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Wastewater Treatment Plant Endocrine Disrupting Chemical Monitoring Study

Minnesota Pollution Control Agency

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Author

Mark Ferrey, Minnesota Pollution Control Agency

Contributors

Kathy Lee, U.S. Geological Survey,
Minnesota Water Science Center

Larry Barber, U.S. Geological Survey,
Boulder, Colorado

Jeffrey Writer, U.S. Geological Survey
Boulder, Colorado

Heiko Schoenfuss, St. Cloud State University

Dalma Martinovic, St. Thomas University

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Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 | www.pca.state.mn.us | 651-296-6300
Toll free 800-657-3864 | TTY 651-282-5332

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Contents

Glossary of terms and abbreviations

EAC	Endocrine active compound
Estrogenic chemical	A chemical that binds to estrogen receptors and elicits a response similar to natural estradiol hormones.
VTG	Vitellogenin; the protein normally found in female fish associated with egg development.
WWTP	Wastewater treatment plan
Units	
One part per million: ppm, mg/Kg, mg/L, µg/g	
One part per billion: ppb, µg/Kg, ng/g, µg/L	
One part per trillion: ppt, ng/Kg, ng/L	

Executive Summary

Some chemicals can mimic the effects of hormones in animals and cause adverse behavioral and physiologic effects, including impairment of the reproductive system or disruption of growth and development of an organism. These *endocrine active chemicals*, or EACs, do not usually exhibit acute toxicity at the levels normally found in the environment, but instead can alter the normal functioning and growth of the exposed organism at very low concentrations (Streets et al. 2008). (Scientists are increasingly adopting the term "endocrine active chemicals" over the term "endocrine disrupting chemicals" as a more accurate description for chemicals affecting the endocrine system).

Previous investigations have shown that EACs, including pharmaceuticals, are widespread at low concentrations in Minnesota's rivers and lakes. These studies show that fish in these waters show signs of endocrine disruption, such as the feminization of male fish.

The Minnesota Pollution Control Agency (MPCA) was directed by the 2009 Minnesota Legislature to monitor surface water for these chemicals at points upstream, at the point of discharge, and downstream from at least 20 wastewater treatment plants (WWTPs). (See Appendix A for statutory language). This report presents the results of this study.

WWTPs that were included in this study differed in capacity and treatment type. Results show that pharmaceuticals, triclosan, nonylphenol, nonylphenol ethoxylates, octylphenol, octylphenol ethoxylates, bisphenol A, and steroid hormones were detected in wastewater, surface water and sediment samples. Several of these compounds were detected at upstream locations as well as downstream from WWTPs, indicating that WWTPs are not the only source of these chemicals.

The most frequently detected contaminants include:

- Nonylphenol, a known EAC that is used in commercial products and is a breakdown product of commercial detergents. Nonylphenol was detected in 80 percent of the effluent samples, in 42 percent of the surface water samples, and in 63 percent of sediment samples. Nonylphenol was found in 33 percent of water samples collected upstream of WWTPs.
- Bisphenol A, which is used to make polycarbonate plastics and is considered an EAC, was detected in 56 percent of effluent samples, in 31 percent of surface water samples, and in 25 percent of upstream water samples.
- The contraceptive hormone 17α-ethinylestradiol, a known EAC, was detected in 40 percent of effluent samples and in 22 percent of all water samples. This hormone was detected both upstream and downstream of WWTPs at similar frequencies (13 percent).
- 17 β-estradiol, a known EAC. This naturally occurring hormone was detected in 68 percent of effluent samples. It was detected in 13 percent of upstream water samples and in 92 percent of sediment samples.
- The pharmaceuticals carbamazepine (an anti-seizure medication used to treat attention deficit disorders) and sulfamethoxazole (a common antibiotic) were detected in 96 percent of effluent water samples. Sulfamethoxazole was found in 46 percent of upstream water samples and in 100 percent of the downstream samples, while carbamazepine was found in 21 percent of the upstream water samples and in 79 percent of the downstream water samples. Antidepressant medications also were frequently detected.

These and other contaminants were detected in the water and sediment at concentrations that ranged from the low part per trillion to parts per billion. Several contaminants, such as hormones, nonylphenol, or bisphenol A, were measured at concentrations that have been shown to impair endocrine function in fish and wildlife. Currently, there are no environmental regulatory standards that are based on the endocrine active properties of chemicals.

The results of this study are consistent with previous investigations that show that many pharmaceutical and EACs are present at low concentrations in wastewater effluent, surface water, and sediment. The results add clarity to the types and amounts of compounds released from WWTPs, and indicate that several of these chemicals are present upstream of WWTP sources.

Fish studies were conducted at five WWTP locations. Fish were exposed to dilutions of WWTP effluent and to water upstream and downstream of the WWTP using a mobile laboratory that provided controlled conditions. Although the observed biological effects were subtle, vitellogenin concentrations in the male fathead minnows increased with the proportion of and time of exposure to WWTP effluent. Vitellogenin is a protein naturally found only in female fish, but is often found in male fish after they have been exposed to EACs. Changes in physical sex characteristics in male fish exposed to WWTP effluent were observed.

Water that contains a mixture of chemicals may have *estrogenic* properties, or, in other words, mimic the effects of hormones. The effluent from most of the 25 WWTPs tested had this hormone-like effect, although the degree of this estrogenicity varied from plant to plant. This also was observed in water collected upstream and downstream of the WWTPs.

At three WWTPs, effluent, upstream water, and downstream water were tested for the ability to turn on or turn off a wide variety of genes in fish using specific gene assays developed for this purpose. Water that contained effluent influenced the expression of several hundred genes in ways that upstream water did not.

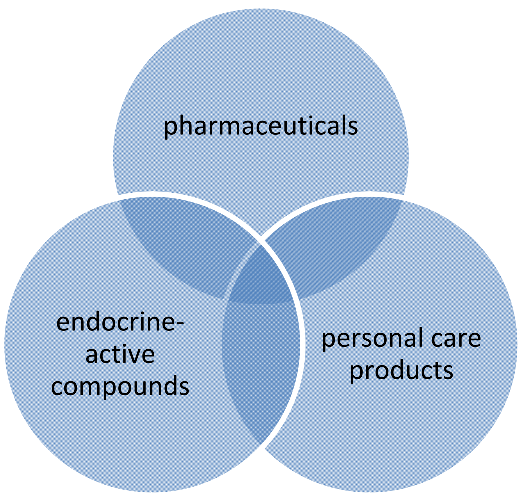
Although this study has advanced an understanding of the presence and concentration of EACs in WWTP effluent, surface water, and sediment, a number of questions remain unanswered. Ongoing research that is focused on monitoring EACs and assessing their effects on fish and wildlife will contribute important information that is needed by resource managers and the public to understand what impact these chemicals have on Minnesota’s environment.

Background

There are more than 500 WWTPs in Minnesota. Chemicals used in homes, industry, and agriculture are collected by the WWTP collection system and treated using a variety of engineering processes. However, compounds introduced into this system - including EACs and pharmaceuticals - are often observed in the effluent discharged to the surface water after treatment. In addition, some endocrine active compounds are produced by the degradation of parent compounds, and pharmaceuticals can be degraded into metabolites that still exhibit biologically active characteristics. EACs do not usually exhibit acute toxicity at concentrations typically found in the environment. Instead, EACs are hormonally active at very low, non-toxic concentrations, and may alter normal physiological functions in organisms that are exposed to them. An unknown number of the more than 87,000 chemicals that are manufactured worldwide may possess endocrine active properties.

Pharmaceuticals, personal care products, anthropogenic (or man-made) compounds, pesticides, or naturally occurring compounds also may be endocrine-active chemicals. Not every chemical found in wastewater, however, is an EAC. In other words, not all of these chemicals possess endocrine-active properties (Figure 1). In this report, the terms "EAC" or "chemical" are used for the sake of simplicity to refer to the broad group of pharmaceuticals, EACs, personal care products, and other chemicals that are detected in wastewater.

Figure 1. Diagram showing the relationship between pharmaceuticals, personal care products, and endocrine-active compounds.



Several previous monitoring studies over the last 15 years identified EACs in Minnesota rivers and lakes, as well as in WWTP effluent (Barber et al. 2007; Barber et al. 2000; Kolpin et al. 2002; Lee et al. 2010; Lee et al. 2004; Lee et al. 2008; Lee et al. 2008; Writer et al. 2010). These investigations also have shown evidence of endocrine disruption in fish downstream of WWTP effluents. Available data suggest that concentrations of EACs in Minnesota WWTPs and receiving streams greatly vary, and that some WWTPs are discharging chemicals at concentrations that could have an effect on fish and wildlife. However, the number of WWTPs sampled among previous studies represents a small fraction of the WWTPs in Minnesota and thus may not be representative of all WWTPs in Minnesota.

The Minnesota Legislature directed the MPCA in 2009 to sample at least 20 WWTPs representing a variety of treatment types, capacities, and regions. The MPCA, after consulting the University of Minnesota, the Minnesota Department of Health, the Minnesota Department of Natural Resources, and the Metropolitan Council Environmental Services, collaborated with the U.S. Geological Survey (USGS), St. Cloud State University (SCSU), and the University of St. Thomas on the study.

A combination of chemical and biological analyses was used to measure the presence and effects of EACs in Minnesota WWTP effluents and receiving waters:

1. Analysis of EACs in water samples collected from the effluents from WWTPs and in the water upstream and downstream of the WWTPs.

   The testing included a total of 67 chemicals, including 20 pharmaceuticals, 17 steroid hormones, 6 alkylphenolmethoxycarboxylates, and 24 alkylphenols and other natural and synthetic chemicals indicative of a variety of wastewaters. These chemicals have been tested in several prior EAC studies in Minnesota but are not routinely monitored at WWTPs. Several of these chemicals, such as nonylphenol and octylphenol (alkylphenols) and various hormones, are known to be endocrine active. Other chemicals, though not possessing endocrine active properties, are natural or synthetic chemicals found in a variety of wastewaters including WWTP effluent, industrial effluent, and runoff from agricultural and urban land use. The effects of most of these chemicals, whether in surface water or sediment, on human health or the environment are unknown.

2. Analysis of EACs in sediments collected upstream and downstream of effluent discharges at a subset of sites.

   The testing included a total of 76 chemicals, including 17 steroid hormones and 57 natural and synthetic chemicals indicative of a variety of wastewaters.

3. Measurement of total estrogenicity of water samples using a gene assay.

   WWTP effluent can have hormone-like properties, although it is rarely clear what specific compounds in the effluent are directly responsible for those effects. In other words, effluent or water may be *estrogenic*. This estrogenicity can be measured by looking at certain genes that are activated, or expressed, when exposed to chemicals. This is a powerful method that allows scientists to look at the overall biological effect of a mixture of many chemicals in water (Martinovic et al. 2008).

4. Measurement of gene expression in fish that were exposed to surface water and WWTP effluent using a DNA microarray test.

   There are many thousands of genes in an organism that can be switched on or off when the animal is exposed to chemicals in the environment, each of which affect the health and behavior of the organism in some way. DNA microarray testing is an emerging technology that uses thousands of genes, allowing scientists to see whether specific genes are activated, or expressed, in response to a chemical or a mixture of chemicals in water. This powerful molecular test can reveal detailed information about the effects that chemicals in WWTP effluent have on fish metabolism.

5. Biological evaluation of fish that are exposed to WWTP effluent at a subset of locations.

   Observing how fish respond when exposed to actual mixtures of chemicals in wastewater demonstrates what effect those mixtures have on wild fish in the environment. A mobile exposure laboratory, which was funded through prior studies on EACs in Minnesota, was used in this study at a few of the 25 WWTPs to investigate how effluent from WWTPs affects fathead minnows, which is a test species recommended by the U.S. Environmental Protection Agency for studies of EACs. These studies reveal how wild fish populations may be affected near WWTPs.

This report presents the methods, results and discussion of the study. The tables and figures referenced in the text begin after page 18 of the report.

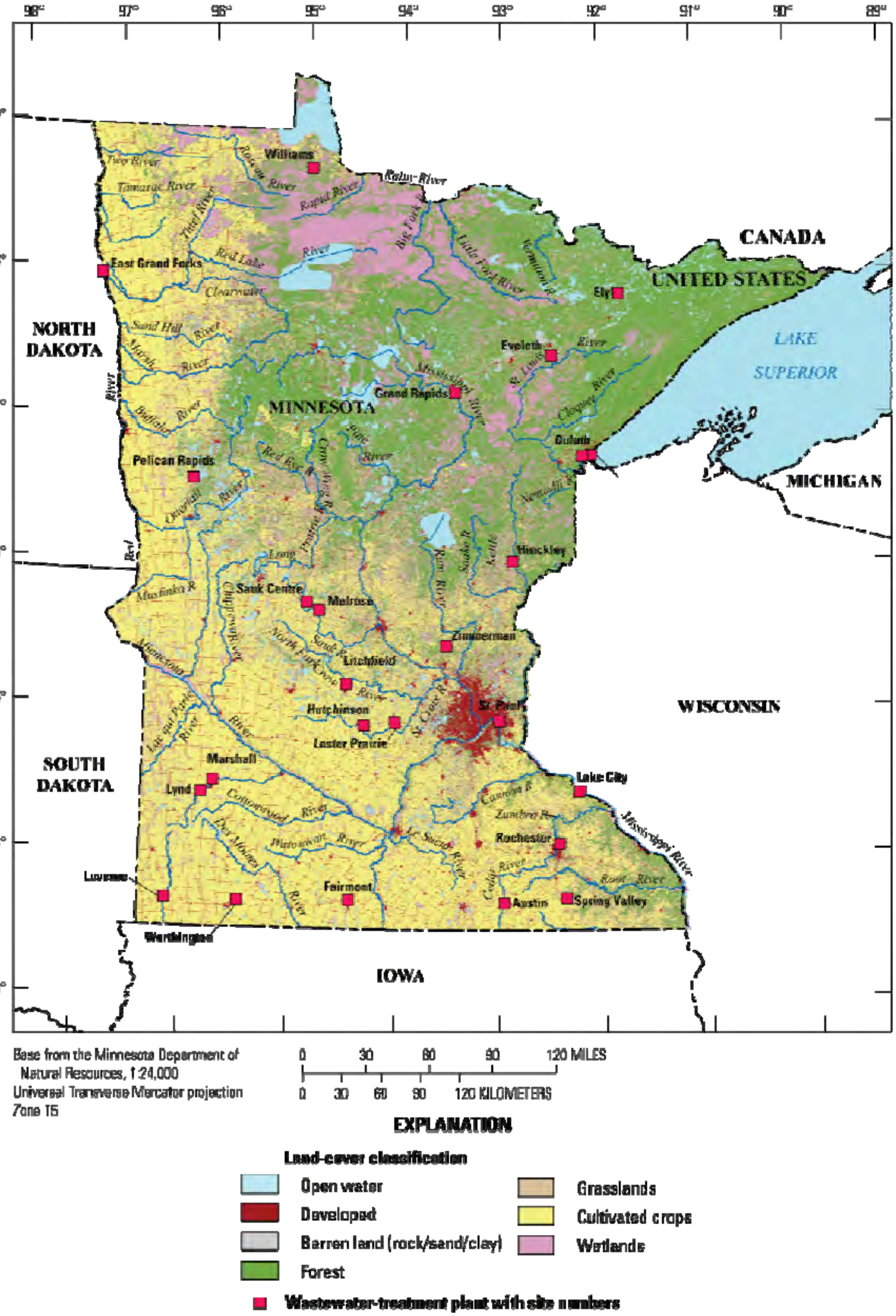
Methods

Sampling locations

A total of 25 WWTPs were selected for sampling based on size, geographical location, treatment type, and capacity (Figure 2). A diversity of WWTPs were selected to include those of differing treatment types and discharge (continuous flow vs. periodic releases), differing processing steps (activated sludge vs. trickling filters), and design flows ranging from 0.04 to 251 million gallons per day (Table 1). Locations were selected to gain an understanding of the effect that typical WWTPs have on surface waters in Minnesota. This study was not designed to focus attention on any particular WWTP. Streams that were selected for study ranged in drainage area from less than 5 to 48,000 square miles. Land use varies upstream of the sampling sites, ranging from forested land in the northern parts of Minnesota to dominantly agricultural land in the southern areas of the state.

Samples of effluent were collected from the discharge of each WWTP participating in the study. In addition, upstream and downstream locations from each WWTP plant were sampled to determine the occurrence of chemicals - including EACs and pharmaceuticals - in water and sediments.

Figure 2. Site locations during 2009. Each square typically represents three sites (one upstream, one downstream, and one wastewater effluent sample).



Description of sampling procedures and analysis

Samples were collected between September 2, 2009, and November 23, 2009. Detailed USGS data collection methods have been described previously (Lee et al. 2011). Stream flow was measured at each stream site and WWTP daily discharge values were obtained from each facility at the time of sampling. Basic water quality properties (dissolved oxygen, pH, specific conductance, temperature, and turbidity) also were measured at each site. Dye tracer studies were performed at selected sites to determine water transit times to the downstream sampling sites.

Water and sediment samples were analyzed for steroid hormones, pharmaceuticals, alkylphenols and alkylphenol ethoxylates, and other chemicals associated with wastewaters as described elsewhere (Lee et al. 2011).

Estrogenicity analysis

Total estrogenic activity of the water samples was measured using an estrogen receptor assay (Wilson et al. 2004). This test assesses the hormone-like properties of environmental samples compared to what a naturally occurring, known hormone would do in the same test. It is based on the tendency of chemicals in the water to bind to a specific steroid receptor on a cell. This binding to the receptor causes genetic responses in the cell that can be measured.

Data from these assays were used to estimate the *total estrogenic equivalents* (EEQs) in the water or effluent samples – in other words, how much of the naturally occurring hormone (17β estradiol) would be needed to generate a similar response in the test. It is expressed as nanograms per liter, or parts per trillion (Lee et al. 2011).

Fish effects analysis

The effects of WWTP effluents on fish were studied at five WWTPs, selected to represent a variety of treatment technologies, population sizes and geographic distributions. At each site, a mobile exposure laboratory trailer was set up to conduct 12-day flow-through dilution series exposures of male fathead minnows. The goal of this work was to simulate likely exposures of native fish populations to WWTP effluent.

Following the 12-day flow-through exposures, male fish were examined for anatomical and physiological effects. Blood was collected from each fish to determine concentrations of vitellogenin in the blood.

Vitellogenin is a protein that is needed for egg production. It is therefore normally found only in female fish. However, it has been discovered that male fish will produce this protein when they are exposed to substances that are estrogenic. This makes vitellogenin a useful indicator of whether male fish have been exposed to EACs in the environment.

In addition, fish livers, testis size, and physical sexual characteristics were assessed in male fathead minnows to measure the effect of WWTP effluent on fish.

Fish health assessment through gene expression

The effects that are observed and measured in caged fish (for example, the observation that vitellogenin is produced by male fish) are extremely important because they relate to known stressors and impairments. These studies can be enhanced by looking at specific changes in the actual genes that are present and that are expressed in fish in response to chemical exposures. Gene expression data allows researchers to determine if other biochemical pathways – for example, the immune system, steroid synthesis, or other systems not otherwise observable - are affected by the exposure to the WWTP effluent.

WWTP effluents, upstream water, and downstream water were examined for effect on gene expression in male fathead minnows. Male fish (n=7) were exposed to water for 96 h at three locations. Fish were exposed to 100 percent effluent using the mobile exposure lab, or to the upstream or downstream water. These fish were used to investigate effects of exposure on the expression of roughly 15,000 genes in these fish using DNA microarray technology.

Results

WWTP effluent, surface water and sediment contaminant analysis

There was a broad range of natural and synthetic chemicals detected among water and bottom sediment samples including pharmaceuticals, alkylphenols, metal complexing agents, plastic components, and disinfectants, some of which are classified as EACs. Up to 58 percent of the 78 chemicals analyzed for this study were detected in effluent samples (Table 2), while 50 percent of the chemicals were detected at upstream locations and 68 percent of the chemicals were detected at downstream locations.

More chemicals were detected on average in WWTP effluent samples (an average of 26) than in surface water upstream (an average of 6) or downstream (an average of 14) samples (Table 2). Surface water downstream of the WWTPs contained from one to 10 pharmaceuticals, from one to seven hormones, and from two to 14 APEs and APECs (detergents), EDTA and NTA (metal complexing agents). However, many of the compounds identified downstream were detected upstream, implying that chemicals are being transported from other sources not identified in this study. Upstream water samples contained from zero and six pharmaceuticals, zero to six hormones, and from one to nine APEs, APECs, EDTA and NTA (Tables 3 and 4).

Results show that:

- At four of the 25 WWTP locations, upstream water samples had equal to or more total chemical detections than the corresponding downstream locations (Table 2).
- The number of pharmaceutical detections in upstream water samples was equal to or exceeded the number of detections in downstream samples at two out of the 25 WWTP locations (Table 3).
- There were a greater number of APEs, APECs, and other EAC detections in upstream samples than downstream water samples at eight out of 25 locations (Table 4).

Pharmaceuticals

Figure 3 shows the individual pharmaceuticals that were detected in effluent, upstream water, and downstream water samples. Pharmaceuticals that were detected included carbamazepine (an anticonvulsant, detected up to a concentration of 1.5 ppb in WWTP effluent and 0.4 ppb in surface water), sulfamethoxazole (an antibiotic, found at 4.2 ppb in effluent and 2.4 ppb in surface water), and venlafaxine (an antidepressant, found at 5.5 ppb in effluent and at 1.8 ppb in surface water). These were the most commonly detected pharmaceuticals in 96 percent of effluent samples and in greater than 40 percent of surface water samples. Other pharmaceuticals found in water samples included trimethoprim (an antibiotic), fluoxetine (an antidepressant found in 80 percent of the effluent samples and 17 percent of downstream water samples); buproprion (an anti-depressant, detected in 80 percent of effluent samples and in 46 percent of downstream water samples); hydroxybuproprion (a degradation product of buproprion), and diphenhydramine (an antihistamine) found in greater than 50 percent of the wastewater effluent samples.

The concentrations of pharmaceuticals detected were generally less than one microgram per liter, (one part per billion (ppb)) and most concentrations were estimated because they were detected in the samples below laboratory quality control reporting levels. Pharmaceuticals generally occurred as mixtures with the number detected ranging from zero to 15 among all samples (Figure 4). There were more pharmaceuticals detected in WWTP effluent samples (an average of eight pharmaceuticals) than in samples collected downstream of the effluent discharge (between one and 10 pharmaceuticals and an average of five) and stream samples collected upstream of the effluent discharge (between zero and six pharmaceuticals and an average of two). Some of the pharmaceuticals (carbamazepine, caffeine, sulfamethoxazole, and codeine) were present both upstream and downstream of WWTP discharges, although concentrations of pharmaceuticals were typically greater downstream from points of WWTP discharge.

Steroid hormones

The number of steroid hormone detections in surface water downstream of WWTPs was generally greater than at the upstream locations and were found in the parts per trillion (ppt) concentrations.

- 17β-estradiol, estrone, estriol, and the synthetic contraceptive hormone ethinylestradiol were all detected at some upstream locations (Figure 5).
- 17β-estradiol, estrone, and estriol were detected in sediment upstream and downstream of WWTPs (Figure 6).
- 17β-estradiol was found in 13 percent of upstream water samples and in 42 percent of downstream surface water samples at a maximum concentration of 3 ppt; it was detected in 40 percent of upstream sediment samples and in 100 percent of downstream sediment samples.
- Estrone was detected in 13 percent of upstream water samples (maximum concentration of 32 ppt) and in 21 percent of downstream water samples (maximum concentration of 10 ppt). In WWTP effluent, it was detected in 52 percent of the samples up to concentrations of 38 ppt. This hormone also was detected in 92 percent of all sediment samples.
- 17α-ethinylestradiol, the synthetic contraceptive hormone, was detected in 13 percent of upstream water samples (1.5 ppt maximum concentration) and 13 percent of downstream water samples (0.5 ppt maximum). It was found in 40 percent of WWTP effluent samples, with a maximum concentration of 0.7 ppt.

Alkylphenols

Alkylphenols, nonylphenol and octylphenol (which are breakdown products of alkylphenol ethoxylate detergents and are EACs), were frequently detected in effluent, surface water, and in sediment (Figures 6, 7):

- Nonylphenol was found in 80 percent of the WWTP effluent samples with concentrations up to 10 parts per billion. Nonylphenol was detected in 33 percent of the upstream and 50 percent of the downstream surface water samples, and was present in 64 percent and 62 percent of the sediments that were collected upstream and downstream of WWTPs, respectively (Fig. 7).
- Octylphenol was detected in 40 percent of WWTP effluent samples (up to 0.4 ppb). Octylphenol was not detected in upstream water samples, but was detected in 8 percent of the downstream water samples (Figure 7) and in 15 percent of the downstream sediment samples. (Figure 8).

Additional chemicals

The insect repellant DEET was detected in 80 percent of the effluent samples (up to 0.8 ppb) and in 38 percent and 50 percent of the upstream and downstream water samples, respectively (up to 0.2 ppb). It was not detected in the sediments.

HHCB and AHTN, chemicals used as fragrances and suspected EACs, were detected in 96 percent and 84 percent of effluent samples, respectively (Figure 6). HHCB and AHTN also were detected in upstream water samples (21 percent and 13 percent, respectively), indicating that there are upstream sources of these EACs to surface water. HHCB and AHTN were found up to 0.6 and 0.1 ppb, respectively, in effluent samples and up to 0.02 and 0.18 ppb, respectively, in water samples.

Triclosan (an antimicrobial) was detected in 76 percent of effluent samples, up to 0.4 ppb. This chemical was not detected in the surface water upstream of WWTP, but was detected in 12 percent of downstream surface water and in 31 percent of the downstream sediment samples. Triclocarban (an antimicrobial) was detected in 88 percent of the effluent samples, up to 0.4 ppb. This chemical was detected in 38 percent of the upstream samples (up to 0.07 ppb) and in 46 percent of the downstream samples (up to 0.4 ppb).

At some locations, the upstream concentrations of particular contaminants were greater than the concentrations measured at the corresponding downstream locations (Figure 9). For example, nonylphenol was found at higher or equal concentrations upstream (at 0.23 parts per billion) than downstream on the Grindstone River. This pattern was observed at the Pelican River, Red River, Jewitt's Creek, Zumbro River, and the Redwood River locations.

Similarly, some nonylphenol ethoxylates were found at higher concentration upstream of WWTPs (up to 4.3 parts per billion) on the Grindstone River, Redwood River, Sauk River, Zumbro River, and Center Creek than in their paired downstream samples.

Bisphenol A, the estrogenic chemical used in the manufacture of polycarbonate plastic, was present in 56 percent of WWTP effluent samples at concentrations up to 22 parts per billion (ppb). It was detected in 25 percent of water samples from upstream of WWTPs (up to 0.09 ppb), and in 33 percent of water samples downstream of the WWTPs (up to 6.2 ppb). Bisphenol A was detected in the sediment at more locations upstream (55 percent) than at downstream locations (39 percent) (Figures 6, 7).

Comparison to previous studies

Table 5 shows a comparison of concentrations for several alkylphenols, alkylphenol ethoxylates, bisphenol A, triclosan, and DEET from this study and previous investigations in Minnesota, including the Mississippi River Study (Lee et al. 2008), the Tributary Study (Lee et al. 2008), and the Statewide EDC Study (Ferrey et al. 2008; Writer et al. 2010). The maximum concentrations of these chemicals measured in surface water downstream of WWTPs from this study are roughly similar to concentrations in water measured in previous studies, including the study of Minnesota lakes.

Of the four studies compared in Table 5, urban lakes with sewered development appear to have the lowest concentrations and detections of these compounds. Two exceptions are DEET, which was detected at greater concentration in urban lakes than in the rivers and streams associated with WWTPs, and bisphenol A, which was detected at much higher concentration downgradient of WWTPs.

Appendix C shows the complete analytical results of chemicals in WWTP effluent and surface water and sediment in upstream and downstream of WWTPs sampled during this study.

Fish Exposure Analysis

The biological effects that were observed in the fish exposure studies were subtle and are based on the results of short (12 day) exposures of mature male fathead minnows.

While there were few changes in the gonadosomatic index (Table 6) suggesting that the relative size of the testis did not change across treatments and time intervals, the hepatosomatic index (HSI) (Table 7) trended higher in treatments containing effluent (especially at 75 percent and 100 percent). Higher HSI values suggest that the livers of these fish had to compensate for higher pollutant loads. Future analysis of these samples by SCSU will further evaluate changes to liver tissues.

The secondary sex characteristics of fathead minnows that were exposed to WWTP effluent (Table 8) declined with longer exposure periods and higher effluent exposure concentrations (especially the 100 percent effluent treatments). Reduced secondary sex characteristics have been associated with reduced ability of fathead minnows to hold and defend nest sites, which is crucial to their reproductive success. Vitellogenin levels in the fish exposed to effluent in the mobile exposure lab showed induction of vitellogenin production in male fish at several sites and concentrations, although the observed effects were complex without a clear pattern (Table 9). In some cases, vitellogenin induction was observed even in control fish (i.e., fish not exposed to effluent), indicating that these fish may have been exposed to estrogenic compounds. This may be due to some of the chemicals in the tanks in which fish were exposed to effluent evaporating and migrating through the air to the control tanks as was suggested in a recently published study (Weinberg et al. 2011).

The effects in fish that were observed in these exposure studies were subtle and are based on the results of short (12 day) exposures of mature male fathead minnows. The effects observed in this study may not be severe enough to endanger populations in an ecosystem. These results should be followed by exposure studies of longer duration, using both sexes, and including studies of vulnerable life stages such as fish embryos and larvae. The observed effects differed between effluents from different treatment plants suggesting that different influent to a WWTP or different treatment technologies may influence fish health.

Estrogenicity and Gene Microarray Analysis

Total estrogenicity – the degree to which the water and effluent samples mimic the hormone estrogen – is reported in EEQs, and ranged from less than the detection limit to 63 ppt among all samples analyzed (Table 10).

For WWTP effluent, all of the effluent samples that were tested were estrogenic and ranged from 0.09 to 63.6 ppt. (Five WWTPs were not tested, and effluent from one appeared to be cytotoxic (thereby interfering with the cell-based assay)). Of the upstream waters, 78 percent were estrogenic, and upstream water EEQs ranged from non-detect to 12.8 ppt. Of the downstream water samples, 89 percent were estrogenic (16 of 18 samples tested), and downstream water ranged from non-detect to 23.2 ppt.

Gene expression analyses using DNA microarrays were done on samples from three sites (Rochester, Ely, and Hutchinson) to better understand the effect that WWTP effluent had on the expression of specific genes.

Microarray analyses did not find estrogenic activity at either the Rochester or Hutchinson WWTPs, but the Ely WWTP effluent activated expression of the gene responsible for the production of vitellogenin. Whether this source of estrogenicity has an effect on the broader population of fish in the lake is unknown.

One of the prominent observations made in the microarray study was that the Hutchinson WWTP effluent affected genes that regulate iron metabolism in fish. Iron is an important micronutrient for fish, and is an integral component of proteins involved in cellular respiration and oxygen transfer. Interestingly, the genes for immune response were affected only at upstream and downstream sites, and not by the Hutchinson WWTP effluent. These results suggest that the Crow River contained some chemicals that affect the immune system in fish that were not present in the Hutchinson WWTP effluent. The source(s) of these substances were not identified. Overall, downstream Crow River gene expression was more similar to the effluent (321 affected genes in common), than to the upstream site (179 affected genes in common) suggesting a detectable effluent signature at the downstream site (c) (Figure 10).

The Rochester WWTP effluent and downstream water appeared to impact the genes for iron homeostasis, as well as the genes that regulate the synthesis of proteins important for oxygen transport. In addition, exposure to the Rochester effluent affected the genes in fish that are needed to break down proteins. Overall, the gene expression observed from exposure to downstream Zumbro River water was more similar to the effluent (350 genes in common), than the upstream site (271 genes in common) suggesting a detectable effluent signature at the downstream site (Figure 11).

The effluent from the Ely WWTP influenced the expression of multiple fish genes, including genes involved with immune response and the genes involved in the breakdown of proteins. As with the other two WWTP locations, effluent from the Ely WWTP had an effect on gene expression that was more similar to downstream sites (517 genes in common) than the upstream sites (314 genes in common), suggesting a detectable effluent signature at the downstream site (Figure 12).

Discussion of Study Results

The results of this study are broadly consistent with previous studies, showing that WWTP effluents contain a wide variety of chemicals, including pharmaceuticals, alkylphenols, steroid hormones – many of which are EACs – that are discharged to surface water. It also confirms previous observations that fish exposed to WWTP effluent show signs of endocrine disruption. However, the scale of this study is unique, including 25 treatment plants that varied in capacity and treatment types located in various environmental settings throughout Minnesota. It provides a more detailed picture of the types of contaminants WWTPs contribute and the impact they are having on surface water.

It is clear from the results of this study that WWTPs commonly discharge several chemicals including pharmaceuticals, steroid hormones, detergents, and alkylphenols into surface water. Most of these compounds were detected in the sediment as well, demonstrating an accumulation of these contaminants in our environment over time. This was not unexpected, since incoming sewage contains a wide variety of these chemicals and treatment plants were not designed with the purpose of removing these compounds from sewage.

The size and location of a treatment plant does not appear to predict the number of contaminants detected in the effluent or the downstream surface water. For example, fewer pharmaceuticals and other chemicals were detected at the St. Paul Metro WWTP, with a capacity of 250 million gallons per day, than in the samples from several other treatment plants that are much smaller in size or capacity. However, it should be noted that this study was not designed to evaluate the effect of WWTP treatment processes on these contaminants.

At some of the study locations, upstream surface water contained as many or more contaminants than the samples that were collected downstream of the treatment plant. This indicates that there were significant upstream sources of nonylphenol, the ethoxylate detergents, and hormones to surface water. On some rivers, other WWTPs that are situated upstream may be contributing to detections at the upstream locations that were sampled, while at other locations, there are no WWTPs located upstream. Where there are upstream WWTPs, several discharge to surface waters only intermittently. Other potential sources of these contaminants are individual sewage treatment systems (septic systems), urban storm water runoff, agricultural operations including feedlots and row cropping, application of biosolids, and atmospheric deposition.

This study, as well as previous studies of pharmaceuticals, organic wastewater compounds, and EACs in Minnesota, suggests that these chemicals are widespread in the aquatic environment at low concentrations. For example, a prior study on three rivers in Minnesota (Lee et al. 2008) showed that alkylphenols and other contaminants were present in river water upstream of WWTPs. Similarly, the Statewide EDC Study (Ferrey et al. 2008; Writer et al. 2010) revealed that several pharmaceuticals, alkylphenols, and hormones were present in surface water and sediment of urban and rural lakes as well as in remote lakes with limited or no development. Table 5 shows that nonylphenol, some of the alkylphenol ethoxylates, and DEET were sometimes detected in urban and rural Minnesota lakes at roughly the same magnitude as were measured in this study downstream of WWTPs.

The data presented in this report represent only a “snapshot” of conditions that exist at a given WWTP, lake, or river location, since only one water or effluent sample was collected from each site at one point in time. Thus, chemical concentration data should be interpreted with caution. Concentrations of a chemical change temporally, so these results are not completely representative of the suite of contaminants at any given location over time.

Nonetheless, concern is growing over the possible effects of exposure to these contaminants in surface water, regardless of the source. Effect studies have shown that exposure to only 5 ppt of 17α-ethinylestradiol can result in the collapse of fathead minnow populations (Kidd et al. 2007); concentrations of 30 ppt of the antidepressant medication fluvoxamine has been observed to cause immediate spawning in freshwater mussels (Fong 1998). Although it is unknown what effects chemicals detected in this study are having on fish populations, it is clear that endocrine active compounds can be biologically active at the concentrations reported in this and prior investigations. In this study, male fathead minnows that were exposed to different concentrations of WWTP effluent under controlled conditions showed an increase in vitellogenin levels, indicating that the effluent had estrogenic effects. These fish also showed changes in secondary sex characteristics. In general, the fish exposure results were consistent with the cell-based estrogen assay that showed that the effluents from most of the WWTPs that were sampled were estrogenic. It is not known what particular chemicals in the effluent or mixtures of them induced these changes in fish, although alkylphenols have been demonstrated to cause similar responses under laboratory conditions (Barber et al. 2007; Lee et al. 2008; Schoenfuss et al. 2008).

The DNA microarray analysis employed in this study revealed that, in addition to estrogenic effects, hundreds of genes in fish can be affected when exposed to chemicals present in WWTP effluent. In future studies, this powerful emerging molecular technology may allow scientists to understand how particular EACs and chemicals found in wastewater cause physiological responses in fish and other organisms.

Summary

- Alkylphenols, bisphenol A, pharmaceuticals, (including antibiotics, antidepressants, and steroid hormones), and other chemicals were present in the effluents of the 25 WWTPs included in this study. These chemicals were generally found more frequently downstream of the WWTP discharge. However at four locations, the number of chemical detections in upstream samples exceeded the number detected downstream.
- Several steroid hormones, including the synthetic hormone used in contraceptives, were found in WWTP effluent as well as at locations downstream of WWTPs. Some steroid hormones also were found at upstream sampling locations.
- Several pharmaceuticals were found in WWTP effluent and in downstream water samples. As a group, antidepressant medications were detected the most in WWTP effluent samples. Some pharmaceuticals were found at upstream locations.
- Several EACs, including bisphenol A, nonylphenol, nonylphenol ethoxylates, octylphenol ethoxylates, and musk fragrances were found in WWTP effluent. However, these chemicals were detected in water and sediment upstream of WWTPs, sometimes at higher concentrations than downstream of the plants, indicating that there were other upstream sources of these chemicals.
- The concentrations of nonylphenol, octylphenol, nonylphenol ethoxylates, and octylphenol ethoxylates found downstream of WWTPs in this study are similar to concentrations reported in previous studies of rivers as well as of lakes influenced by septic systems and other non-point sources.
- The effluents from most of the WWTPs that were tested were estrogenic. The impact of this on fish and wildlife populations is unknown.
- Male fathead minnows exposed to WWTP effluent under controlled conditions produced vitellogenin, a protein associated with egg production that is normally produced only by females. In addition, changes in secondary sex characteristics in these fish were observed.
- DNA microarray analysis showed that gene expression in fish was altered when they were exposed to WWTP effluents and to surface water collected either upstream or downstream of WWTPs. However, the gene expression patterns in fish exposed to downstream water bore similarity to the patterns observed in WWTP effluent-exposed fish.
- The gene expression patterns observed in fish exposed to WWTP effluent and to water downstream of WWTP sites were similar. These patterns were not observed upstream of WWTPs. While this suggests that WWTP effluents have an effect on fish downstream of their discharges, the effect on fish populations in general is not known.

This study demonstrates that several hormones, pharmaceuticals, and other wastewater chemicals are discharged by WWTPs. Many of these are EACs. However, it is clear that many of these contaminants are present upstream of WWTPs and at locations that are not influenced by WWTPs. Together with the results of other EAC studies in Minnesota and elsewhere, the results of this investigation indicate that these chemicals are widespread in our aquatic environment at low concentrations. The MPCA is currently sampling flowing waters in Minnesota at over 100 random locations around the state for similar compounds, and the results of this study will increase our understanding of how widespread these contaminants are in surface water. The MPCA is continuing the collaboration with USGS, St. Cloud State University, and St. Thomas University to study the presence and effects of EACs on Minnesota lakes. The results of these studies will be available by June 30, 2011.

Although this study has advanced an understanding of the presence and concentration of EACs in WWTP effluent, surface water, and sediment, a number of questions remain unanswered:

- It is unclear to what degree other sources of contaminants – including private septic systems, agricultural feedlots, row cropping, biosolids application, and urban runoff – affect surface water.
- The degree to which they persist in sediment and surface water is not well understood. This study and others like it suggest that EACs and other chemicals appear to be accumulating in sediment, where they likely will persist for many years. The long-term ecological consequences of this accumulation in sediment are not known.
- Although it is clear that EACs can affect fish development and reproductive behavior, it is not known what impact EACs have on entire populations of fish and other organisms in the wild.
- The effect of different wastewater treatment processes on the fate of EACs is not well understood. Information about wastewater treatment technologies is needed to understand how variations in treatment might prevent EACs from reaching surface water.

Ongoing research that is focused on monitoring EACs and assessing their effects on fish and wildlife will contribute important information that is needed by resource managers and the public to understand what impact these chemicals have on Minnesota's environment.

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Tables and Figures

Table 1. Specifications for wastewater treatment plants included in this study.

Wastewater Treatment Plant	Design flow (Mgald)	Design flow (cms)	Type	Treatment processes	Number Trickling filters	Disinfection	Population Served	Percent Domestic	Percent Industrial
Williams WWTP Outflow at Williams, MN	0.08	0.0035	Continuous	Activated sludge – extended aeration	0	UV	865	100	0
Ely WWTP Outflow at Ely, MN	1.5	0.0657	Continuous	Activated Sludge - extended aeration; sand filters	0	Chl/DEChl	3900	100	0
Eveleth WWTP Outlflow at Eveleth, MN	1	0.0438	Continuous	Activated Sludge - extended aeration; Sand filters	0	Chl/DEChl	3900	99.4	0.6
Western Lake Superior Sanitary District - WWTP at Duluth, MN	48.4	2.119	Continuous	Activated Sludge – pure oxygen; Sand filters	0	Chl/DEChl	111203	55	45
Pelican Rapids WWTP Outflow at Pelican Rapids, MN	0.91	0.0398	Continuous	Trickling Filter; Rotating biological contactor (1 trickling filter; 3 RBC)	1	Chl/DEChl	2476	67	33
East Grand Forks WWTP Outflow at East Grand Forks, MN	1.4	0.0613	Controlled	Stabilization Ponds	0		8000	80	20
Grand Rapids WWTP Outflow at Grand Rapids, MN	15.2	0.6657	Continuous	Activated Sludge - contact stabilization, conventional, step feed	0	Chl/DEChl	12000	10	90
Sauk Centre WWTP Outflow at Sauk Centre, MN	0.88	0.0385	Continuous	Activated Sludge - contact stabilization, conventional, step feed	0	Chl/DEChl	4111	100	0
Melrose WWTP Outflow at Melrose, MN	3	0.1314	Continuous	Trickling Filter; Activated Sludge - contact stabilization, conventional, step feed	2	Chl/DEChl	3400	20	80
Zimmerman WWTP outflow at Zimmerman, MN	0.45	0.0197	Continuous	Activated Sludge - conventional, sequencing batch reactors	0	UV	5000	100	0
Litchfield WWTP Outflow near Litchfield, MN	2.4	0.1051	Continuous	Trickling Filter; Activated Sludge – contact stabilization, convention, step feed	2	Chl/DEChl	7500	50	50
Hutchinson WWTP Outflow at Hutchinson, MN	5.4	0.2365	Continuous	Membrane Bioreactor	0	NA	13900	68	32

(Table 1 Continued)

Wastewater Treatment Plant	Design flow (Mgald)	Design flow (cms)	Type	Treatment processes	Number Trickling filters	Disinfection	Population Served	Percent Domestic	Percent Industrial
Lester Prairie WWTP Outflow at Lester Prairie, MN	0.36	0.0157	Continuous	Activated Sludge - extended aeration, oxidation ditch	0	UV	1774	90	10
Lynd WWTP Outflow near Lynd, MN	0.045	0.0019	Controlled	Stabilization Ponds	0		410	90	10
Marshall WWTP outfall at Marshall, MN	4.5	0.1971	Continuous	Trickling Filter; Activated Sludge - contact stabilization, conventional, step fee; Sand filter	2	UV	13000	40	60
Fairmont WWTP Outflow at Fairmont, MN	3.9	0.1708	Continuous	Activated Sludge - contact stabilization, conventional, step feed	0	UV	10889	81.7	18.3
Metro Plant (WWTP) Outflow in St. Paul, MN	251	10.99	Continuous	Activated Sludge - contact stabilization, conventional, step feed	0	Chl/DEChl	1800000	na	na
Hinckley WWTP near Hinckley, MN	0.5	0.0219	Continuous	Activated Sludge - extended aeration	0	UV	1438	100	0
Lake City WWTP Outflow at Lake City, MN	1.52	0.066576	Continuous	Activated Sludge - contact stabilization, conventional, step feed	0	UV	5300	75	25
Rochester WWTP Outflow at Rochester, MN	19.1	0.83658	Continuous	Activated Sludge - Pure Oxygen	0	Chl/DEChl	100000	50	50
Spring Valley WWTP Outflow at Spring Valley, MN	0.94	0.041172	Continuous	Activated Sludge - extended aeration, oxidation ditch	0	Chl/DEChl	2561	95	5
Austin WWTP Outflow at Austin, MN	8.5	0.3723	Continuous	Trickling Filter (4 trickling filters + 2 nitrification trickling filters)	6	Chl/DEChl	23000	67	33
Worthington WWTP Outflow at Worthington, MN	4	0.1752	Continuous	Trickling Filter	4	Chl	11283	97	3
Worthington Industrial WWTP Outflow near Worthington, MN	2.29	0.0876	Continuous	Anaerobic Ponds; Activated sludge extended aeration; Sand Filters	0	Chl	0	0	100
Luverne WWTP Outlflow near Luverne, MN	1.5	0.0657	Continuous	Activated sludge; Trickling filter	1	Chl/DEChl	4617	90	10

Table 2. Total number of chemical detections in WWTP effluent and in surface water upstream and downstream of WWTPs.

Site number	Wastewater Treatment Plant	Upstream	Effluent	Downstream
1	Williams WWTP Outflow at Williams, MN	5	13	9
2	Ely WWTP Outflow at Ely, MN	3	38	9
3	Eveleth WWTP Outlflow at Eveleth, MN	7	21	20
4	Western Lake Superior Sanitary District - WWTP at Duluth, MN	2	25	28
5	Pelican Rapids WWTP Outflow at Pelican Rapids, MN	2	40	7
6	East Grand Forks WWTP Outflow at East Grand Forks, MN	9	14	7
7	Grand Rapids WWTP Outflow at Grand Rapids, MN	2	17	3
8	Sauk Centre WWTP Outflow at Sauk Centre, MN	8	38	18
9	Melrose WWTP Outflow at Melrose, MN	14	36	14
10	Zimmerman WWTP outflow at Zimmerman, MN	4	28	28
11	Litchfield WWTP Outflow near Litchfield, MN	3	20	11
12	Hutchinson WWTP Outflow at Hutchinson, MN	10	23	16
13	Lester Prairie WWTP Outflow at Lester Prairie, MN	9	16	7
14	Lynd WWTP Outflow near Lynd, MN	4	24	8
15	Marshall WWTP outfall at Marshall, MN	5	29	12
16	Fairmont WWTP Outflow at Fairmont, MN	8	28	25
17	Metro Plant (WWTP) Outflow in St. Paul, MN	7	32	9
18	Hinckley WWTP near Hinckley, MN	6	25	8
19	Lake City WWTP Outflow at Lake City, MN	10	36	10
20	Rochester WWTP Outflow at Rochester, MN	11	26	14
21	Spring Valley WWTP Outflow at Spring Valley, MN	4	25	9
22	Austin WWTP Outflow at Austin, MN	7	38	28
23	Worthington WWTP Outflow at Worthington, MN	3	23	19
24	Worthington Industrial WWTP Outflow near Worthington, MN	3	10	19
25	Luverne WWTP Outlflow near Luverne, MN	1	36	8

Table 3. Number of pharmaceuticals detected in WWTP effluent and in surface water upstream and downstream of WWTPs.

Site number	Wastewater Treatment Plant	Upstream	Effluent	Downstream
1	Williams WWTP Outflow at Williams, MN	3	5	4
2	Ely WWTP Outflow at Ely, MN	1	15	3
3	Eveleth WWTP Outlflow at Eveleth, MN	6	8	9
4	Western Lake Superior Sanitary District - WWTP at Duluth, MN	1	9	8
5	Pelican Rapids WWTP Outflow at Pelican Rapids, MN	0	11	3
6	East Grand Forks WWTP Outflow at East Grand Forks, MN	3	3	4
7	Grand Rapids WWTP Outflow at Grand Rapids, MN	0	5	2
8	Sauk Centre WWTP Outflow at Sauk Centre, MN	0	11	5
9	Melrose WWTP Outflow at Melrose, MN	4	9	5
10	Zimmerman WWTP outflow at Zimmerman, MN	0	8	8
11	Litchfield WWTP Outflow near Litchfield, MN	0	7	4
12	Hutchinson WWTP Outflow at Hutchinson, MN	0	8	5
13	Lester Prairie WWTP Outflow at Lester Prairie, MN	4	8	4
14	Lynd WWTP Outflow near Lynd, MN	0	7	1
15	Marshall WWTP outfall at Marshall, MN	0	11	4
16	Fairmont WWTP Outflow at Fairmont, MN	0	10	8
17	Metro Plant (WWTP) Outflow in St. Paul, MN	5	11	5
18	Hinckley WWTP near Hinckley, MN	0	8	6
19	Lake City WWTP Outflow at Lake City, MN	5	12	6
20	Rochester WWTP Outflow at Rochester, MN	3	9	7
21	Spring Valley WWTP Outflow at Spring Valley, MN	1	7	4
22	Austin WWTP Outflow at Austin, MN	1	12	10
23	Worthington WWTP Outflow at Worthington, MN	1	7	5
24	Worthington Industrial WWTP Outflow near Worthington, MN	1	1	5
25	Luverne WWTP Outlflow near Luverne, MN	0	10	4

Table 4. Number of detections of alkylphenols, alkylphenol ethoxylates, EDTA, and NTA in WWTP effluent and in surface water upstream and downstream of WWTPs.

		Upstream			Effluent			Downstream		
Site	Wastewater Treatment Plant Location	APEs	APECs	sum	APEs	APECs	sum	APEs	APECs	sum
1	Williams WWTP Outflow at Williams, MN	2	0	2	6	0	6	5	0	5
2	Ely WWTP Outflow at Ely, MN	2	0	2	10	5	15	1	1	2
3	Eveleth WWTP Outlflow at Eveleth, MN	1	0	1	5	4	9	5	2	7
4	Western Lake Superior Sanitary District - WWTP at Duluth, MN	0	0	0	11	5	16	11	3	14
5	Pelican Rapids WWTP Outflow at Pelican Rapids, MN	1	0	1	17	6	23	3	0	3
6	East Grand Forks WWTP Outflow at East Grand Forks, MN	4	0	4	5	1	6	2	0	2
7	Grand Rapids WWTP Outflow at Grand Rapids, MN	2	0	2	7	2	9	0	1	1
8	Sauk Centre WWTP Outflow at Sauk Centre, MN	5	0	5	16	4	20	7	2	9
9	Melrose WWTP Outflow at Melrose, MN	8	1	9	19	3	22	8	0	8
10	Zimmerman WWTP outflow at Zimmerman, MN	2	1	3	12	3	15	10	3	13
11	Litchfield WWTP Outflow near Litchfield, MN	2	0	2	9	3	12	3	1	4
12	Hutchinson WWTP Outflow at Hutchinson, MN	4	0	4	9	3	12	3	2	5
13	Lester Prairie WWTP Outflow at Lester Prairie, MN	2	2	4	4	3	7	1	1	2
14	Lynd WWTP Outflow near Lynd, MN	4	0	4	10	2	12	7	0	7
15	Marshall WWTP outfall at Marshall, MN	2	1	3	10	3	13	4	3	7
16	Fairmont WWTP Outflow at Fairmont, MN	6	0	6	9	4	13	9	3	12
17	Metro Plant (WWTP) Outflow in St. Paul, MN	1	0	1	13	3	16	2	2	4
18	Hinckley WWTP near Hinckley, MN	5	1	6	10	4	14	2	0	2
19	Lake City WWTP Outflow at Lake City, MN	3	0	3	14	4	18	1	1	2
20	Rochester WWTP Outflow at Rochester, MN	6	0	6	10	4	14	3	1	4
21	Spring Valley WWTP Outflow at Spring Valley, MN	3	0	3	13	2	15	5	0	5
22	Austin WWTP Outflow at Austin, MN	2	0	2	14	4	18	8	3	11
23	Worthington WWTP Outflow at Worthington, MN	1	1	2	10	4	14	8	4	12
24	Worthington Industrial WWTP Outflow near Worthington, MN	1	1	2	4	3	7	8	4	12
25	Luverne WWTP Outlflow near Luverne, MN	1	0	1	16	4	20	3	0	3

Table 5. Comparison of maximum chemical concentrations in Minnesota lakes with maximum concentrations found downstream of WWTPs. Concentrations are in parts per trillion (ppt); nd = non detect.

	WWTP Study	Statewide Lake Study			
	Downstream of WWTP	Urban Lakes	Septic Influenced Lakes	Tributary Study	Mississippi River Study
4-Nonylphenol (Grindstone)	290	nd	111	880	nd
NP monoethoxylate (Redwood)	110	59	86	660	nd
NP diethoxylate (Center Creek)	120	nd	171	370	nd
NP triethoxylate (Sauk)	4900	nd	123	870	
NP tetraethoxylate (Sauk)	270	nd	nd	150	
4-t-Octylphenol (Mississippi)	83	nd	nd	15	nd
OP monoethoxylate (Grindstone)	6	nd	nd	28	208
OP diethoxylate (Center Creek)	280	26	34	130	430
OP triethoxylate	nd	nd	14	110	
OP tetraethoxylate (Sauk)	78	nd	nd	15	
Bisphenol A *(Cedar)*	3200	38	20	137	2760
Triclosan	51	nd	10	150	nd
DEET (Grindstone)	150	90000	579	700	224

Table 6. Gonadosomatic index of male fathead minnows exposed in MELT (the GSI is calculated by dividing the testis weight by the total weight of the fish and is commonly used endpoint to judge the relative size of the reproductive organ of the fish).

MELT - Gonadosomatic Index		Control			25% Effluent			50% Effluent			75% Effluent			100% Effluent		
		mean+/-stand. dev.		*(n)*	*mean+/-stand. dev.*		*(n)*	*mean+/-stand. dev.*		*(n)*	*mean+/-stand. ved.*		*(n)*	*mean+/-stand. dev.*		*(n)*
Sauk Centre	Day 4	3.3367	.0500	6	1.6526	.0075	6	1.2299	.0048	6	.	.		1.6050	.0045	3
	Day 8	1.5303	.0082	5	1.9002	.0074	6	3.5974	.0648	6	.	.		1.7272	.0089	5
	Day 12	4.0158	.0491	19	7.5795	.0877	10	2.2101	.0170	8	.	.		8.9091	.0889	10
Hutchinson	Day 4	1.0335	.0048	10	1.2184	.0036	10	1.4430	.0068	10	1.0690	.0041	10	1.3958	.0053	10
	Day 8	1.2638	.0070	8	.8839	.0044	9	1.6091	.0042	6	1.3548	.0081	10	1.2701	.0026	10
	Day 12	1.1921	.0036	9	1.4477	.0037	10	1.6403	.0038	11	1.4343	.0084	10	1.3887	.0064	5
Lester Prairie	Day 4	1.5389	.0030	10	1.4413	.0059	10	2.7099	.0356	10	1.7196	.0042	10	1.3278	.0028	9
	Day 8	.0000		0	1.9242	.0062	5	1.6443	.0044	10	1.6148	.0037	10	1.5051	.0041	11
	Day 12	.0000		0	1.6202	.0023	5	1.2040	.0051	9	1.4860	.0042	11	1.4710	.0048	9
Marshall	Day 4	1.5685	.0046	9	1.0002	.0053	11	1.2109	.0030	10	1.3201	.0070	10	1.1385	.0066	10
	Day 8	1.3839	.0096	10	1.6410	.0058	10	1.4376	.0035	10	1.3636	.0045	10	2.6012	.0251	11
	Day 12	1.3587	.0048	12	1.9154	.0045	11	1.8170	.0096	15	1.2711	.0051	17	1.4047	.0057	17
Rochester	Day 4			0		.		1.7362	.0072	10	2.1043	.0060	10	1.7980	.0073	10
	Day 8			0	1.6147	.0025	9	1.1437	.0053	9	1.1918	.0039	8	1.1199	.0051	9
	Day 12			0	1.5836	.0073	8	1.9836	.0072	12	1.6414	.0043	12	3.2001	.0323	16

Table 7. Hepatosomatic Index of male fathead minnows exposed in MELT (the HSI is calculated by dividing the liver weight by the total weight of the fish and is a commonly used endpoint to judge the relative size of the liver of the fish).

MELT - Hepatosomatic Index		Control			25% Effluent			50% Effluent			75% Effluent			100% Effluent		
		mean+/-stand. dev.		(n)	mean+/-stand. dev.		(n)	mean+/-stand. dev.		(n)	mean+/-stand. ved.		(n)	mean+/-stand. dev.		(n)
Sauk Centre	Day 4	1.1552	.0059	6	1.2849	.0058	6	1.4266	.0040	6	.	.		1.5792	.0087	3
	Day 8	2.7357	.0138	5	2.0306	.0069	6	2.3320	.0062	6	.	.		2.4311	.0107	5
	Day 12	1.7035	.0066	19	1.7462	.0032	10	2.1191	.0069	8	.	.		2.5721	.0101	10
Hutchinson	Day 4	2.0567	.0048	10	1.9812	.0093	10	1.5309	.0038	10	1.7464	.0039	10	2.1630	.0066	10
	Day 8	1.8306	.0068	8	1.5051	.0058	9	1.8496	.0072	6	1.6532	.0060	10	1.7464	.0043	10
	Day 12	1.9018	.0056	9	1.9448	.0033	10	1.7254	.0043	11	1.6635	.0112	10	1.1470	.0028	5
Lester Prairie	Day 4	1.8254	.0067	10	1.7471	.0051	10	3.2476	.0482	10	1.1680	.0028	10	1.9451	.0063	9
	Day 8	.0000		0	1.5365	.0029	5	1.9416	.0083	10	1.4536	.0046	10	1.8988	.0062	11
	Day 12	.0000		0	1.6806	.0056	5	1.7710	.0066	9	1.5025	.0034	11	1.3779	.0037	9
Marshall	Day 4	1.4410	.0052	9	1.5435	.0077	11	1.6967	.0075	10	1.2161	.0068	10	1.6895	.0107	10
	Day 8	1.6398	.0053	10	1.6700	.0084	10	1.7121	.0041	10	1.6148	.0038	10	1.8959	.0065	11
	Day 12	1.9683	.0088	12	1.8863	.0045	11	2.0660	.0105	15	1.9826	.0061	17	1.9999	.0066	17
Rochester	Day 4			0		.		1.4862	.0050	10	1.4372	.0041	10	1.2229	.0033	10
	Day 8			0	1.5806	.0065	9	3.5963	.0476	9	1.7144	.0051	8	1.4370	.0055	9
	Day 12			0	1.5013	.0055	8	1.8326	.0084	12	1.6380	.0038	12	3.1343	.0363	16

Table 8. Sum of Secondary Sex Characteristics of male fathead minnows deployed in MELT (the SSC is the sum of three individual scores describing the prominence of nuptial tubercles, dorsal pad and coloration of male fish).

MELT - Secondary Sex Characteristics		Control			25% Effluent			50% Effluent			75% Effluent			100% Effluent		
		median +/-stand. dev.		(n)	median +/-stand. dev.		(n)	median +/-stand. dev.		(n)	median +/-stand. dev.		(n)	median +/-stand. dev.		(n)
Sauk Centre	Day 4	6	2	6	5	3	6	5	3	6			0	5	2	3
	Day 8	6	2	5	6	2	6	5	1	6			0	4	2	5
	Day 12	5	3	19	2	3	10	6	3	8			0	2	4	10
Hutchinson	Day 4	3	2	10	4	2	10	4	2	10	5	2	10	5	3	10
	Day 8	5	2	8	4	2	9	6	3	6	4	2	10	4	2	10
	Day 12	4	2	9	6	3	10	3	2	11	5	2	10	5	2	5
Lester Prairie	Day 4	7	3	10	6	3	10	5	3	10	6	2	10	6	1	9
	Day 8	.	.	0	3	2	5	6	2	10	6	3	10	5	2	11
	Day 12	.	.	0	5	3	5	4	2	9	5	2	11	4	2	9
Marshall	Day 4	6	2	9	5	3	11	6	1	10	5	2	10	6	2	10
	Day 8	6	3	10	5	2	10	6	2	10	6	2	10	4	3	11
	Day 12	7	1	12	7	3	11	6	2	15	5	2	17	4	2	17
Rochester	Day 4				.	.	0	6	1	10	5	3	10	4	2	10
	Day 8				6	2	9	7	3	9	7	2	8	6	2	9
	Day 12				6	2	8	5	3	12	6	3	12	3	3	16

Table 9. Preliminary Plasma Vitellogenin (mg/mL) concentrations in male fathead minnows exposed in MELT. VTG data will require additional quality assurance and quality control procedures before being finalized. The current data set does not yet include samples that fall above or below the detection limit of the standard curve.

MELT - Vitellogenin Concentrations [µg/mL] (Males)		0%			25%			50%			75%			100%		
		Mean	+/- Std. Dev.	(n)	Mean	+/- Std. Dev.	(n)	Mean	+/- Std. Dev.	(n)	Mean	+/- Std. Dev.	(n)	Mean	+/- Std. Dev.	(n)
Sauk Center	4	217.44	144.42	6	161.94	135.43	6	123.72	174.60	6	N/A	N/A	0	563.38	523.48	3
	8	110.04	46.14	5	829.85	418.26	6	602.84	292.58	6	N/A	N/A	0	384.07	448.52	5
	12	1892.56	1898.40	13	2433.16	850.89	5	1523.55	1076.63	7	N/A	N/A	0	1664.56	1537.60	5
Hutchinson	4	32.71	10.50	10	100.40	131.40	10	66.79	68.21	10	198.28	199.72	10	207.13	430.29	10
	8	48.85	34.63	8	31.61	17.53	9	345.03	557.07	6	242.00	317.20	10	241.53	307.60	10
	12	812.54	670.71	9	552.69	718.82	10	815.12	1078.16	11	384.30	387.33	10	224.33	68.61	5
Lester Prairie	4	59.94	52.93	9	58.15	52.82	10	45.73	31.05	9	133.55	225.01	10	246.53	410.20	9
	8	N/A	N/A	0	226.70	288.30	5	394.26	235.51	10	351.10	238.75	10	71.38	52.37	10
	12	N/A	N/A	0	912.20	202.45	5	216.37	268.69	9	440.50	385.45	11	958.88	815.91	9
Marshall	4	447.47	591.84	9	117.75	141.73	11	447.70	583.98	10	456.80	543.44	10	835.26	1712.30	10
	8	885.33	1494.19	10	412.23	302.78	10	449.33	540.36	10	86.48	119.68	10	142.78	299.04	11
	12	413.54	315.75	12	658.83	830.88	11	312.07	395.85	15	394.80	576.75	17	545.67	901.93	17
Rochester	4	N/A	N/A	0	73.33	51.81	10	1070.55	731.18	10	956.75	215.12	10	132.63	135.13	10
	8	N/A	N/A	0	404.92	538.83	9	330.92	490.85	9	790.50	808.76	8	675.60	466.57	9
	12	N/A	N/A	0	186.84	128.67	8	142.20	196.34	12	460.93	392.36	12	167.62	245.75	10

Table 10. Environmental sample results for total estrogenicity analyzed in water at the University of St. Thomas [US, upstream; DS, downstream; WE, wastewater treatment plant; ng/L, nanograms per liter; nd, not detected; na, not available; E, estimated value].

Site Number	Position	USGS Station Name	Estradiol equivalents (ng /L)
1	US	Williams Creek above WWTP at Williams, MN	0.40
2	WWTP	Williams WWTP Outflow at Williams, MN	0.88
3	DS	Williams Creek below WWTP at Williams, MN	23.20
4	US	Shagawa Lake at Mouth of Burntside River near Ely, MN	0.19
5	WWTP	Ely WWTP Outflow at Ely, MN	17.38
6	DS	Shagawa Lake near Ely WWTP Outflow at Ely, MN	0.58
7	US	Elbow Creek above Eveleth WWTP at Eveleth, MN	< 0.21
8	WWTP	Eveleth WWTP Outlflow at Eveleth, MN	0.77
9	DS	Elbow Creek below Eveleth WWTP at Eveleth, MN	2.58
10	US	St. Louis River at Hwy 23 above Fond Du Lac, MN	na
11	WWTP	Western Lake Superior Sanitary District - WWTP at Duluth, MN	0.37
12	DS	Lake Superior in St. Louis Bay at Duluth, MN	0.66
13	US	Pelican River above WWTP at Pelican Rapids, MN	E0.08
14	WWTP	Pelican Rapids WWTP Outflow at Pelican Rapids, MN	22.08
15	DS	Pelican River below WWTP at Pelican Rapids, MN	1.47
16	US	Red R. of the North above WWTP at East Grand Forks, MN	8.07
17	WWTP	East Grand Forks WWTP Outflow at East Grand Forks, MN	5.10
18	DS	Red river of the North Below WWTP at East Grand Forks, MN	5.16
19	US	Mississippi River above WWTP at Grand Rapids, MN	E0.18
20	WWTP	Grand Rapids WWTP Outflow at Grand Rapids, MN	4.87
21	DS	Mississippi River below WWTP at Grand Rapids, MN	na
22	US	Sauk River above Sauk Centre WWTP at Sauk Centre, MN	< 0.21
23	WWTP	Sauk Centre WWTP Outflow at Sauk Centre, MN	2.24
24	DS	Sauk River below Sauk Centre WWTP at Sauk Centre, MN	< 0.21

(Table 10 Continued)

Site Number	Position	USGS Station Name	Estradiol equivalents (ng /L)
25	US	Sauk River above Melrose WWTP at Melrose, MN	< 0.21
26	WWTP	Melrose WWTP Outflow at Melrose, MN	6.13
27	DS	Sauk River below Melrose WWTP at Melrose, MN	0.64
28	US	South Fork Crow River above WWTP at Lester Prairie, MN	na
29	WWTP	Lester Prairie WWTP Outflow at Lester Prairie, MN	1.57
30	DS	South Fork Crow River below WWTP at Lester Prairie, MN	< 0.21
31	US	Tibbets Brook above WWTP outflow at Zimmerman, MN	1.07
32	WWTP	Zimmerman WWTP outflow at Zimmerman, MN	4.38
33	DS	Tibbets Brook below WWTP outflow at Zimmerman, MN	0.71
34	US	Jewitts Creek at U.S. HWY. 12 in Litchfield, MN	2.30
35	WWTP	Litchfield WWTP Outflow near Litchfield, MN	0.49
36	DS	Jewitts Creek near Litchfield, MN	1.93
37	US	South Fork of the Crow River above WWTP at Hutchinson, MN	0.59
38	WWTP	Hutchinson WWTP Outflow at Hutchinson, MN	cytotoxic
39	DS	South Fork of the Crow River below Hutchinson, MN	E0.17
40	US	Redwood River above Lynd WWTP near Lynd, MN	na
41	WWTP	Lynd WWTP Outflow near Lynd, MN	na
42	DS	Redwood River below Lynd WWTP near Lynd, MN	na
43	US	Redwood River above WWTP below Marshall, MN	12.78
44	WWTP	Marshall WWTP outfall at Marshall, MN	1.24
45	DS	Redwood River below WWTP near Marshall, MN	0.53
46	US	Center Creek on Co. Rd. 143, at Fairmont, MN	na
47	WWTP	Fairmont WWTP Outflow at Fairmont, MN	na
48	DS	Center Creek below WWTP at Fairmont, MN	na
49	US	Mississippi River at Industrial Mollasses St. Paul, MN	E0.08
50	WWTP	Metro Plant (WWTP) Outflow in St. Paul, MN	63.64
51	DS	Mississippi River at South St. Paul, MN	2.80
52	US	Grindstone River above WWTP near Hinckley, MN	0.27
53	WWTP	Hinckley WWTP near Hinckley, MN	23.98
54	DS	Grindstone River below Hinckley, MN	1.40
55	US	Mississippi River (Lake Pepin) above Lake City, MN	E0.02
56	WWTP	Lake City WWTP Outflow at Lake City, MN	9.18
57	DS	Mississippi River (Lake Pepin) at Mile 771 near Lake City, MN	0.27
58	US	South Fork Zumbro River at Rochester, MN	11.28
59	WWTP	Rochester WWTP Outflow at Rochester, MN	1.99
60	DS	South Fork Zumbro R. below WWTP near Rochester, MN	0.22
61	US	Spring Valley Creek above Spring Valley WWTP Outflow at Spring Valley, MN	0.63
62	WWTP	Spring Valley WWTP Outflow at Spring Valley, MN	14.65
63	DS	Spring Valley Creek below Spring Valley WWTP Outflow at Spring Valley, MN	na
64	US	Cedar River above Treatment Plant at Austin, MN	na
65	WWTP	Austin WWTP Outflow at Austin, MN	na
66	DS	Cedar River below Treatment Plant at Austin, MN	na
67	US	Okabena Creek above WWTP Outflow at Worthington, MN	na

(Table 10 Continued)

Site Number	Position	USGS Station Name	Estradiol equivalents (ng /L)
68	WWTP-Domestic	Worthington WWTP Outflow at Worthington, MN	na
69	WWTP-Industrial	Industrial WWTP Outflow near Worthington, MN	na
70	DS	Okabena Creek below WWTP Outflow at Worthington, MN	na
71	US	Rock River above WWTP near Luverne, MN	< 0.21
72	WWTP	Luverne WWTP Outlflow near Luverne, MN	E0.09
73	DS	Rock River below WWTP near Luverne, MN	0.49

Figure 3. Detection frequency of pharmaceuticals upstream and downstream of WWTPS and in WWTP effluent.

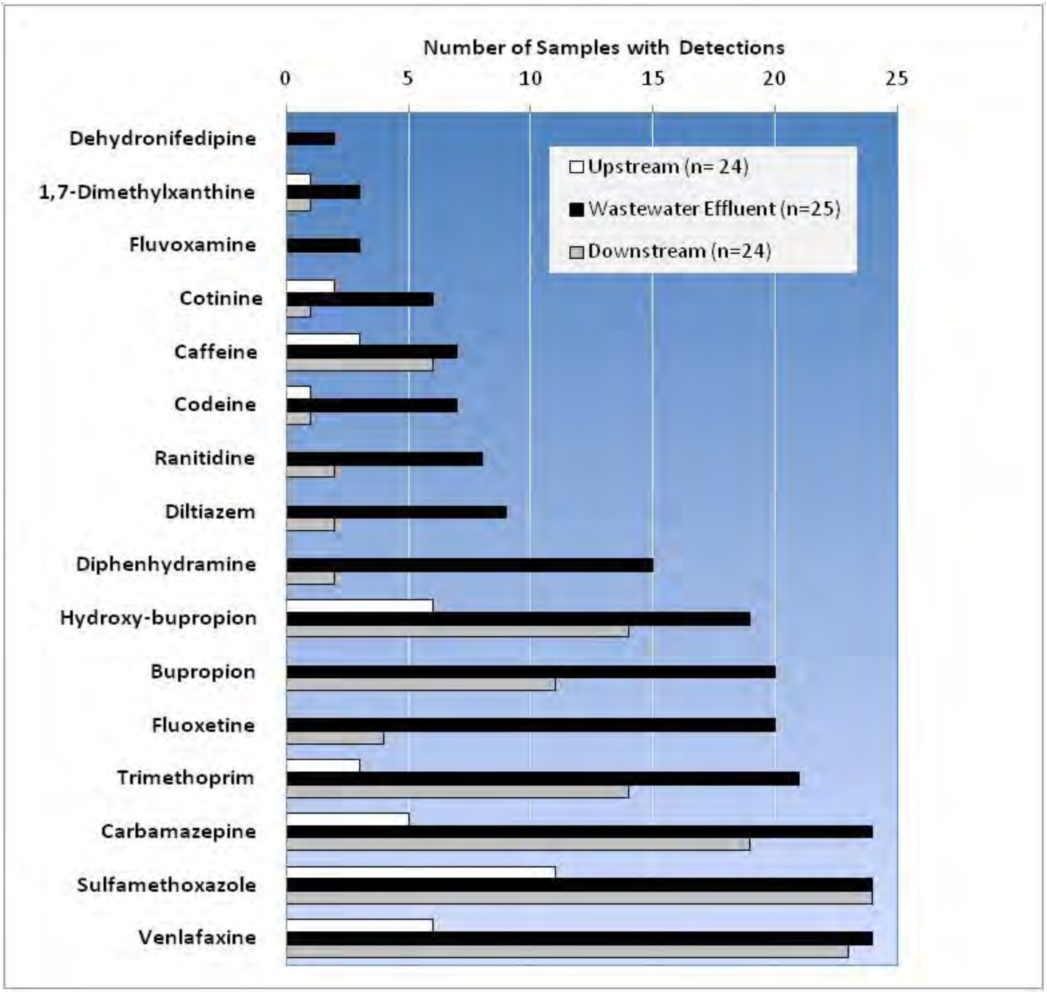


Figure 4. Number of pharmaceuticals detected in the effluent of WWTPs selected for this study.

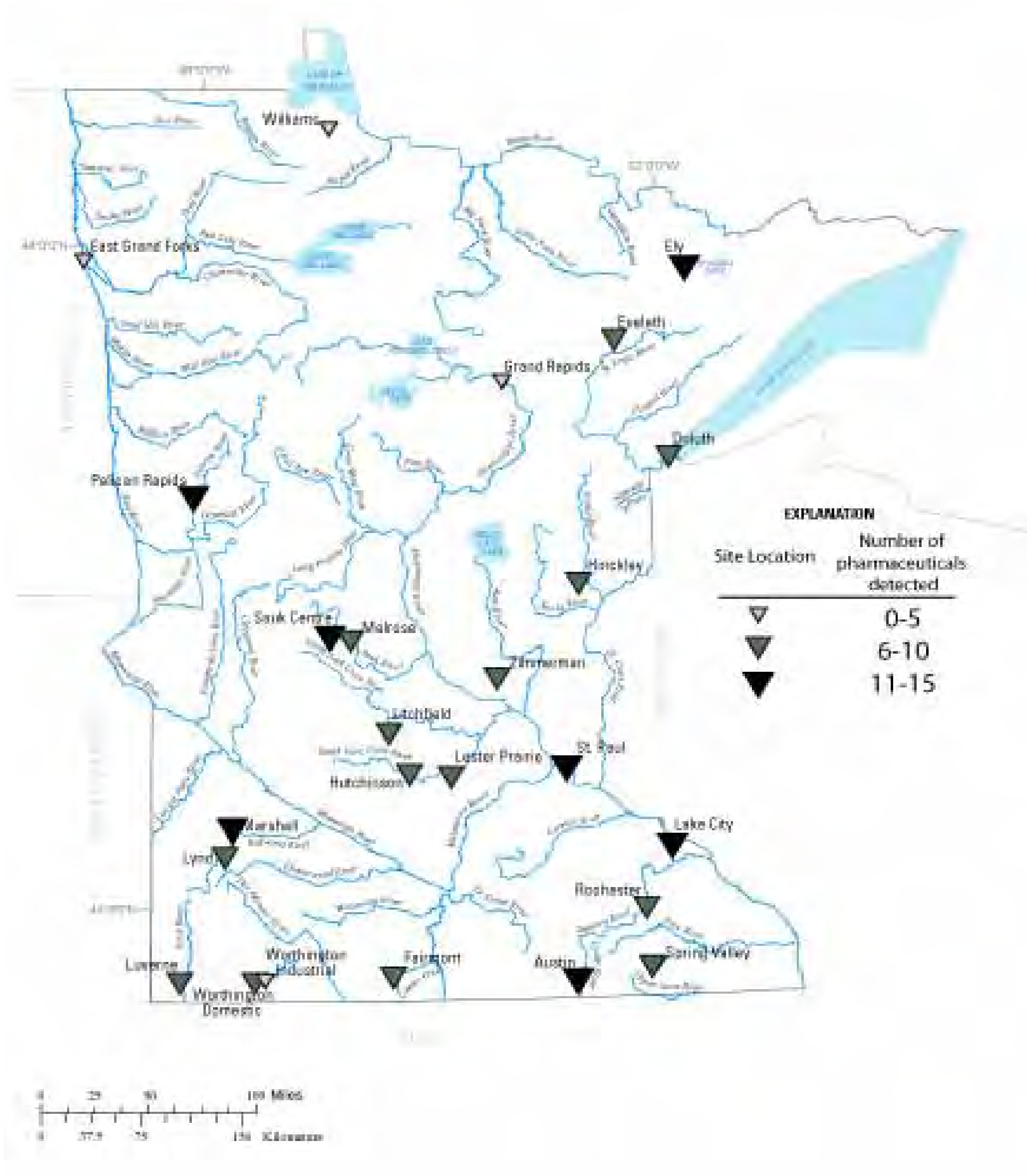


Figure 5. Frequency of hormones detected in upstream water, downstream water, and in WWTP effluent.

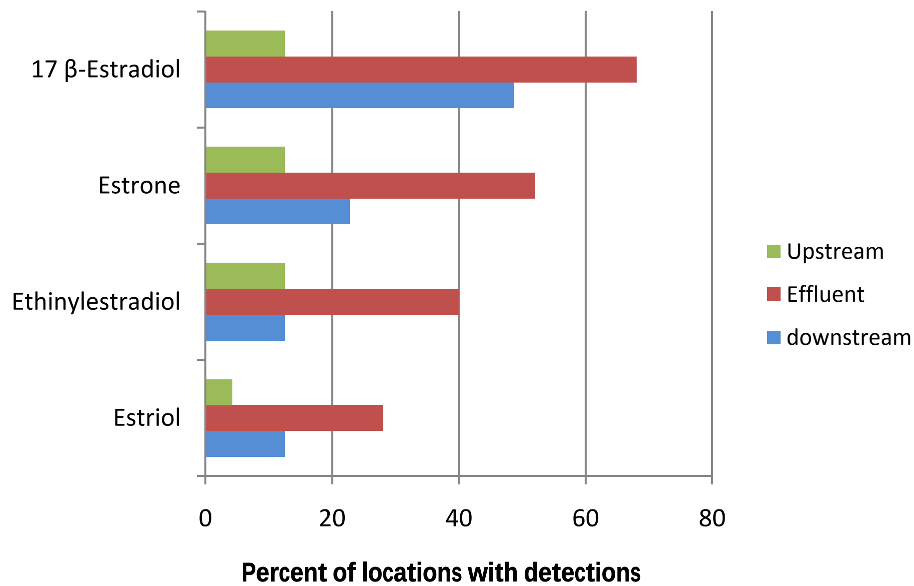


Figure 6. Frequency of hormone detections in sediment collected upstream and downstream of WWTPs.

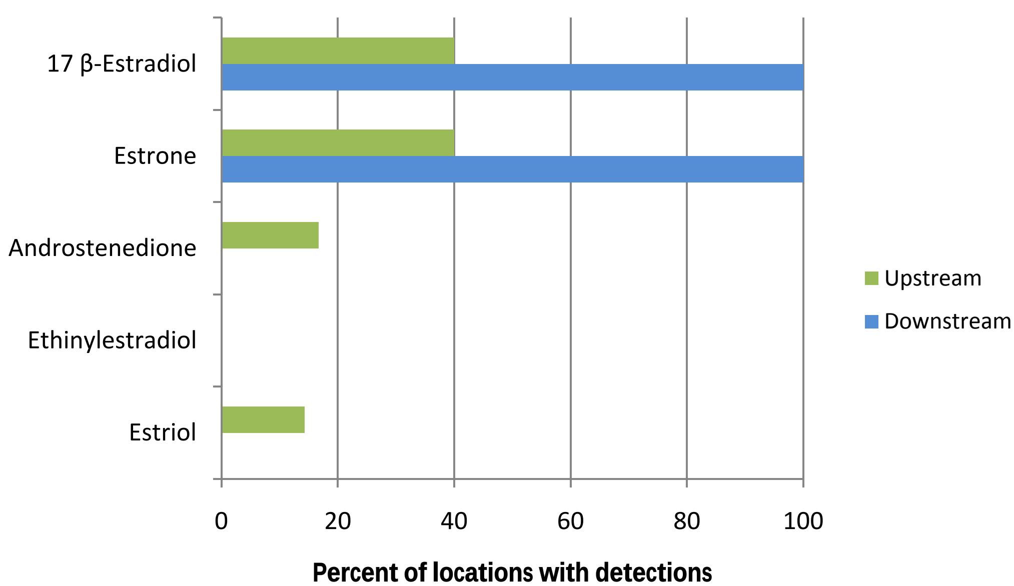


Figure 7. Frequency of chemicals detected in upstream water, downstream water, and in WWTP effluent.

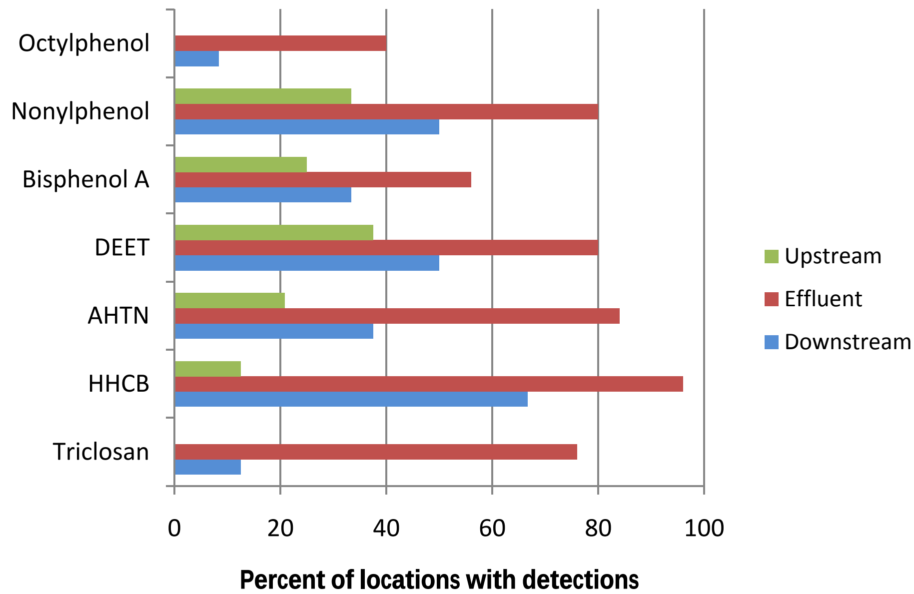


Figure 8. Frequency of chemicals detected in sediment collected upstream and downstream of WWTPs.

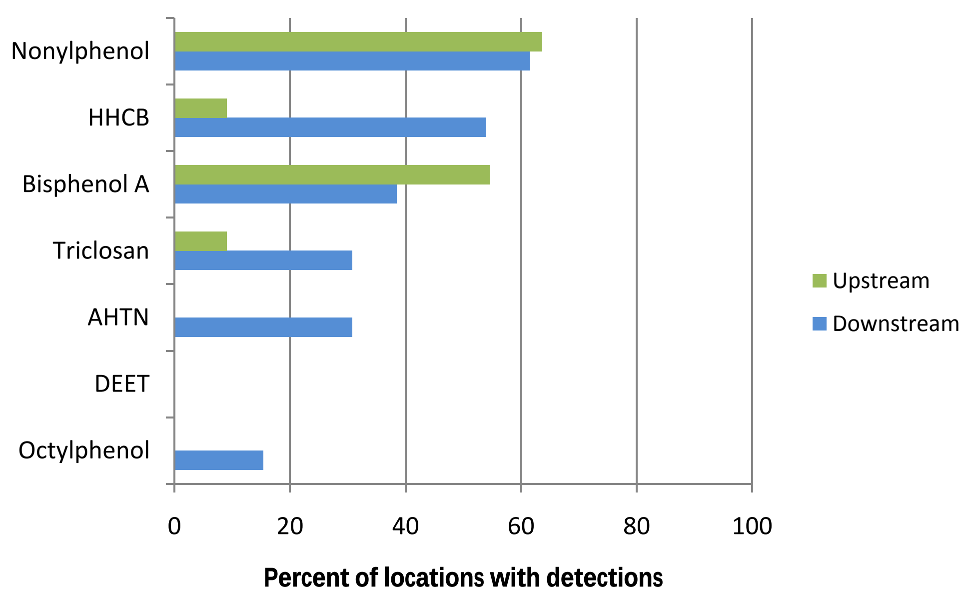


Figure 9. EACs found at higher concentrations at locations upstream of WWTP selected for this study.

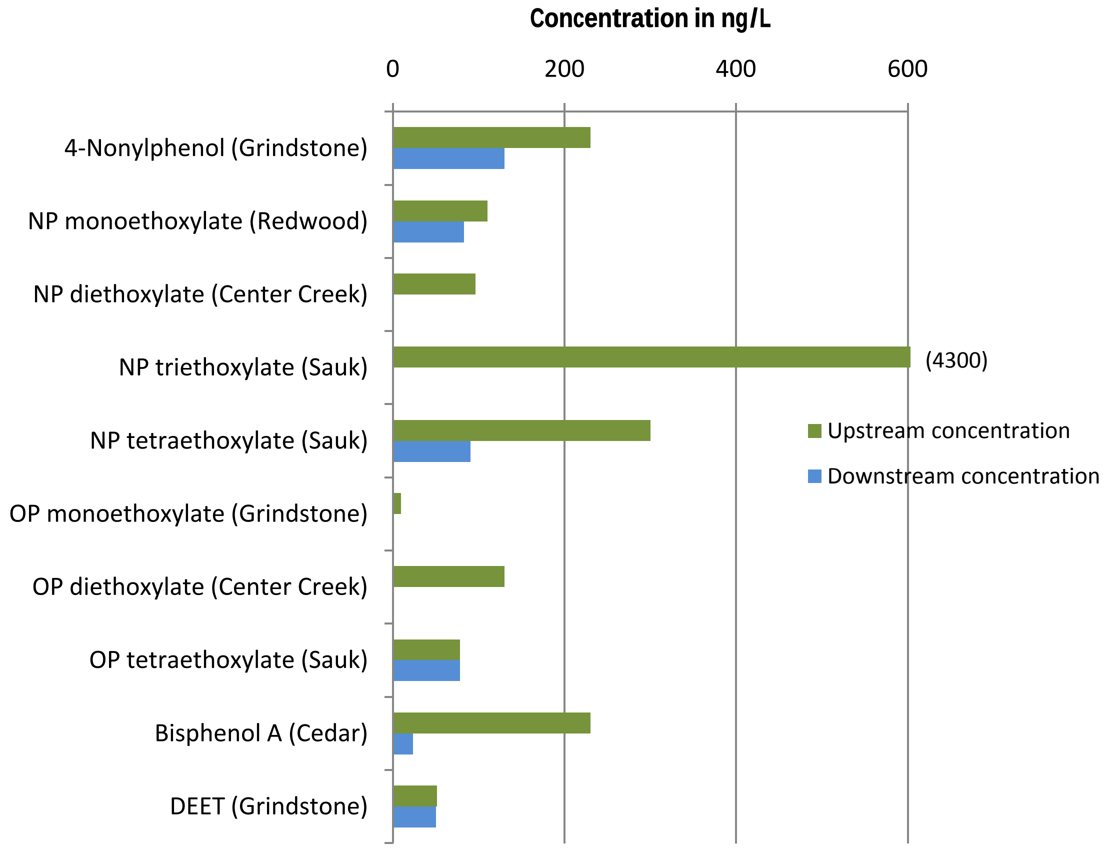


Figure 10. Diagram showing the number of genes that were affected by exposure to the Hutchinson WWTP effluent as well as by exposure to upstream or downstream water. The values in the overlapping regions indicate the number of genes affected by both treatments. For example, 238 genes were affected by exposure to both effluent and downstream water, while there were 1336 genes affected only by effluent exposure.

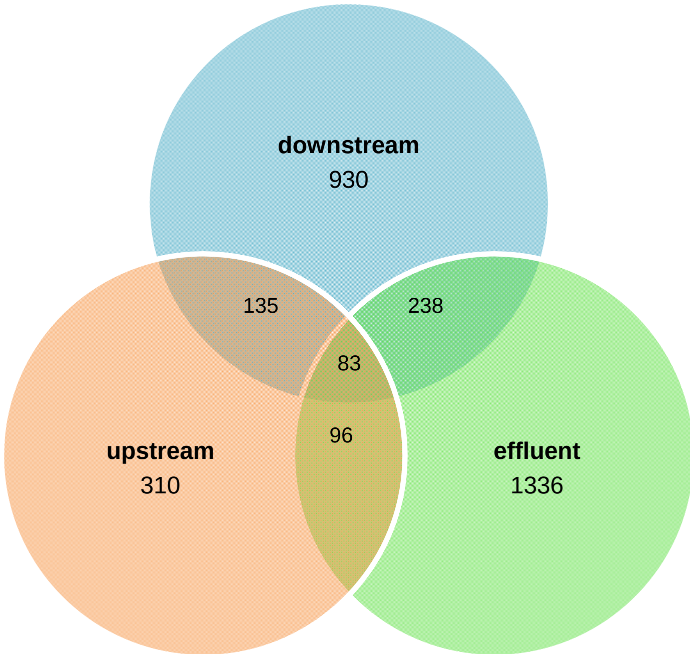


Figure 11. Diagram showing the number of genes that were affected by exposure to the Rochester WWTP effluent as well as by exposure to upstream or downstream water. The values in the overlapping regions indicate the number of genes affected by both treatments. For example, 216 genes were affected by exposure to both WWTP effluent and downstream water, while 842 genes were affected only by effluent exposure.

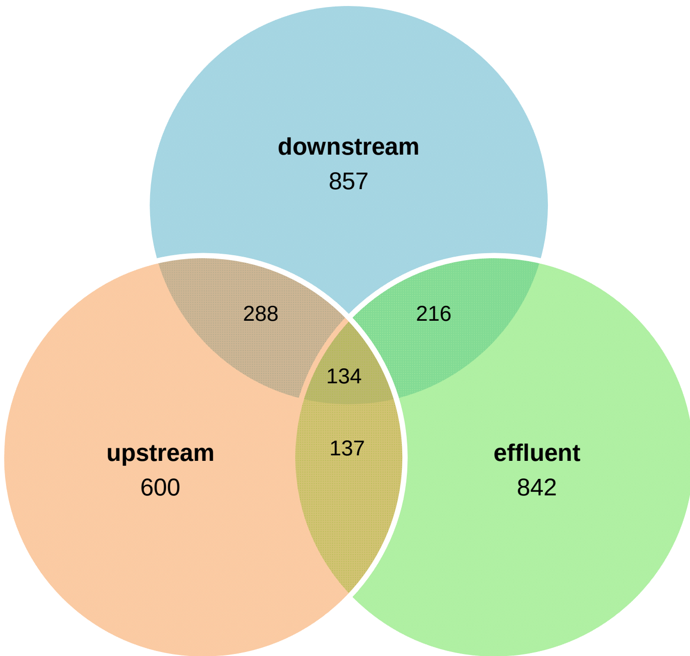
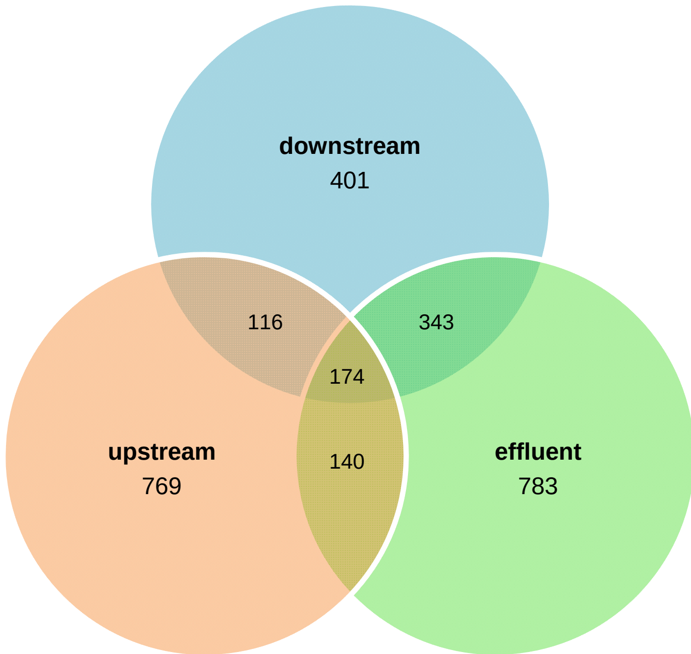


Figure 12. Diagram showing the number of genes that were affected by exposure to the Ely WWTP effluent as well as by exposure to upstream or downstream water. The values in the overlapping regions indicate the number of genes affected by both treatments. For example, 343 genes were affected by exposure to both WWTP effluent and downstream water, while 783 genes were affected only by exposure to effluent.



Appendix A

2009 Statutory Language for Endocrine Disruptor Monitoring

From 2009 Session Law Chapter 172, Article 2, Sec. 4 (f) and Sec. 29 (f) $896,000 the first year is to establish a network of water monitoring sites, to include at least 20 additional sites, in public waters adjacent to wastewater treatment facilities across the state to assess levels of endocrine-disrupting compounds, antibiotic compounds, and pharmaceuticals as required in this article. The data must be placed on the agency's website.

Sec. 29. Endocrine-Disruptor Monitoring

(a) The commissioner of the Pollution Control Agency shall establish a network of water monitoring sites in public waters adjacent to wastewater treatment facilities across the state to assess levels of endocrine disrupting compounds, antibiotic compounds, and pharmaceuticals.

(b) Each of the monitoring sites must provide enhanced monitoring of the effluent at the discharge point of the wastewater treatment facility and monitoring of the public waters above and below the discharge point.

(c) The monitoring sites must be located throughout the state, represent a variety of wastewater treatment facility sizes based on the number of gallons of water discharged per day, and represent a variety of waste treatment systems used for primary, secondary, and tertiary disinfecting treatment and management of biosolids.

(d) In establishing the monitoring network, the commissioner of the Pollution Control Agency must consult with the commissioners of health and natural resources, the United States Geological Survey, the Metropolitan Council, local wastewater treatment facility operators, and the Water Resources Center at the University of Minnesota. Consideration may be given to monitoring sites at facilities identified as part of a total maximum daily load study and facilities located on a water body identified for enhanced protection. The initial monitoring network must include at least ten sites.

(e) Monitoring must include, but is not limited to, endocrine-disrupting compounds from natural and synthetic hormones, pharmaceuticals, personal care products, and a range of industrial products and by-products. At a minimum, concentrations of estrone, nonylphenol, bisphenol-A, 17-beta-estradiol, 17-alpha-ethynylestradiol, estriol, and antibacterial triclosan must be monitored. Additional compounds, antibacterial compounds, and pharmaceuticals potentially impacting human health and aquatic communities may be considered for identification and monitoring including, but not limited to, nonylphenol ethoxylates, octylphenol, and octylphenol ethoxylates; the hormones androstenedione, trenbelone, and diethylphthalate; antidepressant medications, including fluoxetine and fluvoxamine; carbamazepine; and triclocarban.

(f) The commissioner of the Pollution Control Agency shall begin the monitoring and testing required under this section no later than November 1, 2009. Information about requirements under this section and the results from the monitoring and testing must be available on the agency's website by June 1, 2010. The commissioner shall submit a preliminary report on the results of the monitoring and testing to the chairs of the legislative committees with jurisdiction over environment and natural resources policy and finance by April 15, 2010, and a final report no later than January 15, 2011.

Appendix B

List of compounds, sources, and their uses

Hormone	Description
11-ketotestosterone	A male sex hormone
17α-estradiol	A female estrogenic hormone
17β-estradiol	One of three naturally occurring estrogens; a female hormone
Androstenedione	Precursor to testosterone and estrogen, the male and female sex hormones
Androsterone	Steroid hormone with weak androgenic activity
Equilenin	An estrogen used in hormone replacement therapy
Equilin	An estrogen used in hormone replacement therapy
Estriol	One of three naturally occurring estrogens; a female hormone
Estrone	One of three naturally occurring estrogens; a female hormone
17α-ethinylestradiol	Synthetic oral contraceptive in birth control prescriptions
Mestranol	An estrogen used in oral contraceptives, converted to ethinylestradiol
Progesterone	A female steroid hormone
Testosterone	A male sex hormone and anabolic steroid

Organic Wastewater Compound	Application/description
1,3-dichlrobenzene	Moth repellent, deodorant
1,4-dichlorobenzene	Moth repellent, deodorant
1-methylnaphthalene	A PAH, or polyaromatic hydrocarbon
2,6-dimethylnaphthalene	A PAH, or polyaromatic hydrocarbon
2,6-di-tert-butyl-1,4-benzoquinone	Chemical reagent in the synthesis of other chemicals
2,6-di-tert-butyl-4-methylphenol	BHT. Antioxidant food additive, also used in fuels, cosmetics, pharmaceuticals.
2,6-di-tert-butylphenol	One of many alkylphenols. Alkylphenols are used to synthesize detergents, fragrances, polymers, and other compounds
2-methylnaphthalene	A PAH, or polyaromatic hydrocarbon
3-beta coprostenol	Breakdown product of cholesterol; indicator of fecal matter
3-methylindole	Skatole; naturally occurring chemical in feces
3-t-butyl-4-hydroxyanisole	Precursor of synthetic chemicals
4-(tert-octyl)phenol	Nonionic detergent or breakdown product of detergent

Organic Wastewater Compound	Application/description
4-ethylphenol	One of many alkylphenols. Alkylphenols are used to synthesize detergents, fragrances, polymers, and other compounds
4-methylphenol (cresol)	Wood preservative; can also be naturally occurring.
4-*tert*-Octylphenol (ng/L); 4-tert-OP	An alkylphenol, a breakdown product of octylphenol ethoxylate
4-n-octylphenol; 4-OP	An alkylphenol; Nonionic detergent or breakdown product of detergent
4-*tert*-Octylphenol monoethoxylate; 4-OP1EO	Nonionic detergent
4-*tert*-Octylphenol diethoxylate; 4-OP2EO	Nonionic detergent
4-*tert*-Octylphenol tetraethoxylate; 4-OP4EO	Nonionic detergent
4-*tert*-Octylphenol pentaethoxylate; 4-OP5EO	Nonionic detergent
4-*tert*-Pentylphenol	An alkylphenol
4-nonylphenol	An alkylphenol; breakdown product of nonylphenol ethoxylate detergent
4-Nonylphenol monoethoxylate; 4-NP1EO	Nonionic detergent; nonylphenol ethoxylate
4-Nonylphenol diethoxylate 4-NP2EO	Nonionic detergent; nonylphenol ethoxylate
4-Nonylphenol triethoxylate 4-NP3EO	Nonionic detergent; nonylphenol ethoxylate
4-Nonylphenol tetraethoxylate 4-NP4EO	Nonionic detergent; nonylphenol ethoxylate
4-propylphenol	One of many alkylphenols. Alkylphenols are used to synthesize detergents, fragrances, polymers, and other compounds
4-tert-butylphenol	One of many alkylphenols. Alkylphenols are used to synthesize detergents, fragrances, polymers, and other compounds
4-tert-pentylphenol	One of many alkylphenols. Alkylphenols are used to synthesize detergents, fragrances, polymers, and other compounds
5-methyl-1H-benzotriazole	Anticorrosive; rust inhibitor
Acetophenone	Precursor to fragrances and resins
AHTN (Acetylhexamethyltetrahydronaphthalene)	Fragrance chemical
APECs (Alkylphenol ethoxycarboxylates)	Detergents
Anthracene	A PAH, or polyaromatic hydrocarbon
Anthraquinone	Precursor to dyes; used in wood pulp bleaching
Benzo-a-pyrene	A PAH; polyaromatic hydrocarbon
Benzophenone	UV inhibitor, sunscreen
Beta-sitosterol	Plant sterol, similar to cholesterol

Organic Wastewater Compound	Application/description
Beta-stigmasterol	Plant sterol
Bisphenol A	Monomer used to synthesize polycarbonate plastic
Bis(2-ethylhexyl)phthalate	Plasticizer
Bromacil	Pesticide
Camphor	Widely used medicinal and culinary additive
Carbazole	Chemical used in the production of pigments
Chlorpyrifos	Pesticide
Cresol	Naturally occurring and man-made chemical used as a disinfectant and a cleaner.
DEET (N,N-diethyl-*meta*-toluamide)	Insect repellant
Diazinon	Pesticide
Diethylhexylphthalate	Plasticizer
Diethylphthalate	Plasticizer
EDTA (Ethylenediaminetetraacetic acid)	Compound that binds metals in solution; widespread industrial and commercial application
Fluoranthene	A PAH; polyaromatic hydrocarbon
HHCB (hexahydrohexamethylcyclopentabenzopyran)	Fragrance chemical
Indole	Precursor to fragrances and pharmaceuticals
Isoborneol	Precursor to chemical synthesis
Isophorone	Solvent and precursor to chemical synthesis
Isoquinoline	Precursor to dyes, insecticides, paints
Limonene	Terpene used in detergent production
Methylnaphthalene	PAH; polyaromatic hydrocarbon
Metolachlor	Pesticide
Metribuzin	Pesticide
Naphthalene	PAH; polyaromatic hydrocarbon
NTA (Nitrilotriacetic acid)	Compound that binds metals in solution; widespread industrial and commercial application

Organic Wastewater Compound	Application/description
PBDE (Polybrominated diphenylether)	Flame retardant
Prometon	Herbicide
Triclosan	Antimicrobial
Triclocarban	Antimicrobial

Pharmaceutical	Description
Acetaminophen	Analgesic
Albuterol	Asthma medication
Buproprion	Antidepressant
Caffeine	Stimulant
Carbamazepine	Anticonvulsive used to treat epilepsy and attention-deficit hyperactivity disorder (ADHD)
Cimetidine	Antacid
Citalopram	Antidepressant
Codeine	Analgesic
Cotinine	Metabolite of nicotine
Dihydronifedipine	Metabolite of nifedipine
Diltiazem	Heart medication
Dimethylxanthine	Metabolite of caffeine
Diphenhydramine	Antihistamine
Fluoxetine	Antidepressant
Fluvoxamine	Antidepressant
Hydroxyproprion	Metabolite of buproprion
Miconazole	Topical antifungal medication
Ranitidine	Antacid
Sertraline	Antidepressant
Sulfamethoxazole	Antibiotic
Thiabendazole	Fungicide
Trimethoprim	Antibiotic
Venlafaxine	Antidepressant
Warfarin	Blood thinner
Phytoestrogens (Biochanin A, coumestrol, daidzein, equol, formononetin, genistin, prunetin)	A diverse group of plant-derived, naturally occurring chemicals that have a structural similarity to 17β-estradiol, and can cause estrogenic or/and anti-estrogenic effects in humans and animals.

Appendix C

The following tables contain the analytical data for surface water, effluent, and sediment collected for the WWTP Endocrine Disrupting Chemical Study.

Pharmaceuticals in Water

USGS station name	Site number (shown on fig. 3)	Site type	Acetaminophen (ng/L)	Albuterol (ng/L)	Bupropion (ng/L)-UC	Caffeine (ng/L)	Carbamazepine (ng/L) [<40 RL]	Carbamazepine (ng/L)-UC [<5-RL]	Codeine (ng/L)	Cotinine (ng/L)
Williams Creek above WWTP at Williams, Minn.	1	US				51	55	211		
Williams WWTP outflow at Williams, Minn.	2	WWTP					348	1,475		
Williams Creek below WWTP at Williams, Minn.	3	DS				51	70	274		
Shagawa Lake at Mouth of Burntside River near Ely,	4	US								
Ely WWTP outflow at Ely, Minn.	5	WWTP			395	11500	79	355	51	
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6	DS				72				
Elbow Creek above Eveleth WWTP at Eveleth, Minn.	7	US				1080			6	17
Eveleth WWTP outlflow at Eveleth, Minn.	8	WWTP			916		88	372		
Elbow Creek below Eveleth WWTP at Eveleth, Minn.	9	DS			736	101	64	358		
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.	10	US								
Western Lake Superior Sanitary District - WWTP at	11	WWTP				9000		301		220
Lake Superior in St. Louis Bay at Duluth, Minn.	12	DS				769	3	43		70
Pelican River above WWTP at Pelican Rapids, Minn.	13	US								
Pelican Rapids WWTP outflow at Pelican Rapids, Minn.	14	WWTP			780	665		197	16	48
Pelican River below WWTP at Pelican Rapids, Minn.	15	DS								
Red River of the North above WWTP at East Grand	16	US								
East Grand Forks WWTP Outflow at East Grand Forks Minn.	17	WWTP					7	38		
Red River of the North below WWTP at East Grand	18	DS				58				
Mississippi River above WWTP at Grand Rapids, Minn.	19	US								
Grand Rapids WWTP outflow at Grand Rapids, Minn.	20	WWTP					28	126		9
Mississippi River below WWTP at Grand Rapids, Minn.	21	DS								
Sauk River above Sauk Centre WWTP at Sauk Centre,	22	US								
Sauk Centre WWTP outflow at Sauk Centre, Minn.	23	WWTP			550	261	202	1,295		42
Sauk River below Sauk Centre WWTP at Sauk Centre,	24	DS					2	22		
Sauk River above Melrose WWTP at Melrose, Minn.	25	US						14		
Melrose WWTP outflow at Melrose, Minn.	26	WWTP			28		20	84		
Sauk River below Melrose WWTP at Melrose, Minn.	27	DS					3	23		
Tibbets Brook above WWTP outflow at Zimmerman,	28	US								
Zimmerman WWTP outflow at Zimmerman, Minn.	29	WWTP			701		8	71		
Tibbets Brook below WWTP outflow at Zimmerman, Minn.	30	DS			236		5	45		
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.	31	US								
Litchfield WWTP outflow near Litchfield, Minn.	32	WWTP			77		90	492		
Jewitts Creek near Litchfield, Minn.	33	DS			17		6	51		
South Fork of the Crow River above WWTP at	34	US								
Hutchinson WWTP outflow at Hutchinson, Minn.	35	WWTP			68		75	415		
South Fork of the Crow River below Hutchinson, Minn.	36	DS			12		7	58		
South Fork Crow River above WWTP at Lester Prairie,	37	US						21		
Lester Prairie WWTP outflow at Lester Prairie, Minn.	38	WWTP			515		187	1,146		
South Fork Crow River below WWTP at Lester Prairie,	39	DS						26		
Redwood River above Lynd WWTP near Lynd, Minn.	40	US								
Lynd WWTP outflow near Lynd, Minn.	41	WWTP			10.4	81		87		
Redwood River below Lynd WWTP near Lynd, Minn.	42	DS								
Redwood River above WWTP below Marshall, Minn.	43	US								
Marshall WWTP outfall at Marshall, Minn.	44	WWTP			206		72	376	22	
Redwood River below WWTP near Marshall, Minn.	45	DS					9	29		
Center Creek on Co. Rd. 143, at Fairmont, Minn.	46	US								
Fairmont WWTP outflow at Fairmont, Minn.	47	WWTP			971		137	531		
Center Creek below WWTP at Fairmont, Minn.	48	DS			273		105	398		
Mississippi River at Industrial Mollasses, St. Paul, Minn.	49	US						16		
Metro Plant (WWTP) outflow in St. Paul, Minn.	50	WWTP			1,138		99	597	71	
Mississippi River at South St. Paul, Minn.	51	DS					21	47		
Grindstone River above WWTP near Hinckley, Minn.	52	US								
Hinckley WWTP near Hinckley, Minn.	53	WWTP			255		135	526		
Grindstone River below Hinckley, Minn.	54	DS			10.8			5.7		
Mississippi River (Lake Pepin) above Lake City, Minn.	55	US						20		
Lake City WWTP outflow at Lake City, Minn.	56	WWTP			1,056		17	252	79	36
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	57	DS			15		3	35		
South Fork Zumbro River at Rochester, Minn.	58	US				126				19
Rochester WWTP outflow at Rochester, Minn.	59	WWTP			1,556		111	535		
South Fork Zumbro River below WWTP near Rochester,	60	DS			164		71	185		
Spring Valley Creek above Spring Valley WWTP outflow at Spring Valley, Minn.	61	US								
Spring Valley WWTP outflow at Spring Valley, Minn.	62	WWTP			185		393	965		
Spring Valley Creek below Spring Valley WWTP outflow	63	DS			24		73	152		
Cedar River above treatment plant at Austin, Minn.	64	US								
Austin WWTP outflow at Austin, Minn.	65	WWTP			4,298	332	50	375	56	
Cedar River below treatment plant at Austin, Minn.	66	DS			98	79	23	64	13	
Okabena Creek above WWTP outflow at Worthington,	67	US								
Worthington WWTP outflow at Worthington, Minn.	68	WWTP			260		102	430		
Industrial WWTP outflow near Worthington, Minn.	69	WWTP								
Okabena Creek below WWTP outflow at Worthington,	70	DS			36		44	172		
Rock River above WWTP near Luverne, Minn.	71	US								
Luverne WWTP outflow near Luverne, Minn.	72	WWTP			245	338	89	344	56	56
Rock River below WWTP near Luverne, Minn.	73	DS						8		

Pharmaceuticals in Water (continued)

USGS station name	Dehydronifedipine (ng/L)	Diltiazem (ng/L)	1,7-Dimethylxanthine (ng/L)	Diphenhydramine (ng/L)	Fluoxetine (ng/L)-[<16-RL]	Fluoxetine (ng/L)-UC-[<10-RL]	Fluvoxamine (ng/L)-UC	Hydroxy-bupropion (ng/L)-UC	Ranitidine (ng/L)	Sulfamethoxazole (ng/L) [<160RL]
Williams Creek above WWTP at Williams, Minn.										
Williams WWTP outflow at Williams, Minn.				47				6		
Williams Creek below WWTP at Williams, Minn.										
Shagawa Lake at Mouth of Burntside River near Ely,										
Ely WWTP outflow at Ely, Minn.	4	40	4320	127		63	21	404	130	26
Shagawa Lake near Ely WWTP outflow at Ely, Minn.										
Elbow Creek above Eveleth WWTP at Eveleth, Minn.			73					1.3		
Eveleth WWTP outlflow at Eveleth, Minn.		28		43	53	52				91
Elbow Creek below Eveleth WWTP at Eveleth, Minn.		25		30	20	44				29
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.										
Western Lake Superior Sanitary District - WWTP at			464		9	19		128		
Lake Superior in St. Louis Bay at Duluth, Minn.			137					20		
Pelican River above WWTP at Pelican Rapids, Minn.										
Pelican Rapids WWTP outflow at Pelican Rapids, Minn.			82		18	11		255		
Pelican River below WWTP at Pelican Rapids, Minn.										
Red River of the North above WWTP at East Grand								2.4		
East Grand Forks WWTP Outflow at East Grand Forks Minn.					7			14		
Red River of the North below WWTP at East Grand								1.9		4
Mississippi River above WWTP at Grand Rapids, Minn.										
Grand Rapids WWTP outflow at Grand Rapids, Minn.								3.7		
Mississippi River below WWTP at Grand Rapids, Minn.										
Sauk River above Sauk Centre WWTP at Sauk Centre,										
Sauk Centre WWTP outflow at Sauk Centre, Minn.		46		88		36		303		224
Sauk River below Sauk Centre WWTP at Sauk Centre,								1		7
Sauk River above Melrose WWTP at Melrose, Minn.										4
Melrose WWTP outflow at Melrose, Minn.		13		29		16		2.4		24
Sauk River below Melrose WWTP at Melrose, Minn.								1.4		6
Tibbets Brook above WWTP outflow at Zimmerman,										
Zimmerman WWTP outflow at Zimmerman, Minn.					3	27		1,975	56	
Tibbets Brook below WWTP outflow at Zimmerman, Minn.					8	17		592	62	
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.										
Litchfield WWTP outflow near Litchfield, Minn.				36	14	15				
Jewitts Creek near Litchfield, Minn.										
South Fork of the Crow River above WWTP at										
Hutchinson WWTP outflow at Hutchinson, Minn.						15		377	15	222
South Fork of the Crow River below Hutchinson, Minn.								34		
South Fork Crow River above WWTP at Lester Prairie,								10		
Lester Prairie WWTP outflow at Lester Prairie, Minn.					2	21		1,970	46	180
South Fork Crow River below WWTP at Lester Prairie,								10		
Redwood River above Lynd WWTP near Lynd, Minn.										
Lynd WWTP outflow near Lynd, Minn.								85		
Redwood River below Lynd WWTP near Lynd, Minn.										
Redwood River above WWTP below Marshall, Minn.										
Marshall WWTP outfall at Marshall, Minn.		11		40	6	18		369	20	65
Redwood River below WWTP near Marshall, Minn.								29		9
Center Creek on Co. Rd. 143, at Fairmont, Minn.										
Fairmont WWTP outflow at Fairmont, Minn.		41		35	4	30		1,023	110	273
Center Creek below WWTP at Fairmont, Minn.		29			3			330	86	289
Mississippi River at Industrial Mollasses, St. Paul, Minn.								1.3		
Metro Plant (WWTP) outflow in St. Paul, Minn.	4	26		38		47		705		267
Mississippi River at South St. Paul, Minn.								26		40
Grindstone River above WWTP near Hinckley, Minn.										
Hinckley WWTP near Hinckley, Minn.					10	31		523	19	
Grindstone River below Hinckley, Minn.								12.5		
Mississippi River (Lake Pepin) above Lake City, Minn.								3		
Lake City WWTP outflow at Lake City, Minn.		21		47	66	46		786	48	
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.					10			27		
South Fork Zumbro River at Rochester, Minn.										
Rochester WWTP outflow at Rochester, Minn.				18		76	17	48		119
South Fork Zumbro River below WWTP near Rochester,						13		4		31
Spring Valley Creek above Spring Valley WWTP outflow at Spring Valley, Minn.										
Spring Valley WWTP outflow at Spring Valley, Minn.				38		30				182
Spring Valley Creek below Spring Valley WWTP outflow										22
Cedar River above treatment plant at Austin, Minn.										
Austin WWTP outflow at Austin, Minn.		19		29		28	16	53		
Cedar River below treatment plant at Austin, Minn.				9		10		1		48
Okabena Creek above WWTP outflow at Worthington,								7		
Worthington WWTP outflow at Worthington, Minn.				12	4	23				
Industrial WWTP outflow near Worthington, Minn.					6					
Okabena Creek below WWTP outflow at Worthington,					5					48
Rock River above WWTP near Luverne, Minn.										
Luverne WWTP outflow near Luverne, Minn.				24	11	31				37
Rock River below WWTP near Luverne, Minn.										

Pharmaceuticals in Water (continued)

USGS station name	Sulfamethoxazole (ng/L)-UC [<5 RL]	Thiabendazole (ng/L)	Trimethoprim (ng/L) [<20-RL]	Trimethoprim (ng/L)-UC [5-RL]	Warfarin (ng/L)	Venlafaxine (ng/L)-UC
Williams Creek above WWTP at Williams, Minn.	5					
Williams WWTP outflow at Williams, Minn.	65					748
Williams Creek below WWTP at Williams, Minn.	5					15
Shagawa Lake at Mouth of Burntside River near Ely,	9					
Ely WWTP outflow at Ely, Minn.	235		198	571		3,018
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	9					11
Elbow Creek above Eveleth WWTP at Eveleth, Minn.						57
Eveleth WWTP outlflow at Eveleth, Minn.	871		271	779		2,238
Elbow Creek below Eveleth WWTP at Eveleth, Minn.	645		233	632		1,840
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.	6					
Western Lake Superior Sanitary District - WWTP at	233			80		230
Lake Superior in St. Louis Bay at Duluth, Minn.	73			15		92
Pelican River above WWTP at Pelican Rapids, Minn.						
Pelican Rapids WWTP outflow at Pelican Rapids, Minn.	2,324		91	242		520
Pelican River below WWTP at Pelican Rapids, Minn.	29			8		7
Red River of the North above WWTP at East Grand	38					6
East Grand Forks WWTP Outflow at East Grand Forks Minn.	15					
Red River of the North below WWTP at East Grand	36					5
Mississippi River above WWTP at Grand Rapids, Minn.						
Grand Rapids WWTP outflow at Grand Rapids, Minn.	200					80
Mississippi River below WWTP at Grand Rapids, Minn.	19					11
Sauk River above Sauk Centre WWTP at Sauk Centre,						
Sauk Centre WWTP outflow at Sauk Centre, Minn.	4,166		281	1,191		2,323
Sauk River below Sauk Centre WWTP at Sauk Centre,	58			20		18
Sauk River above Melrose WWTP at Melrose, Minn.	48			6		6
Melrose WWTP outflow at Melrose, Minn.	220			10		118
Sauk River below Melrose WWTP at Melrose, Minn.	66			6		15
Tibbets Brook above WWTP outflow at Zimmerman,						
Zimmerman WWTP outflow at Zimmerman, Minn.	1,066		350	1,463		2,532
Tibbets Brook below WWTP outflow at Zimmerman, Minn.	1,107		210	635		945
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.						
Litchfield WWTP outflow near Litchfield, Minn.	339			15		680
Jewitts Creek near Litchfield, Minn.	46					62
South Fork of the Crow River above WWTP at						
Hutchinson WWTP outflow at Hutchinson, Minn.	1,667			31		1,060
South Fork of the Crow River below Hutchinson, Minn.	207					63
South Fork Crow River above WWTP at Lester Prairie,	97					9
Lester Prairie WWTP outflow at Lester Prairie, Minn.	2,282			17		5,451
South Fork Crow River below WWTP at Lester Prairie,	91					11
Redwood River above Lynd WWTP near Lynd, Minn.						
Lynd WWTP outflow near Lynd, Minn.	72			18		12
Redwood River below Lynd WWTP near Lynd, Minn.	5					
Redwood River above WWTP below Marshall, Minn.						
Marshall WWTP outfall at Marshall, Minn.	1,244		7	23		524
Redwood River below WWTP near Marshall, Minn.	98					41
Center Creek on Co. Rd. 143, at Fairmont, Minn.						
Fairmont WWTP outflow at Fairmont, Minn.	3,031		100	305		2,789
Center Creek below WWTP at Fairmont, Minn.	2,417		55	146		799
Mississippi River at Industrial Mollasses, St. Paul, Minn.	64			10		12
Metro Plant (WWTP) outflow in St. Paul, Minn.	2,980		178	642		2,392
Mississippi River at South St. Paul, Minn.	221		29	37		52
Grindstone River above WWTP near Hinckley, Minn.						
Hinckley WWTP near Hinckley, Minn.	901		165	572		1,319
Grindstone River below Hinckley, Minn.	21			9		28
Mississippi River (Lake Pepin) above Lake City, Minn.	73			9		6
Lake City WWTP outflow at Lake City, Minn.	981		96	558		2,023
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	118			40		60
South Fork Zumbro River at Rochester, Minn.	6					
Rochester WWTP outflow at Rochester, Minn.	1,474		13	46		1,885
South Fork Zumbro River below WWTP near Rochester,	435			13		334
Spring Valley Creek above Spring Valley WWTP outflow at Spring Valley, Minn.	5					
Spring Valley WWTP outflow at Spring Valley, Minn.	1,508			23		930
Spring Valley Creek below Spring Valley WWTP outflow	146					74
Cedar River above treatment plant at Austin, Minn.	11					
Austin WWTP outflow at Austin, Minn.	2,021		70	376		1,330
Cedar River below treatment plant at Austin, Minn.	275		21	41		95
Okabena Creek above WWTP outflow at Worthington,						
Worthington WWTP outflow at Worthington, Minn.	841		17	65		603
Industrial WWTP outflow near Worthington, Minn.						5
Okabena Creek below WWTP outflow at Worthington,	450			18		204
Rock River above WWTP near Luverne, Minn.						
Luverne WWTP outflow near Luverne, Minn.	834		120	357		610
Rock River below WWTP near Luverne, Minn.	37		6	6		15

Phytoestrogens - Triclocarbaban in Water

USGS station name	Site Number (shown on fig. 3)	Site type	Triclocarban (ng/L)-UC	Biochanin A (ng/L)	Coumestrol (ng/L)	Daidzein (ng/L)	Daidzin (sugar) (ng/L)	Equol (ng/L)	Formononetin (ng/L)	Genistein (ng/L)	Genistin (sugar) (ng/L)	Glycitein (ng/L)	Prunetin (ng/L)
Williams Creek above WWTP at Williams, Minn.	1	US											
Williams WWTP outflow at Williams, Minn.	2	WWTP	121										
Williams Creek below WWTP at Williams, Minn.	3	DS											
Shagawa Lake at Mouth of Burntside River near Ely, Minn.	4	US											
Ely WWTP outflow at Ely, Minn.	5	WWTP	201									15	
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6	DS	23										
Elbow Creek above Eveleth WWTP at Eveleth, Minn.	7	US											
Eveleth WWTP outlflow at Eveleth, Minn.	8	WWTP	416										
Elbow Creek below Eveleth WWTP at Eveleth, Minn.	9	DS	370										
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.	10	US							4				
Western Lake Superior Sanitary District - WWTP at Duluth, Minn.	11	WWTP	175										
Lake Superior in St. Louis Bay at Duluth, Minn.	12	DS	20										
Pelican River above WWTP at Pelican Rapids, Minn.	13	US											
Pelican Rapids WWTP outflow at Pelican Rapids, Minn.	14	WWTP	43										
Pelican River below WWTP at Pelican Rapids, Minn.	15	DS											
Red River of the North above WWTP at East Grand Forks, Minn.	16	US	31										
East Grand Forks WWTP Outflow at East Grand Forks Minn.	17	WWTP											
Red River of the North below WWTP at East Grand Forks, Minn.	18	DS											
Mississippi River above WWTP at Grand Rapids, Minn.	19	US	70										
Grand Rapids WWTP outflow at Grand Rapids, Minn.	20	WWTP	31										
Mississippi River below WWTP at Grand Rapids, Minn.	21	DS	33										
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	22	US											
Sauk Centre WWTP outflow at Sauk Centre, Minn.	23	WWTP	123									11	
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	24	DS							1				
Sauk River above Melrose WWTP at Melrose, Minn.	25	US	31										
Melrose WWTP outflow at Melrose, Minn.	26	WWTP	33										
Sauk River below Melrose WWTP at Melrose, Minn.	27	DS											
Tibbets Brook above WWTP outflow at Zimmerman, Minn.	28	US											
Zimmerman WWTP outflow at Zimmerman, Minn.	29	WWTP	168										
Tibbets Brook below WWTP outflow at Zimmerman, Minn.	30	DS	64										
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.	31	US											
Litchfield WWTP outflow near Litchfield, Minn.	32	WWTP	33										
Jewitts Creek near Litchfield, Minn.	33	DS											
South Fork of the Crow River above WWTP at Hutchinson, Minn.	34	US							2				
Hutchinson WWTP outflow at Hutchinson, Minn.	35	WWTP	72										
South Fork of the Crow River below Hutchinson, Minn.	36	DS			6				5				

Phytoestrogens - Triclocarbaban in Water (continued)

USGS station name	Site Number (shown on fig. 3)	Site type	Triclocarban (ng/L)-UC	Biochanin A (ng/L)	Coumestrol (ng/L)	Daidzein (ng/L)	Daidzin (sugar) (ng/L)	Equol (ng/L)	Formononetin (ng/L)	Genistein (ng/L)	Genistin (sugar) (ng/L)	Glycitein (ng/L)	Prunetin (ng/L)
South Fork Crow River above WWTP at Lester Prairie, Minn.	37	US							2				
Lester Prairie WWTP outflow at Lester Prairie, Minn.	38	WWTP	116										
South Fork Crow River below WWTP at Lester Prairie, Minn.	39	DS							2				
Redwood River above Lynd WWTP near Lynd, Minn.	40	US			2	4			3				
Lynd WWTP outflow near Lynd, Minn.	41	WWTP	28										
Redwood River below Lynd WWTP near Lynd, Minn.	42	DS			2	4			3				
Redwood River above WWTP below Marshall, Minn.	43	US	52						1				
Marshall WWTP outfall at Marshall, Minn.	44	WWTP											
Redwood River below WWTP near Marshall, Minn.	45	DS	21						2				
Center Creek on Co. Rd. 143, at Fairmont, Minn.	46	US	20						2				
Fairmont WWTP outflow at Fairmont, Minn.	47	WWTP	96										
Center Creek below WWTP at Fairmont, Minn.	48	DS	52										
Mississippi River at Industrial Mollasses, St. Paul, Minn.	49	US			2				1				
Metro Plant (WWTP) outflow in St. Paul, Minn.	50	WWTP	136										
Mississippi River at South St. Paul, Minn.	51	DS							3				
Grindstone River above WWTP near Hinckley, Minn.	52	US							2				
Hinckley WWTP near Hinckley, Minn.	53	WWTP											
Grindstone River below Hinckley, Minn.	54	DS							2				
Mississippi River (Lake Pepin) above Lake City, Minn.	55	US											
Lake City WWTP outflow at Lake City, Minn.	56	WWTP	53										
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	57	DS											
South Fork Zumbro River at Rochester, Minn.	58	US	32										
Rochester WWTP outflow at Rochester, Minn.	59	WWTP	92										
South Fork Zumbro River below WWTP near Rochester, Minn.	60	DS	26						2				
Spring Valley Creek above Spring Valley WWTP outflow at Spring Valley, Minn.	61	US											
Spring Valley WWTP outflow at Spring Valley, Minn.	62	WWTP	173										
Spring Valley Creek below Spring Valley WWTP outflow at Spring Valley, Minn.	63	DS	21										
Cedar River above treatment plant at Austin, Minn.	64	US	40		1				2				
Austin WWTP outflow at Austin, Minn.	65	WWTP	257										
Cedar River below treatment plant at Austin, Minn.	66	DS	32		4				4				
Okabena Creek above WWTP outflow at Worthington, Minn.	67	US	63										
Worthington WWTP outflow at Worthington, Minn.	68	WWTP	172										
Industrial WWTP outflow near Worthington, Minn.	69	WWTP	45										
Okabena Creek below WWTP outflow at Worthington, Minn.	70	DS	35										
Rock River above WWTP near Luverne, Minn.	71	US	31										
Luverne WWTP outflow near Luverne, Minn.	72	WWTP	296										
Rock River below WWTP near Luverne, Minn.	73	DS											

Alkylphenols in Water

USGS station name	Site Number (shown on fig. 3)	Site Type	Acetyl hexamethyl tetrahydronaphthalene (ng/L)	Bisphenol A (ng/L)	4-*tert*-Butylphenol (ng/L)	Caffeine (ng/L)	2,6-Di-*tert*-butyl-1,4-benzoquinone (ng/L)	1,3-Dichlorobenzene (ng/L)	1,4-Dichlorobenzene (ng/L)	N,N-diethyl-*meta*-toluamide (ng/L)	Hexahydrohexamethylcyclopenta-benzopyran (ng/L)
Williams Creek above WWTP at Williams, Minn.	1	US				71					6
Williams WWTP outflow at Williams, Minn.	2	WWTP	11			33			13		300
Williams Creek below WWTP at Williams, Minn.	3	DS		25		100					15
Shagawa Lake at Mouth of Burntside River near Ely,	4	US				30				20	
Ely WWTP outflow at Ely, Minn.	5	WWTP	10	84	86	9,900			27		75
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6	DS				40					
Elbow Creek above Eveleth WWTP at Eveleth, Minn.	7	US				840					
Eveleth WWTP outlflow at Eveleth, Minn.	8	WWTP	22		56	26				27	100
Elbow Creek below Eveleth WWTP at Eveleth, Minn.	9	DS	17		46	150				19	85
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.	10	US									
Western Lake Superior Sanitary District - WWTP at	11	WWTP		22,000		9,400			97	780	230
Lake Superior in St. Louis Bay at Duluth, Minn.	12	DS	13	3,200	11	1,700			8	150	46
Pelican River above WWTP at Pelican Rapids, Minn.	13	US									
Pelican Rapids WWTP outflow at Pelican Rapids,	14	WWTP	16	47	73	2,100	500		280	150	330
Pelican River below WWTP at Pelican Rapids, Minn.	15	DS				39					9
Red River of the North above WWTP at East Grand	16	US		28			400				9
Wastewater lift station outflow at East Grand Forks,	17	WWTP								120	10
Red River of the North below WWTP at East Grand	18	DS									8
Mississippi River above WWTP at Grand Rapids,	19	US									
Grand Rapids WWTP outflow at Grand Rapids, Minn.	20	WWTP		38		21				48	13
Mississippi River below WWTP at Grand Rapids,	21	DS									
Sauk River above Sauk Centre WWTP at Sauk	22	US									
Sauk Centre WWTP outflow at Sauk Centre, Minn.	23	WWTP	37		62	630	2,200		64	320	180
Sauk River below Sauk Centre WWTP at Sauk	24	DS				29				24	
Sauk River above Melrose WWTP at Melrose, Minn.	25	US	1	62		35				35	
Melrose WWTP outflow at Melrose, Minn.	26	WWTP	2	31	31	27	600	26	25	55	36
Sauk River below Melrose WWTP at Melrose, Minn.	27	DS	3			28				24	
Tibbets Brook above WWTP outflow at Zimmerman,	28	US					400			36	
Zimmerman WWTP outflow at Zimmerman, Minn.	29	WWTP	41	170	110	62			85		450
Tibbets Brook below WWTP outflow at Zimmerman,	30	DS	16	91	46				33	18	180
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.	31	US	1								
Litchfield WWTP outflow near Litchfield, Minn.	32	WWTP	2			55	1,200			72	65
Jewitts Creek near Litchfield, Minn.	33	DS	3		6						8
South Fork of the Crow River above WWTP at	34	US		27	9	25				23	
Hutchinson WWTP outflow at Hutchinson, Minn.	35	WWTP	9	65	27	28	500		15	16	93
South Fork of the Crow River below Hutchinson, Minn.	36	DS			12					20	9
South Fork Crow River above WWTP at Lester Prairie,	37	US				33				21	
Lester Prairie WWTP outflow at Lester Prairie, Minn.	38	WWTP	17		12				30		130
South Fork Crow River below WWTP at Lester Prairie,	39	DS				31					
Redwood River above Lynd WWTP near Lynd, Minn.	40	US				70				28	
Lynd WWTP outflow near Lynd, Minn.	41	WWTP		33	9	190				85	19
Redwood River below Lynd WWTP near Lynd, Minn.	42	DS				65	400			29	7
Redwood River above WWTP below Marshall, Minn.	43	US									6
Marshall WWTP outfall at Marshall, Minn.	44	WWTP	9		38	47	400		14	25	180
Redwood River below WWTP near Marshall, Minn.	45	DS		25		46					14
Center Creek on Co. Rd. 143, at Fairmont, Minn.	46	US	1	58						27	
Fairmont WWTP outflow at Fairmont, Minn.	47	WWTP	2	150	22	28	600		28	100	150
Center Creek below WWTP at Fairmont, Minn.	48	DS	3	180	27	26	500		22	91	120
Mississippi River at Industrial Mollasses, St. Paul,	49	US								16	
Metro Plant (WWTP) outflow in St. Paul, Minn.	50	WWTP	42	80	58	70	800		140	24	200
Mississippi River at South St. Paul, Minn.	51	DS							11		20
Grindstone River above WWTP near Hinckley, Minn.	52	US								51	
Hinckley WWTP near Hinckley, Minn.	53	WWTP	9		16	53	600		39	54	82
Grindstone River below Hinckley, Minn.	54	DS								50	
Mississippi River (Lake Pepin) above Lake City, Minn.	55	US	1				1,300				
Lake City WWTP outflow at Lake City, Minn.	56	WWTP	2	50	30	66	1,900		110	99	190
Mississippi River (Lake Pepin) at Mile 771 near Lake	57	DS	3								
South Fork Zumbro River at Rochester, Minn.	58	US		37		230	1,300				
Rochester WWTP outflow at Rochester, Minn.	59	WWTP	110	30	16			30	30	59	99
South Fork Zumbro River below WWTP near	60	DS					1,200			27	
Spring Valley Creek above Spring Valley WWTP	61	US									
Spring Valley WWTP outflow at Spring Valley, Minn.	62	WWTP	52		33	51	1,200		40	63	200
Spring Valley Creek below Spring Valley WWTP	63	DS	17	27							14
Cedar River above treatment plant at Austin, Minn.	64	US		230		29					
Austin WWTP outflow at Austin, Minn.	65	WWTP	9	62	34	790	500			430	69
Cedar River below treatment plant at Austin, Minn.	66	DS		23	9	170				94	15
Okabena Creek above WWTP outflow at Worthington,	67	US	1								
Worthington WWTP outflow at Worthington, Minn.	68	WWTP	2		20	150	700		11	130	160
Industrial WWTP outflow near Worthington, Minn.	69	WWTP	1			67	900				
Okabena Creek below WWTP outflow at Worthington,	70	DS	3	34	11	110	500			78	30
Rock River above WWTP near Luverne, Minn.	71	US									
Luverne WWTP outflow near Luverne, Minn.	72	WWTP	27	30	63	610	1,000		28	55	640
Rock River below WWTP near Luverne, Minn.	73	DS				28					19

Alkylphenols in Water (continued)

USGS station name	5-Methyl-1H-benzotriazole (ng/L)	4-Nonylphenol (ng/L)	4-Nonylphenol-monoethoxylate (ng/L)	4-Nonylphenol-diethoxylate (ng/L)	4-Nonylphenol-triethoxylate (ng/L)	4-Nonylphenol-tetraethoxylate (ng/L)	4-*tert*-Octylphenol (ng/L)	4-*tert*-Octylphenol-monoethoxylate (ng/L)	4-*tert*-Octylphenol-diethoxylate (ng/L)	4-*tert*-Octylphenol-triethoxylate (ng/L)	4-*tert*-Octylphenol-tetraethoxylate (ng/L)	4-*tert*-Octylphenol-pentaethoxylate (ng/L)	4-*tert*-Pentylphenol (ng/L)	Triclosan (ng/L)	Total Detections
Williams Creek above WWTP at Williams, Minn.															2
Williams WWTP outflow at Williams, Minn.		160												17	6
Williams Creek below WWTP at Williams, Minn.		200	52												5
Shagawa Lake at Mouth of Burntside River near Ely,															2
Ely WWTP outflow at Ely, Minn.		440	130				68							69	10
Shagawa Lake near Ely WWTP outflow at Ely, Minn.															1
Elbow Creek above Eveleth WWTP at Eveleth, Minn.															1
Eveleth WWTP outlflow at Eveleth, Minn.															5
Elbow Creek below Eveleth WWTP at Eveleth, Minn.															5
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.															0
Western Lake Superior Sanitary District - WWTP at		910	600				430	24					51	410	11
Lake Superior in St. Louis Bay at Duluth, Minn.		270	110				83							51	11
Pelican River above WWTP at Pelican Rapids, Minn.		190													1
Pelican Rapids WWTP outflow at Pelican Rapids,	340	10,000	2,200	3,400		220	99	31					9	340	17
Pelican River below WWTP at Pelican Rapids, Minn.		160													3
Red River of the North above WWTP at East Grand		150													4
Wastewater lift station outflow at East Grand Forks,		230	74											11	5
Red River of the North below WWTP at East Grand		150													2
Mississippi River above WWTP at Grand Rapids,	46		67												2
Grand Rapids WWTP outflow at Grand Rapids, Minn.	120		90											51	7
Mississippi River below WWTP at Grand Rapids,															0
Sauk River above Sauk Centre WWTP at Sauk					4,300	300			46		78	4,100			5
Sauk Centre WWTP outflow at Sauk Centre, Minn.	129	330	350	390		230		13	850				18	40	16
Sauk River below Sauk Centre WWTP at Sauk	24					90			280		78	260			7
Sauk River above Melrose WWTP at Melrose, Minn.			63			180			74		69				8
Melrose WWTP outflow at Melrose, Minn.	160	220	220	140		250		10	150			1,400	34	52	19
Sauk River below Melrose WWTP at Melrose, Minn.					4,900	270			33		50	4,000			8
Tibbets Brook above WWTP outflow at Zimmerman,															2
Zimmerman WWTP outflow at Zimmerman, Minn.		560	80				100	8					39	41	12
Tibbets Brook below WWTP outflow at Zimmerman,		190					30						15	21	10
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.		110													2
Litchfield WWTP outflow near Litchfield, Minn.	28	130	75											24	9
Jewitts Creek near Litchfield, Minn.															3
South Fork of the Crow River above WWTP at															4
Hutchinson WWTP outflow at Hutchinson, Minn.							24								9
South Fork of the Crow River below Hutchinson, Minn.															3
South Fork Crow River above WWTP at Lester Prairie,															2
Lester Prairie WWTP outflow at Lester Prairie, Minn.															4
South Fork Crow River below WWTP at Lester Prairie,															1
Redwood River above Lynd WWTP near Lynd, Minn.		170	110												4
Lynd WWTP outflow near Lynd, Minn.		280	210				17	10						29	10
Redwood River below Lynd WWTP near Lynd, Minn.		160	83					6							7
Redwood River above WWTP below Marshall, Minn.		160													2
Marshall WWTP outfall at Marshall, Minn.		120	80											67	10
Redwood River below WWTP near Marshall, Minn.		290													4
Center Creek on Co. Rd. 143, at Fairmont, Minn.	160			96					130						6
Fairmont WWTP outflow at Fairmont, Minn.		140													9
Center Creek below WWTP at Fairmont, Minn.		100													9
Mississippi River at Industrial Mollasses, St. Paul,															1
Metro Plant (WWTP) outflow in St. Paul, Minn.	390	240	280				43							120	13
Mississippi River at South St. Paul, Minn.															2
Grindstone River above WWTP near Hinckley, Minn.		230	90			73		9							5
Hinckley WWTP near Hinckley, Minn.		190	80											40	10
Grindstone River below Hinckley, Minn.		130													2
Mississippi River (Lake Pepin) above Lake City, Minn.						95									3
Lake City WWTP outflow at Lake City, Minn.	1,000	380	410				62	26						180	14
Mississippi River (Lake Pepin) at Mile 771 near Lake															1
South Fork Zumbro River at Rochester, Minn.		120	77			95									6
Rochester WWTP outflow at Rochester, Minn.	190					100	14								10
South Fork Zumbro River below WWTP near	57														3
Spring Valley Creek above Spring Valley WWTP						190			66			1,300			3
Spring Valley WWTP outflow at Spring Valley, Minn.		190	63			88			230			220		32	13
Spring Valley Creek below Spring Valley WWTP									24			290			5
Cedar River above treatment plant at Austin, Minn.															2
Austin WWTP outflow at Austin, Minn.		330	180	390		94		8		29				150	14
Cedar River below treatment plant at Austin, Minn.		170		120										28	8
Okabena Creek above WWTP outflow at Worthington,															1
Worthington WWTP outflow at Worthington, Minn.		120	67											18	10
Industrial WWTP outflow near Worthington, Minn.		110													4
Okabena Creek below WWTP outflow at Worthington,		110													8
Rock River above WWTP near Luverne, Minn.		100													1
Luverne WWTP outflow near Luverne, Minn.	72	350	350	570		46	21	10						95	16
Rock River below WWTP near Luverne, Minn.		140													3

Carboxylic Acids in Water

USGS station name	Site number (shown on fig. 3)	USGS station identification number	Site type	Ethylenediamine-tetraacetic acid (µg/L)	Nitrilotriacetic acid (µg/L)	4-Nonylphenol-monoethoxy-carboxylate (µg/L)	4-Nonylphenol-diethoxy-carboxylate (µg/L)	4-Nonylphenol-triethoxy-carboxylate (µg/L)	4-Nonylphenol-tetraethoxy-carboxylate (µg/L)	**Total Detections**
Williams Creek above WWTP at Williams, Minn.	1	05137050	US							0
Williams WWTP outflow at Williams, Minn.	2	484627094570801	WWTP							0
Williams Creek below WWTP at Williams, Minn.	3	05137055	DS							0
Shagawa Lake at Mouth of Burntside River near Ely, Minn.	4	475504091545401	US							0
Ely WWTP outflow at Ely, Minn.	5	475435091522601	WWTP	60.468	8.774	16.482	20.116	1.924		5
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6	475436091522501	DS				1.56			1
Elbow Creek above Eveleth WWTP at Eveleth, Minn.	7	04018765	US							0
Eveleth WWTP outlflow at Eveleth, Minn.	8	472737092324501	WWTP	82.99	8.588	7.664	3.054			4
Elbow Creek below Eveleth WWTP at Eveleth, Minn.	9	04018767	DS			3.672	4.468			2
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.	10	04024025	US							0
Western Lake Superior Sanitary District - WWTP at Duluth, Minn.	11	464538092072601	WWTP	110	9.68	8.232	4.788		5.506	5
Lake Superior in St. Louis Bay at Duluth, Minn.	12	464523092065501	DS		2.424	1.884			2	3
Pelican River above WWTP at Pelican Rapids, Minn.	13	05040340	US							0
Pelican Rapids WWTP outflow at Pelican Rapids, Minn.	14	463408096052401	WWTP	160	3.976	110	130	18.896	7	6
Pelican River below WWTP at Pelican Rapids, Minn.	15	05040345	DS							0
Red River of the North above WWTP at East Grand Forks, Minn.	16	05082520	US							0
East Grand Forks WWTP Outflow at East Grand Forks Minn.	17	475834097032002	WWTP			2.414				1
Red River of the North below WWTP at East Grand Forks, Minn.	18	475854097032001	DS							0
Mississippi River above WWTP at Grand Rapids, Minn.	19	05211020	US							0
Grand Rapids WWTP outflow at Grand Rapids, Minn.	20	471336093301801	WWTP	340		1.712				2
Mississippi River below WWTP at Grand Rapids, Minn.	21	05211030	DS	38						1
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	22	05270181	US							0
Sauk Centre WWTP outflow at Sauk Centre, Minn.	23	454308094562601	WWTP	280	1.658	9.49	7.564			4
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	24	05270183	DS			2.382	3.486			2
Sauk River above Melrose WWTP at Melrose, Minn.	25	05270195	US			3.118				1
Melrose WWTP outflow at Melrose, Minn.	26	454040094480701	WWTP	140		21.68	14.736			3
Sauk River below Melrose WWTP at Melrose, Minn.	27	05270197	DS							0
Tibbets Brook above WWTP outflow at Zimmerman, Minn.	28	05274850	US			2.396				1
Zimmerman WWTP outflow at Zimmerman, Minn.	29	452559093345601	WWTP	160		15.178	10.398			3
Tibbets Brook below WWTP outflow at Zimmerman, Minn.	30	05274855	DS	85.696		15.238	9.468			3
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.	31	05278080	US							0
Litchfield WWTP outflow near Litchfield, Minn.	32	450833094311001	WWTP	320.144		4.534	3.826			3
Jewitts Creek near Litchfield, Minn.	33	05278083	DS	44.73						1
South Fork of the Crow River above WWTP at Hutchinson, Minn.	34	05278570	US							0
Hutchinson WWTP outflow at Hutchinson, Minn.	35	445220094212201	WWTP	580.252		3.188	3.066			3
South Fork of the Crow River below Hutchinson, Minn.	36	05278580	DS	39.5		2.642				2
South Fork Crow River above WWTP at Lester Prairie, Minn.	37	05278650	US	47.91		2.068				2
Lester Prairie WWTP outflow at Lester Prairie, Minn.	38	445243094020301	WWTP	61.494		8.86	3.482			3
South Fork Crow River below WWTP at Lester Prairie, Minn.	39	05278655	DS	35.718						1
Redwood River above Lynd WWTP near Lynd, Minn.	40	05314985	US							0
Lynd WWTP outflow near Lynd, Minn.	41	442415095523001	WWTP			5.415	2			2
Redwood River below Lynd WWTP near Lynd, Minn.	42	05314988	DS							0
Redwood River above WWTP below Marshall, Minn.	43	05315045	US	110						1
Marshall WWTP outfall at Marshall, Minn.	44	442846095463201	WWTP	180		5.816	5.078			3
Redwood River below WWTP near Marshall, Minn.	45	05315050	DS	40.366		5.106	5.37			3
Center Creek on Co. Rd. 143, at Fairmont, Minn.	46	05318170	US							0
Fairmont WWTP outflow at Fairmont, Minn.	47	434018094273301	WWTP	180	1.9	3.076	2.058			4
Center Creek below WWTP at Fairmont, Minn.	48	05318171	DS	150		4.404	1.924			3
Mississippi River at Industrial Mollasses, St. Paul, Minn.	49	05331005	US							0
Metro Plant (WWTP) outflow in St. Paul, Minn.	50	445509093024301	WWTP	210		9.46	5.177			3
Mississippi River at South St. Paul, Minn.	51	05331400	DS	30.458		2.71				2
Grindstone River above WWTP near Hinckley, Minn.	52	05337003	US			3.436				1
Hinckley WWTP near Hinckley, Minn.	53	460107092543101	WWTP	180	2.632	5.892	2.672			4
Grindstone River below Hinckley, Minn.	54	05337005	DS							0
Mississippi River (Lake Pepin) above Lake City, Minn.	55	05355260	US							0
Lake City WWTP outflow at Lake City, Minn.	56	442626092152201	WWTP	55.663	1.521	33.205	9.124			4
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	57	05355331	DS			4.716				1
South Fork Zumbro River at Rochester, Minn.	58	05372995	US							0
Rochester WWTP outflow at Rochester, Minn.	59	440350092275501	WWTP	250	3.145	1.672	2			4
South Fork Zumbro River below WWTP near Rochester, Minn.	60	05373005	DS	100						1
Spring Valley Creek above Spring Valley WWTP outflow at Spring Valley, Minn.	61	05383820	US							0
Spring Valley WWTP outflow at Spring Valley, Minn.	62	434122092225001	WWTP	230		2.944				2
Spring Valley Creek below Spring Valley WWTP outflow at Spring Valley, Minn.	63	05383822	DS							0
Cedar River above treatment plant at Austin, Minn.	64	05455975	US							0
Austin WWTP outflow at Austin, Minn.	65	433913092581601	WWTP	230	2.518	5.362	4.474			4
Cedar River below treatment plant at Austin, Minn.	66	05455978	DS	36.866		1.874	2.956			3
Okabena Creek above WWTP outflow at Worthington, Minn.	67	05474883	US		1.598					1
Worthington WWTP outflow at Worthington, Minn.	68	433838095344201	WWTP	229.892	2.404	6.554	5.528			4
Industrial WWTP outflow near Worthington, Minn.	69	433847095330001	WWTP	28.286		3.44	2.274			3
Okabena Creek below WWTP outflow at Worthington, Minn.	70	05474884	DS	53.357	1.66	6.644	3.497			4
Rock River above WWTP near Luverne, Minn.	71	06483005	US							0
Luverne WWTP outflow near Luverne, Minn.	72	433856096115801	WWTP	220	1.961	7.986	8.294			4
Rock River below WWTP near Luverne, Minn.	73	06483010	DS							0

Hormones in Water

USGS station name	Site number (shown on fig. 3)	Site type	4-Androstene-3,17-dione (ng/L)	***cis*-Androsterone (ng/L)**	Bisphenol A (ng/L)	Cholesterol (ng/L)	Coprostanol (ng/L)	Diethylstilbestrol (ng/L)	Equilenin (ng/L)	Equilin (ng/L)	17-*alpha*-estradiol (ng/L)
Williams Creek above WWTP at Williams, Minn.	1	US									
Williams WWTP outflow at Williams, Minn.	2	WWTP				11000	660				
Williams Creek below WWTP at Williams, Minn.	3	DS									
Shagawa Lake at Mouth of Burntside River near Ely, Minn.	4	US									
Ely WWTP outflow at Ely, Minn.	5	WWTP			220	5900	2000		2		2.5
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6	DS				9800	4400				
Elbow Creek above Eveleth WWTP at Eveleth, Minn.	7	US									
Eveleth WWTP outlflow at Eveleth, Minn.	8	WWTP				23000	13000		0.343684147		
Elbow Creek below Eveleth WWTP at Eveleth, Minn.	9	US				20000	10000		0.312244182		
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.	10	US									
Western Lake Superior Sanitary District - WWTP at Duluth, Minn.	11	WWTP			1200						
Lake Superior in St. Louis Bay at Duluth, Minn.	12	DS			5000	6100	5500		8.157850686		
Pelican River above WWTP at Pelican Rapids, Minn.	13	US				2500					
Pelican Rapids WWTP outflow at Pelican Rapids, Minn.	14	WWTP			45.51687533	4900	3600				1.173846
Pelican River below WWTP at Pelican Rapids, Minn.	15	DS									
Red River of the North above WWTP at East Grand Forks, Minn.	16	US				6700	250				
Wastewater lift station outflow at East Grand Forks, Minn.	17	WWTP				20000	250		1.844185234		
Red River of the North below WWTP at East Grand Forks, Minn.	18	DS				3100					
Mississippi River above WWTP at Grand Rapids, Minn.	19	US									
Grand Rapids WWTP outflow at Grand Rapids, Minn.	20	WWTP									0.48499149
Mississippi River below WWTP at Grand Rapids, Minn.	21	DS									
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	22	US				8700					
Sauk Centre WWTP outflow at Sauk Centre, Minn.	23	WWTP				9900	4000		0.979464793		
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	24	DS				8600	230				
Sauk River above Melrose WWTP at Melrose, Minn.	25	US				5100					
Melrose WWTP outflow at Melrose, Minn.	26	WWTP				8300	1200				
Sauk River below Melrose WWTP at Melrose, Minn.	27	DS				5100					
Tibbets Brook above WWTP outflow at Zimmerman, Minn.	28	US									0.61243535
Zimmerman WWTP outflow at Zimmerman, Minn.	29	WWTP			470		360				
Tibbets Brook below WWTP outflow at Zimmerman, Minn.	30	DS			200	3200	790		1.4		0.4
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.	31	US				4400					
Litchfield WWTP outflow near Litchfield, Minn.	32	WWTP					310				
Jewitts Creek near Litchfield, Minn.	33	DS				3800			0.97369702		
South Fork of the Crow River above WWTP at Hutchinson, Minn.	34	US				14000			2.085907182		
Hutchinson WWTP outflow at Hutchinson, Minn.	35	WWTP					230				
South Fork of the Crow River below Hutchinson, Minn.	36	DS				14000		1.025093872			
South Fork Crow River above WWTP at Lester Prairie, Minn.	37	US				5300					
Lester Prairie WWTP outflow at Lester Prairie, Minn.	38	WWTP					450				
South Fork Crow River below WWTP at Lester Prairie, Minn.	39	DS				4300					
Redwood River above Lynd WWTP near Lynd, Minn.	40	US									
Lynd WWTP outflow near Lynd, Minn.	41	WWTP				44000	1800				1.03418772
Redwood River below Lynd WWTP near Lynd, Minn.	42	DS									
Redwood River above WWTP below Marshall, Minn.	43	US			89.67845043	4900					
Marshall WWTP outfall at Marshall, Minn.	44	WWTP				9200	2500				
Redwood River below WWTP near Marshall, Minn.	45	DS				9600					
Center Creek on Co. Rd. 143, at Fairmont, Minn.	46	US							1.6		
Fairmont WWTP outflow at Fairmont, Minn.	47	WWTP			47.49916383	3100	750		2.898985646		
Center Creek below WWTP at Fairmont, Minn.	48	DS				5500	450		7.140988059		
Mississippi River at Industrial Mollasses, St. Paul, Minn.	49	US				7600					
Metro Plant (WWTP) outflow in St. Paul, Minn.	50	WWTP			130	3800	1700				
Mississippi River at South St. Paul, Minn.	51	DS									
Grindstone River above WWTP near Hinckley, Minn.	52	US									
Hinckley WWTP near Hinckley, Minn.	53	WWTP				4200	920				
Grindstone River below Hinckley, Minn.	54	DS									
Mississippi River (Lake Pepin) above Lake City, Minn.	55	US				4900		0.1			
Lake City WWTP outflow at Lake City, Minn.	56	WWTP				13000	9400				
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	57	DS				6400					
South Fork Zumbro River at Rochester, Minn.	58	US			48.78028599	5000					
Rochester WWTP outflow at Rochester, Minn.	59	WWTP			49.70154713	4300	2400				
South Fork Zumbro River below WWTP near Rochester, Minn.	60	DS				4400	650		0.462429171		
Spring Valley Creek above Spring Valley WWTP outflow at Spring Valley, Minn.	61	US									
Spring Valley WWTP outflow at Spring Valley, Minn.	62	WWTP				3200	980		0.292420056		
Spring Valley Creek below Spring Valley WWTP outflow at Spring Valley, Minn.	63	DS									
Cedar River above treatment plant at Austin, Minn.	64	US				13000					0.3931119
Austin WWTP outflow at Austin, Minn.	65	WWTP		4.623477289		92000			2.462896999		0.61600146
Cedar River below treatment plant at Austin, Minn.	66	DS			6200	30000	12000		1.124757416		
Okabena Creek above WWTP outflow at Worthington, Minn.	67	US									
Worthington WWTP outflow at Worthington, Minn.	68	WWTP				5800	4600				
Industrial WWTP outflow near Worthington, Minn.	69	WWTP				5200	750				
Okabena Creek below WWTP outflow at Worthington, Minn.	70	DS				5300	790				
Rock River above WWTP near Luverne, Minn.	71	US									
Luverne WWTP outflow near Luverne, Minn.	72	WWTP		3		49000	14000				
Rock River below WWTP near Luverne, Minn.	73	DS									

Hormones in Water (continued)

USGS station name	17-*beta* - estradiol (ng/L)	Estriol (ng/L)	Estrone (ng/L)	17-*alpha* - Ethynylestradiol (ng/L)	Mestranol (ng/L)	Norethindrone (ng/L)	Progesterone (ng/L)	Testosterone (ng/L)	dihydro-Testosterone (ng/L)	epi-Testosterone (ng/L)	11-*keto* - Testosterone (ng/L)
Williams Creek above WWTP at Williams, Minn.											
Williams WWTP outflow at Williams, Minn.											
Williams Creek below WWTP at Williams, Minn.											
Shagawa Lake at Mouth of Burntside River near Ely, Minn.											
Ely WWTP outflow at Ely, Minn.	0.5	4	14.42996324	0.5374361							
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	0.5		9.25116601								
Elbow Creek above Eveleth WWTP at Eveleth, Minn.											
Eveleth WWTP outlflow at Eveleth, Minn.	0.815420525										
Elbow Creek below Eveleth WWTP at Eveleth, Minn.	1.198679416										
St. Louis River at Hwy. 23 above Fond Du Lac, Minn.				0.1							
Western Lake Superior Sanitary District - WWTP at Duluth, Minn.											
Lake Superior in St. Louis Bay at Duluth, Minn.	1.927104118		10								
Pelican River above WWTP at Pelican Rapids, Minn.											
Pelican Rapids WWTP outflow at Pelican Rapids, Minn.	10.23004137	11	18.33534579								
Pelican River below WWTP at Pelican Rapids, Minn.	0.572297467										
Red River of the North above WWTP at East Grand Forks, Minn.											
Wastewater lift station outflow at East Grand Forks, Minn.	1.40042727		4.4660423								
Red River of the North below WWTP at East Grand Forks, Minn.											
Mississippi River above WWTP at Grand Rapids, Minn.											
Grand Rapids WWTP outflow at Grand Rapids, Minn.	1.126559027		5.517569751								
Mississippi River below WWTP at Grand Rapids, Minn.											
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	1.379995901			0.3285714							
Sauk Centre WWTP outflow at Sauk Centre, Minn.	0.43092614	0.6565981	2.112875125	0.2057044							
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	0.66637931			0.3014498							
Sauk River above Melrose WWTP at Melrose, Minn.											
Melrose WWTP outflow at Melrose, Minn.	1.735572696		9.398497322	0.1793881							
Sauk River below Melrose WWTP at Melrose, Minn.											
Tibbets Brook above WWTP outflow at Zimmerman, Minn.											
Zimmerman WWTP outflow at Zimmerman, Minn.	0.739949562	0.5		0.4791786				0.6			
Tibbets Brook below WWTP outflow at Zimmerman, Minn.		0.5			0.17594551						
Jewitts Creek at U.S. Hwy. 12 in Litchfield, Minn.											
Litchfield WWTP outflow near Litchfield, Minn.											
Jewitts Creek near Litchfield, Minn.	0.437317975										
South Fork of the Crow River above WWTP at Hutchinson, Minn.	3.249375365	1.4219765	32.49050024	1.4595928							
Hutchinson WWTP outflow at Hutchinson, Minn.	1.128185378			0.7086538							
South Fork of the Crow River below Hutchinson, Minn.	0.60805298	0.3542575	8.136452664	0.4940863							
South Fork Crow River above WWTP at Lester Prairie, Minn.											
Lester Prairie WWTP outflow at Lester Prairie, Minn.											
South Fork Crow River below WWTP at Lester Prairie, Minn.											
Redwood River above Lynd WWTP near Lynd, Minn.											
Lynd WWTP outflow near Lynd, Minn.	6.8		18								
Redwood River below Lynd WWTP near Lynd, Minn.											
Redwood River above WWTP below Marshall, Minn.											
Marshall WWTP outfall at Marshall, Minn.	0.90800407		3.043365303	0.1143584							
Redwood River below WWTP near Marshall, Minn.											
Center Creek on Co. Rd. 143, at Fairmont, Minn.			2.681337024								
Fairmont WWTP outflow at Fairmont, Minn.	1.480564629		9.616783908								
Center Creek below WWTP at Fairmont, Minn.	2.454692417		5.54873475								
Mississippi River at Industrial Mollasses, St. Paul, Minn.											
Metro Plant (WWTP) outflow in St. Paul, Minn.	4.349213326		38	0.2429927							
Mississippi River at South St. Paul, Minn.											
Grindstone River above WWTP near Hinckley, Minn.											
Hinckley WWTP near Hinckley, Minn.	1.045261468										
Grindstone River below Hinckley, Minn.											
Mississippi River (Lake Pepin) above Lake City, Minn.											
Lake City WWTP outflow at Lake City, Minn.	2.848898466	0.9	18.09060116	0.292281							
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.				0.1846247							
South Fork Zumbro River at Rochester, Minn.											
Rochester WWTP outflow at Rochester, Minn.				0.3099377							
South Fork Zumbro River below WWTP near Rochester, Minn.											
Spring Valley Creek above Spring Valley WWTP outflow at Spring Valley, Minn.											
Spring Valley WWTP outflow at Spring Valley, Minn.											
Spring Valley Creek below Spring Valley WWTP outflow at Spring Valley, Minn.											
Cedar River above treatment plant at Austin, Minn.	2.23274765		2.678512638								
Austin WWTP outflow at Austin, Minn.	1.950427975	2.7	22.02493145	0.2648889							
Cedar River below treatment plant at Austin, Minn.	3.27303747	0.5	6.228977842								
Okabena Creek above WWTP outflow at Worthington, Minn.											
Worthington WWTP outflow at Worthington, Minn.											
Industrial WWTP outflow near Worthington, Minn.											
Okabena Creek below WWTP outflow at Worthington, Minn.											
Rock River above WWTP near Luverne, Minn.											
Luverne WWTP outflow near Luverne, Minn.	1.239229961	1.4	5.685112741								
Rock River below WWTP near Luverne, Minn.	0.476988607										

Organic Wastewater Compounds in Sediment

USGS station identification number	Site number (shown on fig. 3)	Acetophenone (ng/g)	Acetyl hexamethyl tetrahydro-naphthalene (ng/g)	Anthracene (ng/g)	9,10-Anthraquinone (ng/g)	Atrazine (ng/g)	Benzo[a]pyrene (ng/g)	Benzophenone (ng/g)	Bisphenol A	Bromacil (ng/g)
Shagawa Lake at mouth of Burntside River near Ely, Minn.	4									
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6		20	520	580		1500			
St. Louis River at Hwy 23 above Fond Du Lac, Minn.	10			20			30		100	
Lake Superior in St. Louis Bay at Duluth, Minn.	12		80	370	340		560	120	310	
Mississippi River above WWTP at Grand Rapids, Minn.	19			310	640		960		190	
Mississippi River below WWTP at Grand Rapids, Minn.	21			30			90		40	
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	22	60		30	64		60		80	
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	24	110		30	70		80			
Sauk River below Melrose WWTP at Melrose, Minn.	27			40	55		120			
South Fork of the Crow River above WWTP at Hutchinson, Minn.	34	20		10	18		30		70	
South Fork of the Crow River below Hutchinson, Minn.	36				14		20		40	
South Fork Crow River above WWTP at Lester Prairie, Minn.	37									
South Fork Crow River below WWTP at Lester Prairie, Minn.	39								110	
Center Creek on Co. Rd. 143, at Fairmont, Minn.	46			50	100		180			
Center Creek below WWTP at Fairmont, Minn.	48									
Mississippi River at Industrial Mollasses St. Paul, Minn.	49			30			80		60 Org	
Metro Plant (WWTP) outflow in St. Paul, Minn.	50	70	190	1000	540		3300		90	
Mississippi River at South St. Paul, Minn.	51			60	58		180			
Grindstone River above WWTP near Hinckley, Minn.	52						30		70	
Grindstone River below Hinckley, Minn.	54						10			
Mississippi River (Lake Pepin) above Lake City, Minn.	55			20	33		50			
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	57						20			
Okabena Creek above WWTP outflow at Worthington, Minn.	67			10	28		50			
Okabena Creek below WWTP outflow at Worthington, Minn.	70		20	10	21		20			

Organic Wastewater Compounds in Sediment (continued)

USGS station identification number	3- *tert* -Butyl-4-hydroxyanisole,~~sd~~ (ng/g)	Camphor (ng/g)	Carbazole (ng/g)	Chlorpyrifos (ng/g)	Cholesterol (ng/g)	3- *beta* -Coprostanol (ng/g)	*p* -Cresol (ng/g)	4-Cumylphenol (ng/g)	1,4-Dichlorobenzene (ng/g)	Diethylhexyl phthalate (ng/g)	2,6-Dimethlnaphthalene, ng/g
Shagawa Lake at mouth of Burntside River near Ely, Minn.						0	360				20
Shagawa Lake near Ely WWTP outflow at Ely, Minn.			280		4900	3800	340		94	610	100
St. Louis River at Hwy 23 above Fond Du Lac, Minn.						230	110				30
Lake Superior in St. Louis Bay at Duluth, Minn.			170		3500	3700	1000		240	830	340
Mississippi River above WWTP at Grand Rapids, Minn.			320		4500	650	600	400		590	70
Mississippi River below WWTP at Grand Rapids, Minn.			30		6500	440	1800				230
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.			20		3300	0	360				80
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.			30		4400	560	170				80
Sauk River below Melrose WWTP at Melrose, Minn.			20		6200	420	60				60
South Fork of the Crow River above WWTP at Hutchinson, Minn.			10		700	180	60	10			30
South Fork of the Crow River below Hutchinson, Minn.					1900	290	60				30
South Fork Crow River above WWTP at Lester Prairie, Minn.					2100	260	160				50
South Fork Crow River below WWTP at Lester Prairie, Minn.					2000	290	150				70
Center Creek on Co. Rd. 143, at Fairmont, Minn.			70		3400	380	170				50
Center Creek below WWTP at Fairmont, Minn.					4300	560	680				70
Mississippi River at Industrial Mollasses St. Paul, Minn.			10		1600	370	410			170	50
Metro Plant (WWTP) outflow in St. Paul, Minn.			130		1800	1900	270		53	560	140
Mississippi River at South St. Paul, Minn.			10		1800	620	50				50
Grindstone River above WWTP near Hinckley, Minn.			20		2900	620	130				40
Grindstone River below Hinckley, Minn.					1200	330	30				20
Mississippi River (Lake Pepin) above Lake City, Minn.					2800	630	90				300
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.					1500	260	60				70
Okabena Creek above WWTP outflow at Worthington, Minn.			10		2200	500	30				30
Okabena Creek below WWTP outflow at Worthington, Minn.					1300	570	30				20

Organic Wastewater Compounds in Sediment (continued)

USGS station identification number	Fluoranthene (ng/g)	Hexahydrohexa-methylcyclopenta-benzopyran (HHCB) (ng/g)	Indole (ng/g)	Isophorone (ng/g)	Isopropylbenzene (ng/g)	*d*-Limonene (ng/g)	3-Methyl-1H-indole (ng/g)	1-Methylnaphthalene (ng/g)	2-Methylnaphthalene (ng/g)	Metolachlor (ng/g)
Shagawa Lake at mouth of Burntside River near Ely, Minn.	70		1300				70			
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6000	60	1000	20		80	90	100	190	
St. Louis River at Hwy 23 above Fond Du Lac, Minn.	80		310			60	10			
Lake Superior in St. Louis Bay at Duluth, Minn.	2800	400	670		50		80	430	850	
Mississippi River above WWTP at Grand Rapids, Minn.	4700		830			280	70	30	40	
Mississippi River below WWTP at Grand Rapids, Minn.	350		360				60			
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	300		720	10			80			
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	300	10	1200	10			50			
Sauk River below Melrose WWTP at Melrose, Minn.	330		1100	10			40			
South Fork of the Crow River above WWTP at Hutchinson, Minn.	130		150				10			
South Fork of the Crow River below Hutchinson, Minn.	70		150							
South Fork Crow River above WWTP at Lester Prairie, Minn.	10		540				30			
South Fork Crow River below WWTP at Lester Prairie, Minn.	20		650				40			
Center Creek on Co. Rd. 143, at Fairmont, Minn.	830		480				30			
Center Creek below WWTP at Fairmont, Minn.	40	90	730				80			
Mississippi River at Industrial Mollasses St. Paul, Minn.	200		260				30	10	20	
Metro Plant (WWTP) outflow in St. Paul, Minn.	5600	1000	410				30	180	380	
Mississippi River at South St. Paul, Minn.	480	30	210				10			
Grindstone River above WWTP near Hinckley, Minn.	90		740	10			30			
Grindstone River below Hinckley, Minn.	30		380			50	20			
Mississippi River (Lake Pepin) above Lake City, Minn.	150		590	20			50			
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	60		230	10			10			
Okabena Creek above WWTP outflow at Worthington, Minn.	130	30	220				10			
Okabena Creek below WWTP outflow at Worthington, Minn.	80	40	150							

Organic Wastewater Compounds in Sediment (continued)

USGS station identification number	Naphthalene (ng/g)	N,N-diethyl-*meta*-toluamide (DEET) (ng/g)	4-Nonylphenol (all isomers) (ng/g)	4-Nonylphenol-diethoxylate (ng/g)	4-Nonylphenol-monoethoxylate (ng/g)	4-*n*-Octylphenol (ng/g)	4-*tert*-Octylphenol (ng/g)	4-*tert*-Octylphenol-diethoxylate (ng/g)	4-*tert*-Octylphenol-monoethoxylate (ng/g)	Phenanthrene (ng/g)
Shagawa Lake at mouth of Burntside River near Ely, Minn.										
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	240		760							3000
St. Louis River at Hwy 23 above Fond Du Lac, Minn.			1300							50
Lake Superior in St. Louis Bay at Duluth, Minn.	1900		6900	2100	1300		240		410	1900
Mississippi River above WWTP at Grand Rapids, Minn.	90		2200							2300
Mississippi River below WWTP at Grand Rapids, Minn.			560							130
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.			250							140
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.										130
Sauk River below Melrose WWTP at Melrose, Minn.										100
South Fork of the Crow River above WWTP at Hutchinson, Minn.			240							70
South Fork of the Crow River below Hutchinson, Minn.			160							30
South Fork Crow River above WWTP at Lester Prairie, Minn.										
South Fork Crow River below WWTP at Lester Prairie, Minn.										
Center Creek on Co. Rd. 143, at Fairmont, Minn.			250							440
Center Creek below WWTP at Fairmont, Minn.			280							
Mississippi River at Industrial Mollasses St. Paul, Minn.	40		380	1100					50	80
Metro Plant (WWTP) outflow in St. Paul, Minn.	790		2500	1200	750		90			3600
Mississippi River at South St. Paul, Minn.			330							290
Grindstone River above WWTP near Hinckley, Minn.										
Grindstone River below Hinckley, Minn.										
Mississippi River (Lake Pepin) above Lake City, Minn.										50
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.										30
Okabena Creek above WWTP outflow at Worthington, Minn.			0	470						60
Okabena Creek below WWTP outflow at Worthington, Minn.			170	380						40

Hormones in Sediment

USGS Station Identification Number	Site number (shown on fig. 3)	4-Androstene-3,17-dione, (ng/g)	*cis*-Androsterone (ng/g)	Bisphenol A (ng/g)	Cholesterol (ng/g)
Shagawa Lake at mouth of Burntside River near Ely, Minn.	4		0.64		10880
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	6				8163
St. Louis River at Hwy 23 above Fond Du Lac, Minn.	10		0.08	158	3898
Lake Superior in St. Louis Bay at Duluth, Minn.	12		1.21	213	7311
Mississippi River above WWTP at Grand Rapids, Minn.	19		0.29	170	8540
Mississippi River below WWTP at Grand Rapids, Minn.	21		0.18	50.9	12470
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	22			73.9	35360
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	24		0.48	25.4	34540
Sauk River above Melrose WWTP at Melrose, Minn.	25				64030
Sauk River below Melrose WWTP at Melrose, Minn.	27				28020
South Fork Crow River above WWTP at Lester Prairie, Minn.	37		0.15		5360
South Fork of the Crow River above WWTP at Hutchinson, Minn.	37		0.29	154	4985
South Fork Crow River below WWTP at Lester Prairie, Minn.	39	0.79		17.4	7687
South Fork of the Crow River below Hutchinson, Minn.	39		0.15	67.9	9484
Center Creek on Co. Rd. 143, at Fairmont, Minn.	46		0.15		8395
Center Creek below WWTP at Fairmont, Minn.	48		0.17		7658
Mississippi River at Industrial Mollasses St. Paul, Minn.	49		0.2	14	3444
Metro Plant (WWTP) outflow in St. Paul, Minn.	50		0.72	54.3	5410
Mississippi River at South St. Paul, Minn.	51		0.17	14.1	3185
Grindstone River above WWTP near Hinckley, Minn.	52			34.9	4226
Grindstone River below Hinckley, Minn.	54		0.22		3437
Mississippi River (Lake Pepin) above Lake City, Minn.	55		0.2		8140
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	57		0.09		3446
Okabena Creek above WWTP outflow at Worthington, Minn.	67	0.17	0.13	11.8	3513
Okabena Creek below WWTP outflow at Worthington, Minn.	70				3998

Hormones in Sediment (continued)

USGS Station Identification Number	3-*beta*-Coprostanol (ng/g)	*trans*-Diethylstilbestrol (ng/g)	Dihydro-testosterone (ng/g)	Equilenin (ng/g)	Equilin (ng/g)	Estriol (ng/g)
Shagawa Lake at mouth of Burntside River near Ely, Minn.	22010					
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	3388					
St. Louis River at Hwy 23 above Fond Du Lac, Minn.	5920					0.14
Lake Superior in St. Louis Bay at Duluth, Minn.	21260					
Mississippi River above WWTP at Grand Rapids, Minn.	3860					
Mississippi River below WWTP at Grand Rapids, Minn.	2529					
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	610					na
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	1221			1.25		na
Sauk River above Melrose WWTP at Melrose, Minn.	1524					na
Sauk River below Melrose WWTP at Melrose, Minn.	623			1.57		na
South Fork Crow River above WWTP at Lester Prairie, Minn.	1075					
South Fork of the Crow River above WWTP at Hutchinson, Minn.	710					na
South Fork Crow River below WWTP at Lester Prairie, Minn.						na
South Fork of the Crow River below Hutchinson, Minn.	392					na
Center Creek on Co. Rd. 143, at Fairmont, Minn.	1622					
Center Creek below WWTP at Fairmont, Minn.	2590					
Mississippi River at Industrial Mollasses St. Paul, Minn.	1684					
Metro Plant (WWTP) outflow in St. Paul, Minn.	9438					
Mississippi River at South St. Paul, Minn.	2564					
Grindstone River above WWTP near Hinckley, Minn.	409					
Grindstone River below Hinckley, Minn.	319					na
Mississippi River (Lake Pepin) above Lake City, Minn.	3598					
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.	961					
Okabena Creek above WWTP outflow at Worthington, Minn.	410					na
Okabena Creek below WWTP outflow at Worthington, Minn.	724			0.33		na

Hormones in Sediment (continued)

USGS Station Identification Number	17- *alpha* - Estradiol (ng/g)	17- *beta* - Estradiol (ng/g)	Estrone (ng/g)	17- *alpha* - Ethynylestradiol (ng/g)	Mestranol (ng/g)	Norethindrone (ng/g)
Shagawa Lake at mouth of Burntside River near Ely, Minn.		0.23				
Shagawa Lake near Ely WWTP outflow at Ely, Minn.		0.73	3.81			
St. Louis River at Hwy 23 above Fond Du Lac, Minn.		0.26	1.21			
Lake Superior in St. Louis Bay at Duluth, Minn.		0.75	5.14			
Mississippi River above WWTP at Grand Rapids, Minn.			0.61			
Mississippi River below WWTP at Grand Rapids, Minn.		0.22	0.66			
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.	1.01	2.86	2.41			
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.		2.26	1.99			
Sauk River above Melrose WWTP at Melrose, Minn.	4.28	12.2	9.2			
Sauk River below Melrose WWTP at Melrose, Minn.		2.24	2.14			
South Fork Crow River above WWTP at Lester Prairie, Minn.		0.36	1.23			
South Fork of the Crow River above WWTP at Hutchinson, Minn.	0.14	0.41	1.11			
South Fork Crow River below WWTP at Lester Prairie, Minn.		1.47				
South Fork of the Crow River below Hutchinson, Minn.		0.24	0.78			
Center Creek on Co. Rd. 143, at Fairmont, Minn.		0.18	1.86			
Center Creek below WWTP at Fairmont, Minn.		0.49	3.57			
Mississippi River at Industrial Mollasses St. Paul, Minn.		0.44	2.41			
Metro Plant (WWTP) outflow in St. Paul, Minn.	0.14	0.51	5.55			
Mississippi River at South St. Paul, Minn.		0.38	2.2			
Grindstone River above WWTP near Hinckley, Minn.		0.51	0.78			
Grindstone River below Hinckley, Minn.	0.27	0.38	0.27			
Mississippi River (Lake Pepin) above Lake City, Minn.		0.42	2.51			
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.		0.12	0.61			
Okabena Creek above WWTP outflow at Worthington, Minn.			0.14			
Okabena Creek below WWTP outflow at Worthington, Minn.		0.29	0.39			

Hormones in Sediment (continued)

USGS Station Identification Number	Progesterone (ng/g)	Testosterone (ng/g)	epi-Testosterone (ng/g)	11-*keto*-Testosterone (ng/g)
Shagawa Lake at mouth of Burntside River near Ely, Minn.				
Shagawa Lake near Ely WWTP outflow at Ely, Minn.	12.2			
St. Louis River at Hwy 23 above Fond Du Lac, Minn.				
Lake Superior in St. Louis Bay at Duluth, Minn.				
Mississippi River above WWTP at Grand Rapids, Minn.				
Mississippi River below WWTP at Grand Rapids, Minn.				
Sauk River above Sauk Centre WWTP at Sauk Centre, Minn.				
Sauk River below Sauk Centre WWTP at Sauk Centre, Minn.	na			
Sauk River above Melrose WWTP at Melrose, Minn.				
Sauk River below Melrose WWTP at Melrose, Minn.			0.79	
South Fork Crow River above WWTP at Lester Prairie, Minn.				
South Fork of the Crow River above WWTP at Hutchinson, Minn.				
South Fork Crow River below WWTP at Lester Prairie, Minn.				
South Fork of the Crow River below Hutchinson, Minn.	na			
Center Creek on Co. Rd. 143, at Fairmont, Minn.				
Center Creek below WWTP at Fairmont, Minn.				
Mississippi River at Industrial Mollasses St. Paul, Minn.			0.12	
Metro Plant (WWTP) outflow in St. Paul, Minn.				
Mississippi River at South St. Paul, Minn.			0.08	
Grindstone River above WWTP near Hinckley, Minn.			3.14	
Grindstone River below Hinckley, Minn.			0.53	
Mississippi River (Lake Pepin) above Lake City, Minn.			0.12	
Mississippi River (Lake Pepin) at Mile 771 near Lake City, Minn.				
Okabena Creek above WWTP outflow at Worthington, Minn.				
Okabena Creek below WWTP outflow at Worthington, Minn.				