was eliminated entirely from the 2000 compilation.<sup>13</sup>

USGS Circular 1200, *Estimated Use of Water in the United States in 1995*, refers to a guidance publication, "Guidelines for Preparing U.S. Geological Survey Water-Use Estimates in the United States for 1995," that the agency used to develop 1995 consumptive use estimates. The referenced guidelines were meant to be published as an open file report for public distribution, but the document was never completed due to resource constraints of the NWIP.

In the 1985 report, *Great Lakes Diversions and Consumptive Uses*, the International Joint Commission compares its Study Board's consumptive use estimates with those prepared by USGS. The USGS estimated that consumptive use in the U.S. portion of the Great Lakes basin was 2,140 cfs, which is considerably different than the 4,310 cfs estimated by the IJC's Study Board. The major difference was the consumptive use coefficients that were employed. Unfortunately, these are not documented in the IJC Study Board reports and can only be approximated by comparing estimated withdrawals with estimated consumptive uses. The difficulty in understanding these numbers is manifest by the fact that the IJC felt compelled to convene several in-person meetings with the Study Board's principal investigators on consumptive uses, Art Pinsak and Don Tate, to complete this report.<sup>14</sup>

### **Regional Database Consumptive Use Coefficients**

All consumptive use figures contained in the Great Lakes Regional Water Use Database annual reports are provided by the individual jurisdiction to the Great Lakes Commission. The reports include a table of coefficients used by each of the Great Lakes states and provinces in calculating consumptive use but do not discuss the origin or application of the coefficients by the jurisdictions. The Great Lakes Commission does not use the coefficients in any way to compile the data, which are received from the states and provinces, but does note the coefficients as a reference. These coefficients are included in Table 3. The coefficients were updated for the 1998 regional database from the previous report (1993), according to a Great Lakes Commission consumptive use survey conducted in the spring of 2002.

There is a paucity of records about the origins of coefficients, such as scientific or other rationale. Great Lakes states and provinces generally are unable to find documentation, either published or unpublished, to validate the coefficients that they have adopted. Most jurisdictions employ coefficients based on USGS research or work done by the Great Lakes Commission's Technical Work Group of the Water Resources Management Committee, which was established in 1988. This work group was charged with developing uniform estimation procedures for water withdrawal and consumptive use information. When asked about further documentation or substantiation of the source of coefficients, responses reflected the lack of institutional memory and documentation. Common responses included: "I don't know"; "we've always used these coefficients"; "we have no records"; and "my predecessor used them, but I don't know why." Even in Wisconsin,

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which has incorporated coefficients into state statute, state officials have no record of the origin or rationale of the coefficients.<sup>15</sup>

Notwithstanding the lack of documentation or scientific basis for the consumptive use coefficients, state and provincial officials generally believe that the coefficients are worthwhile for providing a sense of consumptive use lost to various water uses. However, the way states use this information is different and sometimes inconsistent. Officials generally agree that all Great Lakes jurisdictions should use consistent coefficients for making Great Lakes water resource policy decisions.

## **Comparison of Consumptive Use Estimation Approaches**

### **USGS Water Use Categories**

Categories of water use, and by association consumptive use, have changed over the years, creating an additional challenge to comparisons of consumptive use information. In the first USGS circular under the NWIP, water use is divided into five major categories: 1) public supply; 2) rural use (including self-supply domestic and livestock); 3) irrigation; 4) self-supplied industrial (including thermoelectric power); and 5) hydroelectric power.<sup>16</sup>

The second report (for U.S. water use in 1985) used nine water use categories: 1) public supply, 2) domestic, 3) commercial, 4) irrigation, 5) livestock, 6) industrial, 7) mining, 8) thermoelectric power, and 9) hydroelectric power. These categories have remained the same in subsequent NWIP 5-year reports. Water use information is separated into offstream use and instream use. Offstream uses include public supply, domestic, commercial, irrigation, livestock, industrial, mining and thermoelectric power. The only instream use is hydroelectric power. Estimates of consumptive use are given for the eight offstream categories; consumptive use for hydroelectric power is considered negligible. Consumptive use information is presented by state and by region, including the Great Lakes basin. Consumptive use is not estimated for public supply because it is accounted for by deliveries to individual water users (e.g., industrial, commercial) served by public water suppliers (see more discussion under “public water supply” below).

### **Great Lakes Regional Water Use Database Water Use Categories**

The annual reports of the Great Lakes Regional Water Use Database provide information on Great Lakes water withdrawals, diversions and consumptive uses throughout the U.S.-Canada Great Lakes basin. The database employs nine categories of water withdrawals and consumptive use: 1) public supply; 2) self-supply domestic; 3) self-supply irrigation; 4) self-supply livestock; 5) self-supply industrial; 6) self-supply thermoelectric (fossil fuel); 7) self-supply thermoelectric (nuclear); 8) self-supply hydroelectric; and 9) other. Although the USGS water use report and the regional database both have nine water use/withdrawal categories, there are some important differences.

### **Key Differences Between USGS and Regional Database Water Withdrawal/Use Categories**

- Commercial use is a separate category for the USGS; for the Great Lakes database, commercial uses are included within public supply and self-supply domestic.
- The regional database includes two categories for thermoelectric – one for fossil fuel plants and one for nuclear plants, while the USGS includes a single category for thermoelectric.
- The regional database has a category for “other” that includes water used for purposes not reported in the other categories. “Examples include, but are not limited to, withdrawals for fish/wildlife, environmental, recreation, navigation, and water quality purposes.”

- The regional database reports consumptive use for public supply whereas the USGS incorporates consumption into that of the individual users of the public water delivered (e.g., domestic, commercial, and industrial).

The commonalities and differences among these categories are described in greater detail within the discussion of individual water use/withdrawal categories below.

Creating subcategories within some existing water withdrawal categories could be beneficial for estimating consumptive use. For example, manufacturing and mining processes generally have a wide range of consumptive use rates related to specific types of practices that could easily translate into subcategories. Similarly, the self-supply domestic and livestock categories have various types of uses. To develop refined consumptive use coefficients, state and provincial agencies could work directly with specific sectors and water users.

## **Consumptive Use by Water Use/Withdrawal Category**

### **Public Supply**

Consumptive use has not been estimated for public supply under the NWIP because consumptive use is accounted for by deliveries to individual water users (e.g., industrial, commercial) served by public water suppliers. From the USGS perspective, public suppliers do not consume water; they withdraw and deliver it. Consumption occurs by the individual users of the delivered water. Conveyance losses are not considered consumptive use because those losses presumably return to the hydrologic system through groundwater recharge. The only true consumptive loss by a public water supplier would be water lost in backwashing filters or other cleaning processes, but the USGS does not track these uses.<sup>17</sup>

“Public use and loss” is different from consumptive use. The 1995 USGS circular describes public use and loss as 1) water that is used for public purposes such as fire fighting and street washing, etc., 2) water that is exported out or imported into the county or basin from outside the county or basin boundaries, 3) errors in metering, or 4) water gained or lost in conveyance.<sup>18</sup> It is usually calculated as the difference between the amount of water the public suppliers withdraw and the amount the public suppliers sell or deliver to customers. A negative public use and loss would mean water is imported into the county or basin.

In contrast to the USGS, the Great Lakes states and provinces do estimate consumptive use for the public water supply category and provide this information to the Great Lakes Commission for the annual database reports. Illinois, Michigan, Minnesota, Ontario, Quebec and Wisconsin use the 10-15 percent range for this category. In Illinois, however, the coefficient does not apply to the Great Lakes basin because all Great Lakes public supply water withdrawals are discharged out of the basin, resulting in 100 percent consumptive use. Indiana uses a straight 15 percent coefficient, while New York and Pennsylvania use 10 percent. The 10-15 percent coefficient is based in statute in Wisconsin, but for other jurisdictions is based on consensus of the Great Lakes Commission Water Resources Management Committee Technical Work Group from the late 1980s and/or USGS guidance.

Great Lakes states, provinces and the Great Lakes Commission could consider public supply as the USGS does, in terms of consumptive use by individual withdrawal/user categories. This could simplify reporting procedures without compromising data quality. The jurisdictions may be advised to have the ability to distinguish the source of the water (e.g., self-supply vs. public supply) for those categories as well as the respective withdrawal quantity.

### **Self-Supply Domestic**

This category differs greatly between USGS and the regional database. The USGS does not have a self-supply domestic water use category, but uses a domestic water category that includes both self-supply and public supply water used “for normal household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens.”

Self-supply domestic water use as defined in the regional database is “water used for normal household purposes” or “residential water use” as well as commercial and institutional water uses. These include “water used for drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns.” Notably, the regional database includes commercial water use, which is a stand-alone category in the NWIP reports. These commercial uses include self-supply water used by motels, hotels, restaurants, office buildings, civilian and military institutions, mobile homes, hospitals, schools, fire fighting, air conditioning, amusement and recreational water uses such as snowmaking and water slides “and other similar uses not covered under public water supply.” The differences in the definitions of domestic prevent simple comparisons of USGS and regional database consumptive use figures.

The regional database domestic definition appears to include the multitude of uses that do not neatly fit into any of the other self-supply water use categories. Because many of these uses are rural and/or unregulated, water use figures are estimated. For the USGS domestic category, water use figures are generated by adding public supply domestic uses to an estimation of self-supply domestic uses. The self-supply figure is produced by applying a per capita water use coefficient (60 to 120 gallons per person per day) to the portion of the population not connected to public water supply. For the regional database self-supply domestic category, which represents more diverse uses, a coefficient of 75 gallons (U.S.) per capita per day is used to estimate water use. Such rough water use estimations inhibit good estimations of consumptive use. Nonetheless, the Great Lakes states and provinces all estimate consumptive use with coefficients ranging between 10 and 15 percent of withdrawals. These consumptive use coefficients are exactly the same as public supply. Absent more science or detailed studies to confirm the basis for these coefficients, the states and provinces generally agree that these numbers provide a good starting point for consumptive use estimations.

### **Self-Supply Irrigation**

Methods of estimating withdrawals for irrigation vary greatly. Methods include theoretical crop requirements (estimates of water applied to given crops based on acreage), application rates and conveyance losses. The USGS calculates consumptive use for irrigation by subtracting return flows and conveyance losses from withdrawals. However, obtaining reliable estimates of conveyance losses is difficult, so some withdrawal estimates may only be rough approximations of actual conditions.<sup>19</sup> Because irrigation withdrawals are estimated with low confidence levels, challenges exist in accurately estimating consumptive uses.

As noted above, irrigation experts and practitioners prefer using evapotranspiration (ET) rates to estimate consumptive use instead of using what many feel is an inflated consumptive use coefficient for irrigation. In the field, ET rates are calculated for particular crops and locales using accepted formulas that consider several factors, including the water holding capacity of the soil, the crop root zone and climate. These formulas are used in the development of models that can determine water needs by particular crops over time, otherwise known as irrigation scheduling.<sup>20</sup> This scientific calculation of water needs allows for more efficient water use. If crops consume 90 percent of applied water, only 10 percent can be attributed to runoff and percolation. Irrigation is a high consumption sector, but sound conservation and application practices along with technological advances have contributed to a higher level of water use efficiency in this sector. These technological advances can help irrigators become more efficient in the amount of water that they use which can be both environmentally and economically beneficial. By applying less

water, pumping costs can be reduced or land owners may be able to irrigate more acreage using the same amount of water.

State and provincial officials in the Great Lakes region generally acknowledge that irrigation is the largest consumptive user and that irrigation practices are relatively efficient. They also acknowledge that irrigation is necessary for the critical production of food and fiber. However, policy questions arise around irrigation withdrawals and consumptive losses increasingly due to location and timing issues. Water for irrigation in the Great Lakes basin comes primarily from inland lakes and groundwater sources – not directly from the Great Lakes – and withdrawals are concentrated at times when natural flows and levels are generally lower and other demands on these water sources are high. The combined effects resulting from quantity, timing and location of irrigation withdrawals raises important questions about the need to balance the critical need for water to produce food and fiber with the availability of water resources (i.e., within sub-basins) for stream and lake ecology and other water use demands. Policymakers might consider evaluating the development of new irrigation systems to determine their impact vis-a-vis existing water supplies and use demands. One option would be to discourage the development of new irrigation systems in areas where groundwater or inland water supplies are limited, while allowing expansion of irrigation systems in areas with adequate water supplies (e.g., abundant groundwater supplies and/or large tributaries that are not easily depleted by intensive water use) and where no significant other use conflicts exist.

Some jurisdictions outside the Great Lakes region have 100 percent consumptive use coefficients for irrigation. None of the Great Lakes jurisdictions use this coefficient, as it would be inconsistent with the regional database definition of consumptive use because it assumes that no water returns to the

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hydrologic system through infiltration and percolation.<sup>21</sup> Eight of the ten Great Lakes jurisdictions use a 90 percent consumptive use coefficient for irrigation. The exceptions are Ontario, which uses 78 percent, and Wisconsin, which uses 70 percent. As with other water use sectors in Wisconsin, the 70 percent coefficient was established in state statute, but the origin of the coefficient is unknown. Principal staff members with the Wisconsin Bureau of Watershed Management involved in the state's water use reporting program have expressed interest in Wisconsin adopting a 90 percent consumptive use coefficient for irrigation that would be in line with the other Great Lakes states.<sup>22</sup> The origin of Ontario's irrigation coefficient could not be established for inclusion in this paper.

### **Self-Supply Livestock**

The USGS and regional database livestock water withdrawal categories both include water for livestock, feed lots, dairies, fish farms and other on-farm needs.<sup>23</sup> Beginning in 1990, USGS considered animal specialties as a subset of livestock due to the large increase in water use for fish farming. USGS reports that consumptive use estimates for livestock nationwide are based on coefficients ranging from 10 to 100 percent, but no explanation is given for the great variability. Great Lakes jurisdictions are more aligned; most states and provinces use an 80 percent consumptive use coefficient for livestock, except for New York and Wisconsin, which use 90 percent. In the 1993 database report, New York used a livestock coefficient of 80 percent and the reason for the change to 90 percent in the 1998 database report is unclear. Wisconsin's livestock coefficient is mandated in state law, but state officials have no recorded basis for the coefficient.

## Self-Supply Industrial

USGS reports separately on water use from industrial and mining activities. For the regional database, these uses are reported in the single self-supply industrial category, which excludes public supply sources and water reused in a closed-loop recirculation cycles.

Michigan and Wisconsin are the only Great Lakes jurisdictions that mandate consumptive use reporting by facilities for the self-supply industrial category. Michigan does not provide coefficients or technical guidance to assist facilities with their estimations, and about 30 percent of facilities that should report consumptive use do. State officials believe the low compliance rate is due to challenges related to the various types of manufacturing discharges. For those that report, consumptive use appears to be estimated based on methods ranging from professional guesses to the difference between withdrawals and discharges.<sup>24</sup> In Wisconsin, consumptive use reporting by self-supply industrial users is virtually non-existent due to lack of enforcement and other weaknesses.<sup>25</sup>

Indiana, New York, Ohio and Pennsylvania have some level of voluntary consumptive use reporting, as explained in the section on mandatory and voluntary reporting. Due to concerns over the accuracy of the facility-provided data, only Pennsylvania opts to use the facility data to determine consumptive use. The preference for coefficients when facility-supplied data are available indicates the general sense among state and provincial officials that facility-provided data is unreliable. However, industrial facilities have the potential to actually measure withdrawals and return flows, which could be used to develop relatively accurate consumptive use estimates. States and provinces working with industry to develop methods to measure and report on consumptive use may be the most feasible method for generating consumptive use data for this category given the number of variables involved (e.g., cost of energy, treatment process, age and type of plant, type of natural resources used, economic factors, etc.). Audits or other quality control measures would help address concerns over data quality and reporting compliance.

*States and provinces working with industry to develop methods to measure and report on consumptive use may be the most feasible method for generating consumptive use data for this category given the number of variables involved.*

Database coefficients vary more for the self-supply industrial category than any other water withdrawal category, ranging from 6 percent in Indiana to 25 percent in New York. Several jurisdictions consider the type of plant and the Standard Industrial Classification (SIC) code, which generally produces an average coefficient that is between 10 and 15 percent. Development of subcategories and associated coefficients that are specific to the type of mining and/or manufacturing activity would facilitate collection and reporting of more detailed and reliable data.

Ontario's experience with an industrial water use coefficient and 1998 data compares the two methodologies. The province used a consumptive use coefficient of 6.8 percent for the self-supply industrial category when preparing information to submit for the 1998 database report. The coefficient was developed from measured withdrawals and returns from previous years of industrial survey data. Subsequent to the 1998 submission, facility-measured data on consumptive use became available. Measured consumptive use data was not available at the time of the reporting, but the province later obtained facility-measured data on consumptive use. Ministry of Natural Resources staff found less than a 5 percent difference between the facility-supplied data and the coefficient-generated calculations. The coefficient resulted in overestimations for some lake basins and underestimations in others, but at the province-wide level these outliers cancelled out.<sup>26</sup> The Canadian industrial water use surveys that have provided measured values in recent years may be discontinued, so the province will continue to use the 6.8 percent coefficient.

## Self-Supply Thermoelectric (fossil fuel and nuclear-powered facilities)

The thermoelectric power water withdrawal category is reported as two distinct categories in the regional database but as a single category in the USGS circulars. The reason for the distinction in the regional database is unknown. For this paper, all thermoelectric water withdrawals are discussed under this heading and distinctions are made where appropriate.

Water withdrawals for power generation are well-monitored by federal and state agencies. In most Great Lakes jurisdictions, facilities measure withdrawals for thermoelectric power and report data to the state or province. This means withdrawal data is readily available and relatively reliable. Consumptive use calculations are done by subtracting discharges from withdrawals. Because the water is used for cooling purposes and is not incorporated into products, consumptive use is generally reported as one percent to two percent of the withdrawal (specifically for once-through cooling methods).

The variability in water cooling and discharge techniques and uncertainties of evaporation rates complicate the process of accurately calculating consumptive use. Continuous loop cooling recycles water through cooling towers or ponds, so less water is withdrawn but more water evaporates. The USGS estimates that approximately 60 percent of the water withdrawn is lost to evaporation through closed-loop cooling systems. However, the U.S. Department of Energy estimates only 30 percent to 40 percent of water is lost to evaporation. Although there is no consensus on the evaporation rate, both methods assume the same quantity of water is used to reduce heat.

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Once-through cooling systems use significantly more water, but the warm water is released back into the system and the evaporation rate is believed to be substantially less. However, there is no consensus on the evaporation rates from once-through facilities. The USGS circular for 1995 attributes a 3 percent evaporation loss from once-through systems.

Similar to the self-supply industrial category, facility-provided withdrawal data is generally not used by the states and provinces to estimate consumptive use. In Michigan, for example, thermoelectric plants must report their water use and consumptive use. Initially state officials evaluated this data to learn more about consumptive use, but the facility data were inconsistent and the process was very time consuming. Michigan examined sector water use and found that nearly all of the high water volume once-through plants have consumptive loss rates between 1 percent and 1.5 percent; the lower volume cooling tower and cooling pond plants had higher rates. Combined, the rates fell in the 1 percent to 2 percent range, so Michigan decided to use this as an overall coefficient.<sup>27</sup>

Indiana, New York, Ohio and Pennsylvania have some level of voluntary consumptive use reporting for fossil fuel and nuclear thermoelectric facilities, as explained in the section on mandatory and voluntary reporting. Due to concerns over the accuracy of the facility-provided data, only Pennsylvania uses the facility-reported data to determine consumptive use.

The preference for coefficients when facility-supplied data are available indicates the general sense among state and provincial officials that facility-provided data is unreliable. This has important implications for the power generation sector because power generation facilities have perhaps the greatest ability to measure withdrawals and returns and thus develop fairly accurate estimates of consumptive use. An outstanding issue is to develop some consensus around evaporation rates associated with the different types of power plants.

*... power generation facilities have perhaps the greatest ability to actually measure withdrawals and return flows, which could be used to develop relatively accurate consumptive use estimates.*

The coefficients used by the states and provinces for thermoelectric vary from 0.5 to 14 percent: Minnesota and Indiana use 2 percent; Ontario uses 0.9 percent; Quebec uses 10 percent; Wisconsin uses 0.5 percent to 1.0 percent; Michigan uses 1 percent to 2 percent; New York uses 2 percent for fossil fuel plants and 5 percent for nuclear powered facilities; Ohio estimates once-through cooling systems to be 1 percent to 2 percent and uses a 14 percent coefficient for closed-loop cooling plants (all of Ohio's nuclear power plants have closed-loop cooling systems); Illinois and Pennsylvania use varying coefficients depending on the cooling process.

## Hydroelectric

Hydroelectric power generation involves the use of falling water to drive turbines that generate electricity. USGS considers hydroelectric power generation to be an instream use, meaning the water use takes place without being diverted or withdrawn from surface or groundwater sources.<sup>28</sup> The regional database hydroelectric power category includes both instream uses and offstream uses. The latter involves pumping and storing the water. USGS and the regional database both assume no consumptive use occurs for hydroelectric power because minimal evaporation occurs. However, the pumping, storage and repeated use of water for offstream processes raise two important issues related to consumptive use: water stored in reservoirs evaporates and the repeated use of the water effectively eliminates the availability of this water for other uses in the basin. Nonetheless, this is the single water use category in which the states and provinces and the USGS have agreed on a single consumptive use coefficient of 0%.

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## Other

This category is only present in the regional database and includes water uses not reported in the other categories. Examples include withdrawals for fish and wildlife, environmental, recreation, navigation and water quality purposes. The states and provinces do not use this category consistently. All jurisdictions report that the coefficient varies depending on the use, except Indiana, which uses a coefficient of 12 percent. Indiana's rationale for the coefficient is unknown.

## Consumptive Use Reporting By Jurisdiction

The following section is a brief discussion of consumptive use reporting frameworks by Great Lakes jurisdictions. Table 2 describes the facility consumptive use reporting processes and applications for jurisdictions with specific provisions. A table with more detailed and comparative information on each jurisdiction's consumptive use reporting and estimating policies and procedures is included in the Report on State and Provincial Water Use and Conservation Programs in the Great Lakes-St. Lawrence Basin (2002), also produced for the Water Resources Management Decision Support System project. Unpublished individual tables were also prepared for each jurisdiction by water use/withdrawal category and can be obtained by contacting Victoria Pebbles at the Great Lakes Commission: 734-971-9135 or vpebbles@glc.org.

**Table 2. Non-Estimated Processes for Consumptive Use Reporting by Facilities**

<b>Jurisdiction</b>	<b>Description</b>	<b>Application</b>
<i>Mandatory Reporting</i>		
<b>Michigan</b>	Required for self-supply fossil fuel and self-supply industrial only	Submitted for database reports
<b>Wisconsin</b>	Required for all water use categories	Submitted for database reports
<i>Voluntary Reporting</i>		
<b>Indiana</b>	Return flow data for all facilities with the capacity of more than 100,000 gal/day included in initial registration form	Not used (concerns over accuracy)
<b>New York</b>	Consumption data for facilities using more than 100,000 gal/day included in withdrawal reports (public supply not included)	Not used (concerns over accuracy)
<b>Ohio</b>	Return flow data for self supply fossil fuel and self-supply nuclear facilities with capacity of more than 100,000 gal/day	Not used (concerns over accuracy)*
<b>Ontario</b>	Many industrial facilities provide data	Submitted for database reports
<b>Pennsylvania</b>	Return flow data included in withdrawal reports for self-supply categories of fossil fuel, nuclear and non-mining industrial	Submitted for database reports

\*Although Ohio does not use this data, consumptive use for the self-supply fossil fuel category is reported by facilities, which apparently base their calculations on withdrawal and return flow data.

### **Mandatory**

Most Great Lakes states and provinces estimate consumptive use at the jurisdictional level, but Wisconsin and Michigan have basic legislative authority to require consumptive use reporting by facilities. Prompted by the Great Lakes Charter of 1985, Wisconsin passed legislation in the late 1980s that requires consumptive use reporting for seven water use categories: irrigation, livestock, thermoelectric power, commercial, industrial, mining, and public water systems.<sup>29</sup> Michigan requires consumptive use reporting for only the self-supply thermoelectric (fossil fuel) and self-supply industrial categories.

### **Voluntary**

Voluntary facility consumptive use reporting occurs in Indiana, New York, Ohio and Pennsylvania through water use registration forms or reports for facilities that use or have the capacity to withdraw 100,000 gallons (380,000 litres) of water per day. New York and Ohio request return flow from registered facilities in withdrawal reports, and Indiana collects return flow data in initial registration forms. In Pennsylvania, the reporting of withdrawals and return flows is only requested for thermoelectric (fossil fuel and nuclear) and industrial (not including mining). Pennsylvania uses this data to calculate consumptive use, but Indiana, New York and Ohio rely on established coefficients due to concerns over its accuracy. Ontario also has some voluntary reporting by industrial facilities, and this data is used for database submissions.

## Recommended Actions for Consumptive Use Estimating, Calculating and Reporting

While mandatory consumptive use reporting by facilities could be established as part of current water use reporting requirements in several jurisdictions, there is little evidence that this would improve consumptive use data. Without accurate and reliable withdrawal data and consistent water withdrawal/use reporting, mandatory reporting for consumptive use would be little more than an administrative exercise. Wisconsin's experience illustrates this point. Wisconsin state law established a consumptive use reporting program and established consumptive use coefficients for seven water withdrawal categories. Wisconsin's consumptive use reporting program was created to be true to the intent of the 1985 Great Lakes Charter. However, the program has seriously faltered for several reasons: there is little validity to the coefficients, much of the withdrawal data is based on estimates, state agency personnel do not have a clear understanding of the purpose of the program and user groups are fearful that reporting consumptive uses will lead to increased regulation. The program essentially has not been implemented due to the overwhelming administrative challenges and costs that would provide questionable benefits. The state devotes very little personnel time to compiling the data that is reported and does not enforce compliance with reporting requirements.<sup>30</sup>

Any methodology for generating accurate consumptive use figures relies on accurate withdrawal data, which is lacking for all water use categories for all jurisdictions. For example, consumptive use data is often an estimate of an estimate – the original withdrawal is estimated and the consumptive use coefficient is an estimate. If decisions on regulations or policies are based on these double estimates, they could easily be criticized and subject to legal challenge. Consumptive use figures that are based on location-specific measured withdrawals and return flows would be more reliable.

Reliable withdrawal and return flow/discharge data are necessary precursors to improved knowledge of consumptive use in the Great Lakes basin. Most Great Lakes jurisdictions have water use reporting programs, but reporting consistency varies widely and withdrawal data is mostly estimated. States and provinces that have facility-measured data are skeptical of the data's reliability. A first step toward establishing a framework that reliably documents consumptive use is to strengthen existing water use reporting programs by requiring actual measurements of withdrawals and returns where feasible and developing a quality control system with audits of facility measurement.

*A first step toward establishing a framework that reliably documents consumptive use is to strengthen existing water use reporting programs by requiring actual measurements of withdrawals and returns where feasible and developing a quality control system with audits of facility measurement.*

One way of addressing uncertainties surrounding measuring return flows would be to develop one or several coefficients that could be used to reflect conveyance losses and leaks, depending on the type and age of the water supply and discharge system and apply these coefficients to NPDES data for return flows (see discussion of NPDES data above).

Where actual measurements of withdrawals or return flows/discharges are not feasible, such as for irrigation, livestock and rural uses, other reliable methods for calculating or estimating consumptive uses can be applied. Several jurisdictions have acknowledged the need to conduct additional research, including pilot or field studies, to reassess existing coefficients and determine defensible consumptive use coefficients that are agreeable to all Great Lakes jurisdictions.<sup>31</sup> Examples of research that would make an important contribution to substantiating consumptive use estimates include studies that measure the use and distribution of irrigation waters from Lake Michigan in Wisconsin and a case study that measures all aspects of public supplies at two Ohio cities.<sup>32</sup> This type of research would help develop common

consumptive use coefficients and lead to improved water withdrawal and use reporting that will advance general understanding of consumptive use.

**Table 3. Consumptive Use Coefficients By Water Use Category Among Great Lakes Jurisdictions and USGS<sup>∅</sup>**

<b>Water Use Category</b>	<b>Illinois</b>	<b>Indiana</b>	<b>Michigan</b>	<b>Minnesota</b>	<b>New York</b>	<b>Ohio</b>	<b>Ontario</b>	<b>Pennsylvania</b>	<b>Quebec</b>	<b>Wisconsin</b>	<b>USGS 1995</b>
<b>Public Supply</b>	10-15%	15%*	10-15%	10-15%	10%*	10-15%	10-15%	10%*	10-15%	10-15%	N/A
<b>Self-Supply Domestic</b>	10-15%	15%*	10-15%	10-15%	10%*	10-15%	10-15%	10%*	10-15%	10-15%	10-15% of withdrawals and deliveries
<b>Self-Supply Irrigation</b>	90%	90%	90%	90%	90%	90%	78%	90%	90%	70%	40-100% of withdrawals and theoretical crop requirements
<b>Self-Supply Livestock</b>	80%	80%	80%	80%	90%*	80%	80%	80%	80%	90%*	10-100% of withdrawals
<b>Self-Supply Industrial</b>	For both mfg. & mining varies by plant and SIC code	6%	10-15%*	For both mfg. & mining varies by plant and SIC code	25%*	10%; except salt mining is 90%*	Facility measured; varies by plant and facility*	For both mfg. & mining varies by plant and SIC code	10% for pulp and paper industry	10.2% for both mfg. and mining	10-40 % depending on type of industry
<b>Self-Supply Thermoelectric (Fossil Fuel)</b>	Varies by individual plant; est. using makeup water for each system.	2%	1-2% for plants using once-through cooling; plant by plant analysis for wet cooling towers*	2%*	2%*	Negligible; estimates based on indiv. plant reports of withdrawals, return flows (1-2% once-through, 14% closed-loop)	0.9% based on reports of increased local lake evaporation due to discharge of heated water to lakes.	Varies among individual plants.	10%; estimates obtained from USGS report	0.5% - 1%	1-100% varies greatly depending on type of plant and cooling process
<b>Self-Supply Thermoelectric (Nuclear)</b>	Varies by individual plant; est. using makeup water for each system.	N/A Indiana has no facilities in the basin	1-2% for plants using once-through cooling; plant by plant analysis for wet cooling towers.*	2%*	5%*	14%; based on reports of increased local lake evaporation due to discharge of heated water to lakes.	0.9% based on reports of increased local lake evaporation due to discharge of heated water to lakes.	Varies among individual plants.	10%; estimates obtained from USGS report	0.5% - 1%	1-100% varies greatly depending on type of plant and cooling process
<b>Hydroelectric</b>	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
<b>Other</b>	Varies based on use	12%	Varies based on use	Varies based on use	Varies based on use	Varies based on use	Varies based on use	Varies based on use	Varies based on use	Varies based on use	N/A (category not used)

<sup>∅</sup>based on Great Lakes Commission Survey, Spring, 2002

\*denotes change from Great Lakes Regional Water Use Data Repository Representing 1993 Data

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- <sup>20</sup> Phone interview with John Barclay, USDA, NRCS. June 24, 2002.
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