STS CONSULTANTS, LTD.

Surface Water Quality Criterion for Perfluorooctanoic Acid

Minnesota Pollution Control Agency
St. Paul, Minnesota

STS Project 200604796

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SURFACE WATER QUALITY CRITERION FOR PERFLUOROOCTANOIC ACID

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1.0 INTRODUCTION

In January 2006, the Minnesota Pollution Control Agency (MPCA) contracted with STS Consultants, Ltd. (STS) to develop an ambient surface water quality criterion for perfluorooctanoic acid (PFOA). The method that was to be used to develop this criterion is that published in Minnesota Rules, Chapter 7050.0218 Methods for Protection of Surface Waters from Toxic Pollutants for Which Numerical Standards Not Promulgated. As detailed in Subpart 10 Applicable Criteria, this effort entails the development of the following values for a chemical:

- a Chronic Criterion (CC) and Maximum Criterion (MC), based on toxicity to aquatic organisms;
- a Chronic Criterion (CC), based on toxicity to aquatic plants;
- a Drinking Water plus Fish Consumption Criterion (dfCC) and a Fish Consumption Criterion (fCC), based on human health risk;
- a Wildlife Chronic Criteria (WCC), based on toxicity to mammalian and avian species; and
- a concentration that will prevent unacceptable taste and/or odor in water, fish or other edible aquatic organisms.

The Minnesota Department of Health (MDH) developed the human health risk values for this project. These values were incorporated into the algorithms used to derive the dfCC and fCC criteria. STS developed the CC and MC criteria, utilizing the EPA's Tier II approach (due to a lack of sufficient toxicity information to calculate a criterion using the Tier I method). STS also calculated the dfCC and fCC criteria using the MDH toxicity values and a project-derived bioaccumulation factor for PFOA. No WCC was calculated due to a lack of sufficient toxicological data on this chemical. Also, no organoleptic criteria were developed because this chemical does not exhibit these chemical properties.

All references in this document can be found in an accompanying three volume binder set (Appendix A details the Table of Contents for these binders).

2.0 CHEMICAL IDENTITY AND CHEMICAL PROPERTIES

2.1 Chemical Identity

Perfluorooctanoic acid has the molecular formula $C_8HF_{15}O_2$. Its chemical name is 2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-pentadecafluoro-1-octanoic acid. The structure of the n-octane isomer is:

$$F_3C - CF_2 - CF_2 - CF_2 - CF_2 - CF_2 - COOH$$

PFOA also exists in various branched chain isomer forms.

PFOA can exist as the acid or as various salts. The most common n-octane isomer forms and their CAS numbers are:

Form	CAS No.
acid	335-67-1
ammonium salt	3825-26-1
sodium salt	335-95-5
potassium salt	2395-00-8

2.2 Relevant Chemical Properties

2.2.1 Water Solubility

In 1981, 3M environmental laboratory performed a non-GLP study to determine the water solubility of the ammonium salt of PFOA (isomer not specified) (AR 226-0486). The test was conducted in deionized water. The results indicated a chemical solubility of >1,000 g/L.

In 2001, 3M environmental laboratory conducted a GLP study to determine the water solubility of the ammonium salt of PFOA (isomer not specified) (STS-159). The procedure was the shake flask method, as based on OECD 105 and OPPTS 830.7840.

The results indicated a water solubility >10% at 23°C. A 10% solution is 100 g/L. This finding indicates that PFOA is highly water soluble.

2.2.2 Vapor Pressure

In 1993, 3M Environmental Laboratory conducted an impinger study to determine the volatility of PFOA (STS-402). The test consisted of dissolving PFOA in a number of aqueous salt solutions and water/isopropanol solutions and then bubbling air through them. The results indicated that with this procedure an average 8.5% of the dissolved PFOA could be released from the aqueous solutions, with only 7% on average was released from the water/isopropanol solutions. In a second experiment, PFOA was dissolved in a solution of 500 ppm ammonium acetate in 1-propanol:water (50:50) and allowed to evaporate at room temperature. As a function of time, impingers were sampled for the compound. No detectable amounts were recorded, indicating that the PFOA vapor pressure from this solution is less than $1x10^{-7}$ torr ($<1.3x10^{-5}$ Pa).

2.2.3 Air-Water Partition Coefficient

No studies found.

2.2.4 Octanol-Water Partition Coefficient

No direct measurement studies found.

In 1981, 3M environmental laboratory calculated the octanol-water partition coefficient for the ammonium salt of PFOA (isomer not specified; AR 226-0493). This was a calculation using a published method based on the chemical fragments/functional groups of chemicals. The calculated log K_{ow} was reported as -0.9, which corresponds to a K_{ow} value of 0.126.

2.2.5 Adsorption-Desorption

In 1978, 3M environmental laboratory conducted a non-GLP adsorption-desorption experiment with the ammonium salt of PFOA (isomer not specified) (226-0488). The method was that recommended by U.S. EPA for pesticide registration. A Brill sandy loam soil was used in the experiment. This soil contained 1.5% organic carbon and had a pH of 6.5. Multiple PFOA concentrations were used (5.2-523 mg/L). Based on the organic content in the soil, a K_{oc} value of 17 was calculated for PFOA, indicating low binding potential. The data obtained from this study, however, are considered estimates only due to multiple reasons (e.g., lack of establishing if equilibrium was reached in the experiment, and the fact that the amount of PFOA desorbed ranged from 26 to 212% of the starting material).

2.2.6 Abiotic Degradation

Hydrolysis

In 2001, 3M environmental laboratory conducted a GLP-consistent study addressing the hydrolysis of the n-octane isomer of PFOA, ammonium salt (STS-157). The procedure used was the method detailed in OPPTS 835.2110. PFOA was dissolved in triplicate in six different buffered solutions with pH ranging from 1.5 to 11.0. The test was run for 109 days at 50°C. No evidence of hydrolysis was observed at any of the pH's tested. Based on the sensitivity of this test system, the hydrolysis half-life for PFOA, calculated from all pooled data for pH 5.0 - 9.0, was reported at >97 years. It was concluded that PFOA was essentially non-hydrolyzable.

Photolysis

In 1979, 3M environmental laboratory conducted a non-GLP photodegradation test (AR 226-0490) on PFOA, ammonium salt (isomer not specified, but the materials section indicated that it was a mixture of straight and branched chain isomers). Simulated sunlight was generated from a GE F-40BL fluorescent black light (290-600 nm). The test lasted for 30 days, with analyses performed on days 0, 1, 3, 7, 15 and 30. The starting PFOA concentration in distilled water was 50 mg/L. Test temperature was 22°C. No

photodegradation was detected in this study, as assessed by TLC autoradiography and gas chromatography.

In 2001, 3M environmental laboratory conducted a GLP-consistent test of the photodegradation of PFOA, ammonium salt (STS-400). The procedure used was the method detailed in OPPTS 835.5270. The test material was incubated at 25°C for up to 164 hours in water, hydrogen peroxide solution, iron oxide solution, and iron oxide plus hydrogen peroxide solution. The latter mixture was used to evaluate possible hydroxyl radical-mediated degradation of the compound. Simulated sunlight (290-850 nm) from a Suntest CPS+ or Suntest XLS+ lamp was used. Direct photolytic decomposition of PFOA was not detected. Indirect photolysis (via hydroxyl radicals) was also not observed in any of the three matrixes. Based on the sensitivity of this test system, the photolytic half-life of PFOA was reported as $\geq$349 days.

In contrast to the above results, Hori et al. (2004) (STS-158) conducted a photodegradation test on the acid form of PFOA (isomer not described) in water, in a hydrogen peroxide solution, and with a known photocatalyst, tungstic heteropolyacid. All solutions were irradiated with UV-Visible light from a Xenon-mercury lamp (220-460 nm). In water, PFOA degraded to short-chain perfluorocarboxylic acids, CO_2 and F^-; after 72 hours of irradiation, 89.5% of the initial PFOA was decomposed. In the presence of H_2O_2, PFOA decomposition occurred but was slower than in the direct hydrolysis reaction. In the presence of the photocatalyst, PFOA degradation occurred the fastest. After 24 hours, all of the initial PFOA had disappeared. The rate of decomposition was reported to be 2.9 times that observed in the direct hydrolysis experiment.

2.2.7 Biodegradation

A number of 3M studies addressing the biodegradability of PFOA were found. The earlier studies, however, could not be used to evaluate this property due to technical problems during the study or due to a lack of details in the study file. These non-useable studies include the 1977 BOD study (AR 226-0487), the 1980 BOD study (AR 226-0492), the 1985 BOD study (AR 226-0494), and the 1987 BOD study (AR 226-0495).

Two PFOA biodegradation studies were found that were performed in a GLP manner, with appropriate documentation. In 1978, 3M environmental laboratory conducted a 2.5 month aerobic shake culture study with the ammonium salt of PFOA (AR 226-0489). The chemical was incubated at 25°C with activated sludge from a wastewater treatment plant. Biodegradation was evaluated by quantifying fluoride ion formation and by ^{14}C-labeled PFOA (both loss of parent compound and formation of any organic metabolites) by GLC and TLC. No biodegradation of PFOA was observed in this study using any of the test endpoints.

In 2001, Pace Analytical conducted an 18 day biodegradation study of the ammonium salt of PFOA (STS-156). Municipal wastewater treatment plant sludge was incubated with the chemical at 26°C under aerobic conditions. No biodegradation of PFOA was measured, using LC/MS to quantify the parent compound and any formed organic metabolites.

Meesters and Schröder (2004; STS-123) incubated PFOA (5 mg/L) with wastewater treatment plant effluent microorganisms under both aerobic and anaerobic conditions. No degradation was observed under aerobic conditions, as measured by the loss of PFOA from the incubate, using LC/MS. Under anaerobic conditions, however, the PFOA concentration gradually decreased, being non-detectable after 25 days. No organic metabolites were detected by LC/MS and no fluoride ion formation occurred. PFOA was also not found to adsorb to the glass walls of the flask. The authors thus could not explain their findings and could not conclude that PFOA was actually degraded.

2.3 Environmental Fate and Transport Summary

PFOA and its salts are fully fluorinated organic compounds. PFOA is persistent in the environment; it does not hydrolyze, photolyze or biodegrade under environmental conditions.

Based on a pKa of 2.8, PFOA will exist in the dissociated form in the environment and thus volatilization from water surfaces would not be expected to be an important fate process for this chemical. In aqueous solutions, PFOA displays good water solubility.

This result, however, may be somewhat artificial in that the perfluoroalkyl chain is likely to remain on the surface forming a film, or if agitated exist in a micellar form in the water column, much like anionic soaps.

Based on its reported soil absorption/desorption properties and from contaminated site information, PFOA can readily migrate through the soil column and also persist in groundwater.

3.0 BIOCONCENTRATION/BIOACCUMULATION/BIOMAGNIFICATION

3.1 Laboratory Tests

In 1978, 3M (226-0491) placed bluegills in effluent water from 3M's Decatur, AL plant for 22 days. Control fish were placed in Tennessee River water. Water concentrations of PFOA were not measured, nor were the fish tissue concentrations. 3M was not able to detect PFOA in the fish, using GC/MS. Of the exposed fish, 12/30 died during the test; none of the control fish died. The effluent-exposed fish were also of smaller average weight than the control animals. Based on the information provided, this study cannot be utilized to develop a BCF for PFOA.

The second study (226-0496) consisted of a static exposure test with the fathead minnow. The ammonium salt of PFOA was used at a single water concentration of 25 mg/L. This test consisted of a 13-day uptake period, followed by a 15-day depuration period. Both water samples and fish tissue samples were taken periodically throughout the test period and analyzed for fluoride (as a surrogate measurement for PFOA). No toxicity was observed in either the exposed animals or the control animals. The depuration half-life was estimated at 20 days, however, there may be another kinetic pool in the animals bodies with a much longer half-life (i.e., the depuration phase showed a floor of PFOA concentration in the fish). Based on the data obtained, a steady-state BCF of 1.8 (whole fish tissue) was calculated. This BCF suggests minimal bioconcentration of this chemical.

Martin et al. (2003) (STS-160) exposed juvenile rainbow trout to PFOA at a single dietary concentration of a mixture of perfluorinated chemicals in a flow-through experimental design. The test consisted of a 34-day exposure period, followed by a 41-day depuration period. The depuration half-life for PFOA was estimated at 3 days. No toxicity to the fish was observed. Kinetic modeling of the data yielded a steady-state bioaccumulation (food-to-tissue) factor of 0.038 for carcass (edible portion). This value again supports the conclusion that this chemical does not significantly bioconcentrate/bioaccumulate in fish.

3.2 Environmental Studies

3.2.1 General Surveys

There have been a number of environmental surveys conducted recently that have addressed the levels of PFOA in the tissues of various animal species at various trophic levels. Since PFOS and other PFCs concentrate in the liver, this tissue has been the focus of these studies. All data are presented at PFOA tissue concentrations on a wet weight basis. Each study has added to the environmental pattern of PFOA, but most in general do not contain sufficient information to estimate BCF/BAF/BMF. Tables A (Freshwater Ecosystems) and B (Marine Ecosystems) summarize these data.

Kannan et al. (2002a) (STS-133) reported that only 2/36 bird livers from Japan and no bird livers from Korea contained measurable concentrations of PFOA. The highest concentration detected, 21 ng/g, was just above their detection limit, 197 ng/g, and was approximately 30 times lower than the PFOS concentration.

Kannan et al. (2002b) (STS-134) in this study evaluated the levels of PFOA in the livers of mink and river otters from the United States. A mink from Illinois contained the highest concentration of PFOA in its liver, 27 ng/g; this was about 200 times lower than its PFOS level. Only 0-8% of the animals from Illinois, South Carolina and Louisiana contained detectable levels of PFOA, in contrast to 58% of the animals in Massachusetts. PFOA was not detected in the livers of otters from either Washington or Oregon.

Kannan et al. (2002c) (STS-135) surveyed a number of marine animals from both the Mediterranean and Baltic Seas in this study. In the Mediterranean samples, PFOA was detected in the livers of dolphins (3.1 ng/g), at approximately 45 times less than PFOS levels. It was also detected in the livers of cormorants. Interestingly, its detected levels in the livers of cormorants was equal to and greater than the levels of PFOS in these animals. It was not detected, however, in the livers of cetaceans, tuna or swordfish. PFOA was detected in 2/52 seals in the Baltic Sea, but again at much lower levels (34 ng/g) than PFOS. It was not detected in salmon, gray seals or in white-tailed sea eagles.

Bossi et al. (2005) (STS-204) reported on the PFOA concentrations in the livers of various marine mammals, fish and birds from Greenland and the Faroe Islands. PFOA was not detected in the livers of any of the animals studied – polar bears, whales, seals, sculpin or guillemot of Greenland and whales or fulmars in the Faroe Islands.

Houde et al. (2005) (STS-205) reported on the liver tissue levels of PFOA in free-range dolphins off the east coast of the United States and off of Florida's west coast. In general, the tissue concentrations corresponded with the general pollution levels in the waters where the animals were caught. Animals caught off of Delaware Bay had the highest tissue levels, at a mean of 72 ng/g. This was followed by mean levels of 44 ng/g off the coast of Charleston, South Carolina. Liver concentrations in dolphins caught in Sarasota Bay (Florida) and around Bermuda were 6.3 ng/g and 0.8 ng/g, respectively.

Smithwick et al. (2005) (STS-206) reported PFOA levels in the livers of polar bears from five locations in the North American Arctic and from two locations in the European Arctic. Both populations of animals exhibited relatively low levels of PFOA, 2.4-36.0 ng/g, over 100 times lower than PFOS.

Holmstrom et al. (2005) (STS-207) reported on the temporal trends of PFCs in guillemot eggs from 1968-2003. In contrast to the increasing trend for PFOS, PFOA was not detected in any of the eggs at any sampling period.

Van de Vijver et al. (2005) (STS-310) monitored the tissue levels of PFOA in harbor seals in the Dutch Wadden Sea. Detected levels of PFOA were reported only for liver tissue, at approximately 100 times lower than the PFOS levels.

Bossi et al. (2005) (STS-311) measured the PFOA concentrations in the livers of adult Ringed Seals from Greenland. Low levels of PFOA were reported, 2-5 ng/g, and no time or spacial (east vs. west) trends were evident.

Verreault et al. (2005) (STS-312) examined PFOA levels in plasma and eggs of adult Glaucous Gulls from the Norwegian Arctic. PFOA was not detected in any of the egg samples, and was detected in only 5% of the plasma samples, at trace amounts.

Olivero-Verbel et al. (2006) (STS-313) examined PFOA concentrations in various tissues of piscivorous birds (pelican) and a bottom feeder fish (mullet) residing off the coast of Columbia, South America (Cartegena Bay and Covenas). PFOA was detected in the bile of the fish at a concentration of 47-370 ng/ml, much higher levels than PFOS. It was not detected in the tissues of the pelican.

Morikawa et al. (2006) (STS-314) studied the tissue levels of PFOA in two species of wild turtles caught along the Ai River in Japan. Surface water samples were taken at the time of turtle capture to determine approximate bioconcentration factors. Along the river, PFOA concentrations varied from 17 to 87,100 ng/L (much higher than the PFOS concentrations). The mean serum concentrations of the animals caught in the river ranged <0.2-870 ng/L. These data led to a reported geometric mean water-serum BCF value of 3.2. The BCFs calculated for the highest contaminated areas were all around unity (0.9-1.2).

Smithwick et al. (2005) (STS-315) reported on the PFOA concentrations in liver tissue of polar bears from east Greenland. The mean PFOA concentration was reported at 10 ng/g, approximately 30 times less than PFOS levels.

So et al. (2006) (STS-316) studied PFOA concentrations in mussels and oysters from the coasts of South China and Japan. PFOA was detected in only 3/7 locations sampled and varied 0.28-0.66 ng/g. These concentrations were of similar magnitude to their reported PFOS concentrations.

DeSilva et al. (2004) (STS-212) evaluated the PFOA isomer pattern in polar bear livers caught in both Greenland and Canada. In the Greenland animals, both linear and branched chain isomers of PFOA were detected, whereas in the Canadian animals, only the linear isomer was present.

Martin et al. (2004) (STS-213) evaluated the PFOA concentrations in the livers of various Canadian arctic animals. Polar bears were the only animal that was found to have

detected levels of this chemical (mean = 8.6 ng/g). This detected level was much less than the corresponding PFOS concentrations in these animals (mean = 3100 ng/g).

Dai et al. (2006) (STS-331) reported on the concentration of PFOA in the serum of both the Giant Panda and the Red Panda in China. PFOA levels measured 0.3-8.2 μg/L (mean = 2.7 μg/L) for the Red Panda and 0.3-1.6 μg/L (mean = 0.8 μg/L) for the Giant Panda. No age or sex differences were observed.

Furdui et. al. (2007) (STS-330) analyzed lake trout whole tissue homogenates for a variety of PFCs. The fish were collected in 2001 from each of the five Great Lakes. The lowest average total PFC level was found in the fish from Lake Superior (13 ng/g); the highest average total PFC level was found in fish from Lake Erie (152 ng/g). As with other water bodies, PFOA was detected at much lower levels than PFOS. The PFOA data from this study and the calculated BAFs by the authors are provided below:

Lake	Average PFOA Concentration (ng/g)	BAF
Superior	1.1 +/- 0.2	2000
Michigan	4.4 +/- 1.6	2500
Huron	1.6 +/- 0.3	4000
Erie	1.6 +/- 0.7	800
Ontario	1.5 +/- 0.4	400
		Mean = 1600

3.2.2 Regional Food Web Studies

There have been four food web studies that have been published on PFOA, two fresh water studies and two marine studies.

Fresh Water

In the first study, Martin et al. (2004) (STS-142) quantified the concentrations of PFOA from benthic macroinvertebrates through a top predator fish, lake trout, in Lake Ontario. The mean PFOA concentration results (whole fish data) indicated the following:

Benthic invertebrate: Diporeia	90.0 ng/g
Benthic invertebrate: Mysis	2.5 ng/g
Forage fish: Alewife	1.6 ng/g
Forage fish: Rainbow smelt	2.0 ng/g
Forage fish: Slimy sculpin	44.0 ng/g
Predator fish: Lake trout	1.0 ng/g

One striking finding in this study is that the highest mean concentration for PFOA was detected in the benthic macroinvertebrate Diporeia, which occupies the lowest trophic level of all of the organisms analyzed. Another interesting finding is that the sculpin are more heavily contaminated than lake trout. These investigators calculated a weighted prey BMF for the lake trout of 0.41 for PFOA.

Kannan et al. (2005) (226-8000) studied PFOA levels in a Great Lakes benthic food web at three separate sites – Raisin River, St. Clair River and Calumet River. The summary results in this study were:

Surface water	4.4 – 14.7 ng/L
Algae	ND (<0.2 ng/g)
Amphipods	ND (<5 ng/g)
Zebra mussel	ND (<5 ng/g)
Round goby	ND (<0.2 ng/g)
Smallmouth bass	ND (<0.2 ng/g)

PFOA also was not detected in the Chinook salmon, lake white fish, brown trout or carp. It was detected in the livers of 2/8 mink, at 3.3-12.2 ng/g, but not detected in the livers of frogs, turtles or bald eagles. The PFOA levels in the mink were about 1000 times lower than the PFOS concentrations reported for these same animals.

Salt Water

In their Marine food web study, Tomy et al. (2004) (STS-317) examined PFOA levels in the livers of animals in a variety of trophic levels from an eastern arctic marine food web. Their mean data are presented below:

Zooplankton	2.6 ng/g
Clams	ND
Glaucous gulls	0.14 ng/g
Shrimp	0.17 ng/g
Cod	0.16 ng/g
Beluga whale	1.60 ng/g
Walrus	0.34 ng/g
Narwhal	0.90 ng/g
Black-legged kittiwake	ND
Red fish	1.20 ng/g

Martin et al. (2004) (STS-213) conducted a multi-trophic level survey of PFOA liver concentrations from animals in the Canadian Arctic. Of the 13 animals studied, detectable liver PFOA concentrations were reported only for the polar bear, at a mean of 8.6 ng/g. PFOA was not detected in the arctic fox, ringed seal, mink, common loon, northern fulmar, black guillemot, white sucker, brook trout, lake whitefish, lake trout, northern pike or arctic sculpin.

3.2.3 Minnesota Site-Specific Studies

In 2006, the Minnesota Pollution Control Agency (MPCA) quantified perfluorinated compound levels in Lake Calhoun in Minneapolis, Minnesota, the St. Croix River along the Minnesota/Wisconsin border, and in several stretches of the Mississippi River (Pools 3, 4, 5 and 5a). Surface water samples were collected and submitted for analysis of PFC concentrations from Lake Calhoun, the St. Croix River and Mississippi River Pool 3. The summary results of the surface water samples submitted for PFOA in this study ranged as follows:

Lake Calhoun	0.01810 - 0.02070 ng/mL
St. Croix River	<0.00241 - <0.00402 ng/mL
Mississippi River Pool 3	0.02730 – 0.03250 ng/mL

Fish tissue samples including fillets and whole animal were submitted by the MPCA for PFC analysis from Lake Calhoun, the St. Croix River and the Mississippi River (Pools 3, 4, 5 and 5a). The fillets for this study were defined as the edible (by humans) portion of

the fish tissue; the samples were scaled but the skin remained at the time of laboratory analysis. The remaining portions of some of the fish (minus the scales) were processed by the analytical laboratory and added to the fillet data in order to obtain whole animal PFC concentrations. This methodology (scaling the larger fish prior to analysis) may have underestimated the animal's PFOA burden that wildlife would encounter because it is possible, given the propensity of this chemical to adhere to materials, that the surface scales of the fish could have had PFOA "stuck" on their surfaces, thus presenting an additional dose to piscivorous animals.

PFOA was identified in only one fish (juvenile white sucker) submitted for analysis from Lake Calhoun at concentrations of 2.39 ng/g in the fillet and 2.28 ng/g in the whole body. PFOA was not detected above laboratory reporting limits in any of the other fish samples submitted for analysis from Lake Calhoun. In addition, PFOA was not detected in any of the fish samples submitted from the Mississippi River (Pools 3, 4, 5 and 5a) or the St. Croix River. The results of the fish tissue analysis (detections) are summarized in Table C. The complete analytical reports prepared by Axys are included in Appendix B.

3.3 Summary Hypothesis and Proposed BAF

As discussed earlier in this section, there have been a number of environmental surveys conducted, both in freshwater and marine systems, that document that PFOA does bioaccumulate in food webs. A summary of the relevant data from these studies is presented on Table A (Freshwater Ecosystems) and Table B (Marine Ecosystems). The majority of these data, although supporting the concept that PFOA does bioaccumulate in food webs, is insufficient to quantitatively calculate accurate bioconcentration, bioaccumulation or biomagnifications factors due to:

- lack of water quality data in area(s) where the aquatic life were sampled,
- only select species were sampled, sometimes only one species,
- lack of food chain/food web information relating to various trophic level animals that were tested.

Two freshwater food web studies have been completed (Martin et al., 2004; Kannan et al., 2006) wherein more complete datasets have been obtained. In the Martin et al. study, no water quality data were collected, so bioconcentration/biomagnification factors could not be calculated. However, since multiple trophic level animals were sampled in a single region of Lake Ontario, biomagnification factors could be approximated. Based on the data provided, the following BMFs are calculated (assuming single food source):

mysis - alewife	3.5
diporeia - alewife	0.16
diporeia - smelt	0.39
mysis - smelt	8.5
mysis- sculpin	34.6
diporeia - sculpin	1.6
sculpin - trout	0.38
alewife - trout	3.7

In nature all of the higher trophic animals would have a mixed diet, so the above values can only be viewed as approximate. In general, however, with the one exception of the mysis-sculpin food chain, the data indicate that PFOA either biomagnifies a small amount (BMF <10) or not at all (BMF <1).

In the study by Kannan et al. surface water data were collected so a better idea can be obtained concerning the food chain behavior of PFOA. Based on their data, it is apparent that the lower trophic level animals - algae, amphipods and mussels - are able to bioconcentrate PFOA to a considerable extent (~1000 fold over the water concentration). Then, as was observed earlier in the first Martin et al. study (table above), further biomagnification is relatively small (<10).

These data suggest that PFOA undergoes bioaccumulation in nature primarily in the lowest trophic level biota. These animals/plants have shown the largest bioconcentration potential (~1000), but whether this is true chemical absorption into their cells or simple chemical adsorption onto their surfaces is unknown at this time. Also unknown is their true potential to bioconcentrate PFOA. It is possible that these lowest trophic level

organisms could simply continue to adsorb/absorb PFOA until they die; and therefore, what is observed in nature are those biota that are still in the process. A definitive controlled laboratory test addressing these two questions would be quite valuable for a BCF/BAF calculation.

There have been three controlled laboratory bioconcentration tests with PFOA with higher trophic level species. Wildlife, Intl. (2001) conducted a flow-through PFOA bioconcentration test using juvenile bluegills. Exposure occurred for 62 days, which was then followed by a 56-day depuration period. Based on the data obtained, the following BCFs were calculated for PFOA: whole fish - 2796; edible portion of fish - 1124. This GLP study was conducted in a technically correct manner; however, several issues are noted that may or may not have affected the calculated results. These issues include:

- The fact that only one PFOA concentration was used to calculate BCFs.
- Since the estimated depuration half-life was calculated at 86 days, the exposure period (56 days) was short. Given the variability in the data during this phase, there is uncertainty over the kinetic extrapolation that was made.

Nevertheless, the calculated values from this study are consistent with the BCF range estimated above from the environmental survey data.

Ankley et al. (2005) exposed fathead minnows to PFOA for 21 days at multiple water concentrations of the chemical. Tissue samples (plasma, liver, gonads) were obtained and analyzed for PFOA only at the end of this exposure period. These data are not appropriate for calculating a BCF for PFOA because:

- Neither whole animal or edible portions were quantified with respect to PFOA concentration.
- Since no depuration phase was included in the study and no time point data for PFOA in the fish were taken during the exposure, there is no way of knowing if steady-state conditions existed at the time of the tissue analysis.

Martin et al. (2003) exposed juvenile rainbow trout to PFOA at a single water concentration (as a component of a mixture of perfluorinated chemicals) in a 12-day exposure, 33 day depuration phase flow-through test. The carcass (edible portions of fish) depuration half-life was calculated at 15 days. Therefore, as with the Wildlife, Intl. study, steady-state BCFs were calculated using kinetic extrapolation. The BCFs reported in this study for PFOA were:

carcass	1100
liver	5400
blood	4300

Whole fish data were not obtained, so a BCF for ecological risk analysis cannot be developed from their data. The carcass BCF is also consistent with the earlier analyses results.

The site-specific analytical data collected from the water samples in the Minnesota study, however do not support the above laboratory BAFs for this chemical. All of the analytical data on the adult fish (bluegill, white sucker, smallmouth bass, largemouth bass, walleye, northern pike, white bass, channel catfish) were non-detection values. Based on the measured water concentrations and the detection limits for PFOA in the fish tissues, the BAF would be less than 48 L/kg.

It is the policy of the MPCA to accept site-specific BAF data over laboratory-generated data. In keeping with general risk assessment and principles concerning non-detection data, one-half of the detection limit is used as a likely conservative surrogate value. In this case, a proposed BAF of 24L/Kg is proposed for the Mississippi River (Pool 3). A separate PFOA human-health criterion is proposed for Lake Calhoun because of a different BAF of 40 L/Kg.

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TABLE A: Freshwater Ecosystems

Animal	Location	PFOA Conc.	Tissue
Algae	3 Gr. Lake rivers	2.4 - 3.1 ng/g	whole animal
Amphipods	3 Gr. Lake rivers	<2 - 2.9 ng/g	whole animal
Diporeia	Lake Ontario	280 ng/g	whole animal
Mysis	Lake Ontario	13 ng/g	whole animal
Zebra mussel	3 Gr. Lake rivers	<2 - 3.1 ng/g	whole animal
Round Goby	3 Gr. Lake rivers	4.1 - 19.1 ng/g	liver
Smallmouth Bass	3 Gr. Lake rivers	<2 - 41 ng/g	liver
Alewife	Lake Ontario	46 ng/g	liver
Rainbow Smelt	Lake Ontario	110 ng/g	liver
Slimy Sculpin	Lake Ontario	450 ng/g	liver
Lake Trout	Lake Ontario	170 ng/g	liver
Lake Trout	Gr. Lakes	1.1 – 4.4 ng/g	whole animal
Lake Whitefish	Gr. Lakes	67-100 ng/g	liver
Gibel Carp	Belgium	11.2 - 781 ng/g	liver
Carp	Belgium	11.3 - 1822 ng/g	liver
Eel	Belgium	17.3 - 9031 ng/g	liver
Turtles	Gr. Lakes	6 (♀) - 137 (♂) ng/g	liver
Mink	Gr. Lakes	18,000 ng/g (x)	liver
Mink	Illinois	47 - 5140 ng/g	liver
Mink	S. Carolina	650 - 3110 ng/g	liver
Mink	Massachusetts	20 - 1100 ng/g	liver
Mink	Louisiana	40 - 320 ng/g	liver
Otter	Oregon	34 - 994 ng/g	liver
Otter	Washington	25 - 442 ng/g	liver
Bald Eagles	Gr. Lakes	1740 ng/g	liver
White sucker	Lake Calhoun (Minneapolis)	<1.40-2.39 ng/g	fillet
White sucker	Lake Calhoun (Minneapolis)	<1.39-2.28 ng/g	Whole animal

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TABLE B: Marine Ecosystems

Animal	Location	PFOA Conc.	Tissue
Zooplankton	E. Arctic	1.8 ng/g	whole animal
Clam	E. Arctic	0.28 ng/g	whole animal
Mussels/Oysters	S. China/Japan	0.11 - 0.59 ng/g	whole animal
Starfish	North Sea	9 - 176 ng/g	whole animal
Shrimp	North Sea	19 - 520 ng/g	whole animal
Shrimp	E. Arctic	0.35 ng/g	whole animal
Crabs	North Sea	24 - 877 ng/g	whole animal
Bib	Belgium	45 ng/g	liver
Plaice	Belgium	900 ng/g	liver
Short-horn Sculpin	Greenland	13 - 18 ng/g	liver
Cod	E. Arctic	1.3 ng/g	liver
Dolphin	S. Carolina Coast	1315 ng/g	liver
Dolphin	Sarasota (Fla.) Bay	781 ng/g	liver
Dolphin	Delaware Bay	751 ng/g	liver
Dolphin	Bermuda	49 ng/g	liver
Dolphin	Coastal U.S.	1520 ng/g	liver
Dolphin	Mediterranean Sea	<1.4 - 110 ng/g	liver
Dolphin	W. Europe	14 - 443 ng/g	liver
Dolphin	W. Europe	<10 - 52 ng/g	liver
Tuna	Mediterranean Sea	21 - 87 ng/g	liver
Swordfish	Mediterranean Sea	<1 - 13 ng/g	liver
Whale	Faroe Islands	28 - 65 ng/g	liver
Whale	W. Europe	<10 - 52 ng/g	liver
Whale	Coastal U.S.	14.8 ng/g	liver
Whale	E. Arctic	12.6 ng/g	liver
Narwhal	E. Arctic	10.9 ng/g	liver
Seal	Greenland	10 - 67 ng/g	liver
Seal	Dutch Wadden Sea	175 ng/g	liver
Seal	E. Greenland	25.5 - 95.6 ng/g	liver
Seal	W. Greenland	12.5 - 27.9 ng/g	liver
Seal	Alaska	<10 - 122 ng/g	liver
Seal	Baltic Sea	190 - 490 ng/g	liver
Seal	W. Europe	<10 - 532 ng/g	liver
Walrus	E. Arctic	2.4 ng/g	liver
Polar Bear	Greenland	1245 - 1325 ng/g	liver
Polar Bear	S. Hudson Bay	2730 ng/g (x)	liver
Polar Bear	Chukchi Sea	729 ng/g (x)	liver
Polar Bear	Northwest Territories	1320 ng/g (x)	liver
Polar Bear	E. Greenland	2470 ng/g (x)	liver
Polar Bear	Alaska	350 ng/g (x)	liver
Glaucous Gull	E. Arctic	20.2 ng/g	liver
Black-headed Gull	Korea	296 ng/g	liver
Kittiwake	E. Arctic	10 ng/g	liver
Fulmar	Faroe Islands	24 - 29 ng/g	liver
Cormorant	Japan	380 ng/g	liver
Cormorant	Mediterranean Sea	32 - 150 ng/g	liver
Pelican	S. America (Columbia)	36.7 ng/g	liver
White-tailed Eagle	Baltic Sea	<3.9 - 127 ng/g	liver

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TABLE C
Lake Calhoun
Aqueous and Fish Tissue Analytical Results - PFOA
Tissue Concentrations in ng/g
Surface Water Concentrations in ng/mL

Compound				**PFOA**
Sample	**Age/sex (yrs/m-f-j)**	**Length (cm)**	**Medium**	
Bluegill 1	3/F	15.5	Tissue - Fillet	<1.40
Bluegill 1	3/F	15.5	Tissue - Whole Body	<1.43
Bluegill 2	2/F	13	Tissue - Fillet	<1.42
Bluegill 2	2/F	13	Tissue - Whole Body	<1.43
Bluegill 3	3/F	15	Tissue - Fillet	<1.50
Bluegill 3	3/F	15	Tissue - Whole Body	<1.39
Bluegill 4	3/F	16	Tissue - Fillet	<1.46
Bluegill 4	3/F	16	Tissue - Whole Body	<1.50
Bluegill 5	3/F	16	Tissue - Fillet	<1.51
Bluegill 5	3/F	16	Tissue - Whole Body	<1.45
White Sucker 1	2/M	29	Tissue - Fillet	<1.53
White Sucker 1	2/M	29	Tissue - Whole Body	<1.50
White Sucker 1 (Duplicate)	2/M	29	Tissue - Whole Body	<1.52
White Sucker 2	2/J	31	Tissue - Fillet	<1.48
White Sucker 2 (Duplicate)	2/J	31	Tissue - Fillet	<1.46
White Sucker 2	2/J	31	Tissue - Whole Body	<2.29
White Sucker 3	2/J	27	Tissue - Fillet	<1.54
White Sucker 3	2/J	27	Tissue - Whole Body	<1.41
White Sucker 4	3/J	35	Tissue - Fillet	**2.39**
White Sucker 4	3/J	35	Tissue - Whole Body	**2.28**
White Sucker 5	2/J	29	Tissue - Fillet	<1.41
White Sucker 5	2/J	29	Tissue - Whole Body	<1.48
Water 1			Surface Water	**0.01810**
Water 1 (Duplicate)			Surface Water	**0.01880**
Water 2			Surface Water	**0.02050**
Water 3			Surface Water	**0.02070**

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TABLE C
St. Croix River
Aqueous and Fish Tissue Analytical Results - PFOA
Tissue Concentrations in ng/g
Surface Water Concentrations in ng/mL

Compound				PFOA
Sample	**Age/sex (yrs/m-f-j)**	**Length (cm)**	**Medium**	
Bluegill 1	3/F	16.5	Tissue - Fillet	<1.93
Bluegill 1 (Duplicate)	3/F	16.5	Tissue - Fillet	<1.51
Bluegill 1	3/F	16.5	Tissue - Whole Body	<1.47
Bluegill 2	2/M	13	Tissue - Fillet	<1.54
Bluegill 2	2/M	13	Tissue - Whole Body	<1.46
Bluegill 3	2/F	14.5	Tissue - Fillet	<1.47
Bluegill 3	2/F	14.5	Tissue - Whole Body	<1.53
Bluegill 4	2/M	14	Tissue - Fillet	<1.46
Bluegill 4	2/M	14	Tissue - Whole Body	<1.41
Bluegill 5	2/J	15	Tissue - Fillet	<1.51
Bluegill 5	2/J	15	Tissue - Whole Body	<1.54
Smallmouth Bass 1	6/M	37	Tissue - Fillet	<1.51
Smallmouth Bass 1	6/M	37	Tissue - Whole Body	<1.50
Smallmouth Bass 2	4/M	29	Tissue - Fillet	<1.52
Smallmouth Bass 2	4/M	29	Tissue - Whole Body	<1.45
Smallmouth Bass 3	4/F	30	Tissue - Fillet	<1.48
Smallmouth Bass 3	4/F	30	Tissue - Whole Body	<1.44
Smallmouth Bass 4	4/F	27	Tissue - Fillet	<1.51
Smallmouth Bass 5	4/M	28	Tissue - Fillet	<1.53
Walleye 1	5/M	40	Tissue - Fillet	<1.51
Walleye 2	6/F	46	Tissue - Fillet	<1.55
Walleye 3	3/J	33	Tissue - Fillet	<1.46
Walleye 4	3/J	28	Tissue - Fillet	<1.48
Walleye 5	3/J	32	Tissue - Fillet	<1.43
Northern Pike 1	6/J	43	Tissue - Fillet	<1.45
Northern Pike 2	6/F	42	Tissue - Fillet	<1.38
Northern Pike 3	7?/M	48	Tissue - Fillet	<1.43
Northern Pike 3 (Duplicate)	7?/M	48	Tissue - Fillet	<1.42
Northern Pike 4	8/M	58	Tissue - Fillet	<1.42
Northern Pike 5	6/F	43	Tissue - Fillet	<1.51
White Sucker 1	3/J	31	Tissue - Fillet	<1.45
White Sucker 2	3/F	36	Tissue - Fillet	<1.39
White Sucker 3	3/F	33	Tissue - Fillet	<1.45
Water 1			Surface Water	<0.00242
Water 2			Surface Water	<0.00402
Water 3			Surface Water	<0.00241

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TABLE C
Mississippi River Pool 3
Aqueous and Fish Tissue Analytical Results - PFOA
Tissue Concentrations in ng/g
Surface Water Concentrations in ng/mL

Compound				**PFOA**
Sample	**Age/sex (yrs/m-f-j)**	**Length (cm)**	**Medium**	
Bluegill 1	3/M	17	Tissue - Fillet	<1.52
Bluegill 1	3/M	17	Tissue - Whole Body	<1.46
Bluegill 2	3/M	17	Tissue - Fillet	<1.46
Bluegill 2	3/M	17	Tissue - Whole Body	<1.48
Bluegill 3	3/M	18	Tissue - Fillet	<1.51
Bluegill 3	3/M	18	Tissue - Whole Body	<1.28
Bluegill 4	3/F	18.5	Tissue - Fillet	<1.48
Bluegill 5	3/M	18	Tissue - Fillet	<1.47
White Bass 1	1/J	12.5	Tissue - Fillet	<1.48
White Bass 1	1/J	12.5	Tissue - Whole Body	<1.79
White Bass 2	1/J	13	Tissue - Fillet	<1.49
White Bass 2	1/J	13	Tissue - Whole Body	<1.51
White Bass 3	1/J	13	Tissue - Fillet	<2.51
White Bass 3	1/J	13	Tissue - Whole Body	<1.51
White Bass 4	1/J	13	Tissue - Fillet	<1.48
White Bass 4	1/J	13	Tissue - Whole Body	<1.48
White Bass 5	1/J	14.5	Tissue - Fillet	<1.51
White Bass 5	1/J	14.5	Tissue - Whole Body	<2.10
Emerald Shiner		~4.5	Whole Body - Composite of 35 Fish	<1.43
Gizzard Shad		~9	Whole Body - Composite of 35 Fish	<1.25
Water 1			Surface Water	**0.03250**
Water 2			Surface Water	**0.03140**
Water 3			Surface Water	**0.02730**

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TABLE C
Mississippi River Pool 4
Aqueous and Fish Tissue Analytical Results - PFOA
Tissue Concentrations in ng/g

Compound				**PFOA**
Sample (Lab Sample ID)	**Age/sex (yrs/m-f-j)**	**Length (cm)**	**Medium**	
Bluegill 1	4/F	20	Tissue - Fillet	<1.43
Bluegill 2	3/M	17.5	Tissue - Fillet	<1.47
Bluegill 3	3/F	18	Tissue - Fillet	<1.52
Bluegill 4	3/M	16	Tissue - Fillet	<1.48
Bluegill 5	3/M	18	Tissue - Fillet	<1.39

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TABLE C
Mississippi River Pool 5
Aqueous and Fish Tissue Analytical Results - PFOA
Tissue Concentrations in ng/g

Compound				**PFOA**
Sample (Lab Sample ID)	**Age/sex (yrs/m-f-j)**	**Length (cm)**	**Medium**	
Bluegill 1	4/F	172	Tissue - Fillet	<1.51
Bluegill 2	4/J	252	Tissue - Fillet	<1.38
Bluegill 3	4/M	199	Tissue - Fillet	<1.43
Bluegill 4	4/F	189	Tissue - Fillet	<1.54
Bluegill 5	3/F	114	Tissue - Fillet	<1.51
Smallmouth Bass 1	8/F	1512	Tissue - Fillet	<1.48
Smallmouth Bass 2	2/J	131	Tissue - Fillet	<1.45
Smallmouth Bass 3	4/M	449	Tissue - Fillet	<1.50
Smallmouth Bass 4	3/F	262	Tissue - Fillet	<1.48
Smallmouth Bass 5	5/M	565	Tissue - Fillet	<1.45
Largemouth Bass 1	6/F	456	Tissue - Fillet	<1.43
Largemouth Bass 2	7/M	1043	Tissue - Fillet	<1.45
Largemouth Bass 3	6/F	689	Tissue - Fillet	<1.38
Largemouth Bass 3 (Duplicate)	6/F	689	Tissue - Fillet	<1.36
Largemouth Bass 4	4/M	455	Tissue - Fillet	<1.41
Largemouth Bass 5	5/M	502	Tissue - Fillet	<1.50
Walleye 1	7/M	47	Tissue - Fillet	<1.54
Walleye 1	7/M	47	Tissue - Fillet	<1.54
Walleye 2	3/J	31	Tissue - Fillet	<1.48
Walleye 3	3/J	33	Tissue - Fillet	<1.47
Walleye 4	5/M	43	Tissue - Fillet	<1.48
Northern Pike 1	8/F	58	Tissue - Fillet	<1.45
Northern Pike 2	8/F	64	Tissue - Fillet	<1.47
Northern Pike 2 (Duplicate)	8/F	64	Tissue - Fillet	<1.37
Northern Pike 3	2/J	28	Tissue - Fillet	<1.47
Northern Pike 4	6/J	45	Tissue - Fillet	<1.42
Northern Pike 5	6/F	42	Tissue - Fillet	<1.50
Channel Catfish 1	?/J	31	Tissue - Fillet	<1.51
Channel Catfish 2	5/M	52	Tissue - Fillet	<1.44
Gizzard Shad		~13	Whole Body - Composite of 40 Fish	<1.48

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TABLE C
Mississippi River Pool 5a
Aqueous and Fish Tissue Analytical Results - PFOA
Tissue Concentrations in ng/g

Compound				PFOA
Sample (Lab Sample ID)	Age/sex (yrs/m-f-j)	Length (cm)	Medium	
Bluegill 1	3/M	17	Tissue - Fillet	<1.32
Bluegill 2	3/M	18	Tissue - Fillet	<1.50
Bluegill 3	4/M	20	Tissue - Fillet	<1.26
Bluegill 4	4/M	20	Tissue - Fillet	<1.60
Bluegill 5	4/F	19	Tissue - Fillet	<1.36
Smallmouth Bass 1	7/M	36	Tissue - Fillet	<1.50
Smallmouth Bass 2	7/M	36	Tissue - Fillet	<1.41
Smallmouth Bass 3	6/F	35	Tissue - Fillet	<1.50
Smallmouth Bass 4	4/M	28	Tissue - Fillet	<1.48
Smallmouth Bass 5	6/M	34	Tissue - Fillet	<1.45
Walleye 1	5/F	41	Tissue - Fillet	<1.48
Walleye 2	6/F	49	Tissue - Fillet	<1.49
Walleye 3	6/F	47	Tissue - Fillet	<1.54
Walleye 4	2/J	25.5	Tissue - Fillet	<1.41
Walleye 5	9/F	55	Tissue - Fillet	<1.47
Channel Catfish 1	6/M	57	Tissue - Fillet	<1.41
Channel Catfish 2	4/F	46	Tissue - Fillet	<1.38
Channel Catfish 3	3/F	41	Tissue - Fillet	<1.55
Channel Catfish 4	2/F	39	Tissue - Fillet	<1.46

4.0 DIRECT TOXICITY TESTING EVALUATION

In this section of the report, the toxicity studies on PFOA with a variety of aquatic organisms is evaluated. Appendix C to this document contains a summary of this information in tabular form, in the format utilized by the MPCA for water quality criteria development.

Table 1: Summary of all useful and non-useful acute and chronic toxicity studies on aquatic animals
Table 2a: Acceptable chronic toxicity data
Table 2b: Acceptable Acute-to-Chronic Ratio (ACR) Data
Table 3a: Acceptable acute toxicity data
Table 3b: GMAV Ranking of Acute Data and Final Acute Value
Table 4a: Summary of all useful and non-useful toxicity studies on aquatic plants
Table 4b: Acceptable aquatic plant toxicity data
Table 5a: All BCF and BAF information
Table 5b: Usable BCF/BAF information
Table 5c: Final chosen BCF/BAF
Table 6: Wildlife acute and chronic toxicity data (not included)
Table 7: Task and odor data (not included)
Table 8: Behavioral effects data (not included)

4.1 Acceptable Toxicity Bioassay Summaries

4.1.1 Aquatic Plants

Myriophyllum spp. (milfoil)

STS-155 (Hanson et al., 2005)
One toxicity test on the effects of PFOA (sodium salt) on *Myriophyllum* spp. (milfoil) was reviewed by STS. In this study the toxicity of PFOA to *Myriophyllum spicatum* and *M. sibricum* was observed using 12,000 L static tank outdoor microcosms at the University of Guelph Microcosm Facility located in Ontario, Canada. Endpoints of toxicity

that were monitored on days -1, 7, 14, 21 and 35 of the study included growth, biomass, root number, primary root length, number of nodes and pigment concentrations. A control sample and four nominal concentrations of PFOA were tested: 0.3, 1.0, 30.0 and 100.0 mg/L. With the exception of the highest concentration which decreased <20%, all PFOA concentrations remained constant throughout the test. Both species were essentially equally sensitive to PFOA. The study identified a 21-day EC50 (based on plant length) of 31.8 mg/L (lowest recorded EC50) and a NOEC of 23.9 mg/L (result consistent for 14 to 35 day observations for all endpoints measured) for *M. spicatum*. We note that *M. spicatum* (Eurasion milfoil) is a non-native species, and that data cannot be used for calculation of the water quality standard for the State of Minnesota. The study identified a 35-day EC50 (based on dry mass) of 35.8 mg/L (lowest recorded EC50) and a NOEC of 23.9 mg/L (result consistent for 14 to 35 day observations for all endpoints measured) for *M. sibricum*.

Selenastrum capricornutum (freshwater alga)

AR226-0506

Bioassay AR226-0506 evaluated the acute and chronic effects of PFOA (ammonium salt) on *Selenastrum capricornutum* (freshwater alga). In this study the acute and chronic toxicity of PFOA to *S. capricornutum* was observed under static conditions at 23°C over 4, 7, 10 and 14 day exposure periods in 1981. The 96-hour acute test followed ASTM-E-35.23 (1981) and OECD (1981). The 14-day chronic test was modified from the aforementioned test methods. *S. capricornutum* used for this test were from 7-day old cultures at test initiation. A control sample and six nominal concentrations of PFOA were tested: 100, 180, 320, 560, 1,000 and 1,800 mg/L. The results of the test identified a 96-hour EC50 (based on cell count) of 49 mg/L, a 96-hour EC50 (based on growth rate) of 149 mg/L PFOA. The 7-day EC50 (based on cell count) was 30 mg/L and the 7-day EC50 (based on growth rate) was 70 mg/L PFOA. The 10-day EC50 (based on cell count) was 27 mg/L and the 10-day EC-50 (based on growth rate) was 49 mg/L PFOA. The 14-day EC50 (based on cell count) was 43 mg/L and the 14-day EC50 (based on growth rate) was 73 mg/L PFOA.

4.1.2 Aquatic Invertebrates

Daphnia magna (water flea)

AR226-0512

A bioassay AR226-0512 on the effects of PFOA (ammonium salt) on *Daphnia magna* (water flea) was reviewed by STS. In this non-GLP study the acute toxicity of PFOA to *D. magna* was observed under static conditions at 21°C over a 48-hour exposure period in April, 1987. The test method was not specifically noted. However, the test procedure generally followed U.S. EPA OPPTS Guidelines. *D. magna* used for this test were less than 24-hours old at test initiation. A control sample and five nominal concentrations of PFOA were tested: 100, 180, 320, 560 and 1,000 mg/L. The results of the two tests identified a 48-hour EC50 of 221 mg/L and 227 mg/L PFOA for *D. magna*.

AR226-0517

A bioassay AR226-0517 on the effects of PFOA (ammonium salt) on *Daphnia magna* (water flea) was reviewed by STS. In this GLP study the acute toxicity of a PFOA test sample of unknown concentration (specified as <45%, but based on the concentrations of the other components, it should be 45-46%) to *D. magna* was observed under static conditions at 20°C over a 48-hour exposure period at the Envirosystems Division of Resource Analysts, Inc. located in Hampton, New Hampshire in February, 1990. The test followed OECD guideline 202 (1984). *D. magna* used for this test were less than 24-hours old at test initiation. A control sample and five nominal concentrations of PFOA were tested: 150, 250, 400, 600 and 1,000 mg/L. The results of the test identified a 48-hour EC50 of 584 mg/L for the PFOA solution for *D. magna*. Assuming a 45% PFOA concentration yields a chemical-specific EC50 of 263 mg/L.

STS-403

A bioassay STS-403 on the effects growth and reproductive toxicity of PFOA (sample N2803-4 – unknown salt) on *Daphnia magna* (water flea) was reviewed by STS. In this GLP study the acute toxicity of PFOA to *D. magna* was observed under static conditions at 19-20°C over a 48-hour exposure period at T.R. Wilbury Laboratories located in Marblehead, Massachusetts in September, 1995. The test followed U.S. EPA Guidelines

(1993). *D. magna* used for this test were less than 24-hours old at test initiation. A control sample and five nominal concentrations of PFOA were tested: 130, 220, 360, 600 and 1,000 mg/L. The results of the test identified a 48-hour EC50 of 720 mg/L, a 48-hour LC50 of 720 mg/L, and a NOEC of 360 mg/L PFOA for *D. magna*. The assumed purity of this sample was 100%; no analytical data were supplied.

AR226-0508

A bioassay AR226-0508 on the effects of PFOA (ammonium salt) on *Daphnia magna* (water flea) was reviewed by STS. In this non-GLP study both the acute and life-cycle toxicity of PFOA to *D. magna* was observed under static and semi-static conditions, respectively at 22 +/- 2°C over a 48-hour and 21-day exposure periods, respectively. The testing was completed in August, 1984. The testing followed U.S. EPA (1982), OECD (1981) and ASTM (1983). *D. magna* used for this test were less than 24-hours old at test initiation. A control sample and eight nominal concentrations of PFOA were tested for the acute test: 25, 40, 63, 100, 160, 250, 400 and 630 mg/L. A control sample and six nominal concentrations of PFOA were tested for the life-cycle test: 5, 8, 13, 22, 36 and 60 mg/L. The results of the static acute test identified a 48-hour EC50 of 266 mg/L PFOA (based on nominal concentrations) for *D. magna*. The results of the life-cycle test identified a 21-day EC50 of 43 mg/L PFOA (based on measured concentrations) and a 21-day NOEC of 22 mg/L (based on measured concentrations) for *D. magna*. The toxic endpoint for both values was reproduction. However, the chronic tests were conducted with water temperatures outside the acceptable test methodology. As such, the chronic data was not utilized.

Chironomus tentans (midge)

STS-408

A bioassay STS-408 on the effects of PFOA (ammonium salt) on *Chironomus tentans* (midge) was reviewed by STS. In this study the acute toxicity of PFOA to *C. tentans* was observed under acute static-renewal conditions. The acute toxicity was observed over a 96-hour exposure period at Wildlife International, Ltd. in Easton, Maryland completed in March 2007. The testing followed ASTM E729-96 (1996). Measured concentrations were tested from a control and five nominal values: 63, 125, 250, 500 and 1000 mg/L.

The results identified a 96-hour LC50 >1090 mg/L PFOA and a 96-hour NOEC of 277 mg/L PFOA for *C. tentans*. However, since there is no definitive LC50 or EC50 endpoint, this study was not used in the final determination of the Final Acute Value (FAV).

4.1.3 Fishes

Pimephales promelas (Fathead minnow)

AR226-0509

A bioassay AR226-0509 on the effects of PFOA (acid form) on *Pimephales promelas* (fathead minnow) was reviewed by STS. In this non-GLP study the acute toxicity of PFOA to *P*. *promelas* was observed at 19-20°C under static conditions over a 96-hour exposure period and was completed in February, 1985. The test methodology was not stated but generally followed U.S. EPA 660/ 3-75-009 (1975). *P*. *promelas* used for this study were juveniles at test initiation. A control sample and five nominal concentrations of PFOA were tested: 690, 750, 810, 870 and 930 mg/L. The results of the two tests identified a 96-hour LC50 of 861 mg/L and 825 mg/L PFOA for *P*. *promelas.*

AR226-0504

A bioassay AR226-0504 on the effects of PFOA (ammonium salt) on *Pimephales promelas* (fathead minnow) was reviewed by STS. In this non-GLP study the acute toxicity of PFOA to *P*. *promelas* was observed at 18-19°C under static conditions over a 96-hour exposure period and was completed in May, 1980. The test methodology followed was U.S. EPA 660/ 3-75-009 (1975). *P*. *promelas* used for this study were juveniles at test initiation. A control sample and five nominal concentrations of PFOA were tested: 560, 650, 750, 870 and 1,000 mg/L. The two test results identified a 96-hour LC50 of 754 mg/L and 776 mg/L PFOA for *P*. *promelas.*

AR226-0513

A bioassay AR226-0513 on the effects of PFOA (ammonium salt) on *Pimephales promelas* (fathead minnow) was reviewed by STS. In this non-GLP study the acute toxicity of PFOA to *P*. *promelas* was observed at 21°C under static conditions over a 96-hour exposure period and was completed in May 1987. The test methodology was not

stated but generally followed U.S. EPA 660/ 3-75-009 (1975). *P. promelas* used for this study were juveniles at test initiation. A control sample and five nominal concentrations of PFOA were tested: 100, 180, 320, 560 and 1,000 mg/L. The two tests identified a 96-hour LC50 of 290 mg/L and 312 mg/L PFOA for *P. promelas.*

Oncorhynchus mykiss (Rainbow trout)

AR226-1803

A bioassay AR226-1803 on the effects of PFOA (ammonium salt) on *Oncorhynchus mykiss* (rainbow trout) was reviewed by STS. In this GLP study the early life stage (embryo, larval and juvenile stages) toxicity of PFOA to *O. mykiss* was observed under flow-through conditions over an 85-day exposure period at CIT Health & Safety Research Laboratories in Evreux, France in the summer of 2003. This study followed OECD Guideline 210. This study was initiated soon after fertilization (day 0). A control and five measured concentrations of PFOA were tested from five nominal values: 3.13, 6.25, 12.5, 25.0 and 50.0 mg/L. Solutions of PFOA were replaced constantly by continuous pumping using a peristaltic pump. The results of the test identified an 85-day NOEC of 40 mg/L, the highest measured concentration tested. However, we note the NOEC result for juvenile mortality cannot be relied on due to statistical issues.

4.2 Unacceptable Toxicity Bioassay Summaries

4.2.1 Aquatic Plants

Selenastrum capricornutum (freshwater alga)

The toxicity data from the following tests were determined to be unacceptable:

STS-407 – The test specimens were too old at test initiation. In addition, we note the ideal temperature for analysis is 25°C. The 96-hour NOEC (based on cell count) was 62 mg/L and the 96-hour NOEC (based on growth rate) was 500 mg/L PFOA. The LOEC (based on cell count) was 130 mg/L and the LOEC (based on growth rate) was 1,000 mg/L PFOA.

AR226-0518 - Low pH due to the acid form of PFOA at outset of study may have skewed results. The reported toxicity value (EC50) was 90 mg/L based on growth rate and cell density.

AR226-0526 – 48 hour EC50 values exceeded the 24 hour values with no discussion in study. Sample was a mixture of straight-chain and branched-chain PFOA isomers. The reported toxicity value (EC50) was 1980 mg/L based on cell count.

STS-153 – The concentration of PFOA in test sample L-13492 is not known. The reported toxicity value (EC50) was 4.9 mg/L PFOA.

STS-406– The actual concentration of PFOA in the test material (N2803-2) is not known. The laboratory assumed 100% active ingredient. Since the data are 1-2 orders of magnitude lower than the test data with essentially pure chemical, the data is not likely reflective of true toxicity of PFOA in water. The reported toxicity value (EC50) was 2.9 mg/L based on cell count.

4.2.2 Aquatic Invertebrates

Daphnia magna (water flea)

The toxicity data from the following tests were determined to be unacceptable:

AR226-0520 – Toxicity as a result of isopropyl alcohol could not be ruled out. The results of the test identified a 48-hour EC50 of 360 mg/L, a 48-hour LC50 of 400 mg/L, and a NOEC of 180 mg/L PFOA for *D. magna*.

AR226-0507 – Non-GLP screening-level study. The test method was not described. The variance between substance concentrations exceeded current EPA test guidelines. The reported toxicity value (EC50) was 126 mg/L.

AR226-508 - Chronic portions of this study did not follow GLP in regards to test temperatures.

AR226-0527 – Screening-level static acute test. GLP not followed. Data may not accurately relate toxicity of the test sample with the test substance due to the fact that both straight-chain and branch-chain analogs were present. The reported toxicity value (EC50) was 1200 mg/L.

STS-404 – The actual concentration of PFOA in liquid sample N2803-2 is not known. Data obtained are not consistent with other studies. The reported toxicity value (EC50) was 62 mg/L.

STS-405 - The actual concentration of PFOA in liquid sample L-13492 is not known. Data obtained are not consistent with other studies. The reported toxicity value (EC50) was 34 mg/L.

Chironomus tentans (midge)

The toxicity data from the following tests were determined to be unacceptable:

STS-110 – This study was generally viewed as acceptable in terms of methodology. However, no usable data were obtained (NOEC >100 mg/L).

4.2.3 Fishes

Pimephales promelas (Fathead minnow)

The toxicity data from the following tests were determined to be unacceptable:

AR226-0501/AR226-0502/AR226-0503 – GLP not followed. Non-standard test protocol. Some information regarding the analysis of the test solution concentrations was not available. The reported toxicity value (egg hatchability, survival and growth) was reported >100 mg/L.

AR226-0497 – GLP not followed. Not enough documentation of methodology. Not enough data points; no replicates. Data obtained are not consistent with other studies. The reported toxicity value (LC50) was 70 mg/L.

AR226-0498 – GLP not followed. One replicate. Not enough documentation of methodology. Health of test species not noted. Number of fish per replicate not specified. Too wide a result gap between concentrations (0 vs. 100%). The reported toxicity value (LC50) was 440 mg/L.

AR226-0519 – Low pH at upper doses; no adverse response at lower doses. Therefore, no usable data are available. The reported toxicity value (LC50) was 140 mg/L.

STS-150 – The actual concentration of PFOA in the test sample (L-13492) is not known. The reported toxicity value (LC50) was 890 mg/L.

STS-151 - The actual concentration of PFOA in the test sample (N2803-2) is not known. The reported toxicity value (LC50) was 960 mg/L.

STS-152 – Microcosm test with non-standard testing methodology.

AR226-0525 – The actual concentration of PFOA is not known. Sample is a mixture of straight-chain and branch-chain isomers. The reported toxicity value (LC50) was 2470 mg/L.

AR226-0516 – Reported toxicity value (LC50) as >1000 mg/L. Based on an assumed 45% PFOA concentration, LC50 for PFOA >450 mg/L. Absolute value not determined. The NOEC was reported at >1000 mg/L.

Lepomis machrochirus (Bluegill sunfish)

The toxicity data from the following test were determined to be unacceptable:

AR226-0499 – Non-GLP study. Method not noted. The test temperatures were out of range per current EPA test guidelines. The average fish weight at test initiation was considered suspect. No replicates. The reported LC50 was >420 mg/L.

Oncorhynchus mykiss (Rainbow trout)

The toxicity data from the following tests were determined to be unacceptable:

AR226-1531 - Non-standard methodology. Substance used for toxicity testing was a mixture PFAs.

4.3 Microcosm Toxicity Testing

A total of two 35 day microcosm studies of exposure of zooplankton to PFOA were reviewed by STS (STS-209 and STS-201). Community structures in the studies over the 35 day study periods shifted from larger zooplankton dominated communities to communities dominated by smaller zooplankton species (presumably due to differential susceptibility to PFOA). Toxicity values (EC 50, etc.) in the microcosm tests were less than those in referenced laboratory toxicity bioassays – highlighting the possibility that PFOA is accumulated from food more than concentrated from water. Summaries of the microcosm tests are presented below:

STS-209 (Sanderson et al., 2003)
Toxicity of PFOA (unspecified form) to zooplankton communities was observed over a 35 day exposure period using 30 L indoor aquaria in a static conditions test. Zooplankton microcosm communities consisted of *Cyclops canthocamptus staphylinus*, *C. strenuous*, *C. diaptomus*, *Daphnia magna*, *Keratella quadrata*, *Phyllopoda* sp., *Echninorhynchus* sp., *Ostracoda* sp., and total *Rotifera* sp. Other macrophytes and invertebrates were also present. The ecosystem food supply consisted of the freshwater algae *Scenedesmus acutus*. The endpoints of toxicity that were measured included species abundance and species richness. The ecosystem was evaluated on days -1, 1, 2, 4, 7, 14, 21, 28 and

35. The study identified three outcomes: (1) *D. magna* were the most sensitive species in the systems with a NOEC of 10 mg/L and a LOEC of 20 mg/L; (2) although the total zooplankton abundance showed no trends, *Rotifera* sp. increased at the expense of other more sensitive species; and (3) all of the temporal fluctuations observed in the study were followed by rapid recovery upon removal of PFOA.

STS-201 (Sanderson et al., 2004)
Toxicity of PFOA (sodium salt) to zooplankton communities was observed using both indoor and outdoor static aquaria tests. Results were compared to a 21-day static chronic laboratory bioassay performed on *Daphnia magna* and *D. pulicaria*. Zooplankton microcosm communities for this study consisted of *Cyclops canthocamptus staphylinus*, *C. strenuous*, *C. diaptomus*, *D. magna*, *Keratella quadrata*, *Phyllopoda* sp., *Echninorhynchus* sp., *Ostracoda* sp., and total *Rotifera* sp. Other macrophytes and invertebrates were also present. The microcosm study identified an overall community shift from a larger zooplankton dominated community to a community dominated by smaller and more robust species, especially Rotifers.

Neither a 21-day static chronic NOEC or 21-day static chronic LOEC could be calculated for PFOA for *Daphnia* spp. The 35-day indoor microcosm LOEC (community) value for PFOA was 30 – 70 mg/L. The 35-day outdoor microcosm LOEC (community) value for PFOA was 70 mg/L. The order of sensitivity rank for the aforementioned 35-day microcosm tests was Cladocera>Copepoda>Rotifera. The LOEC value for *D. magna* was lower in the microcosm test than in the reference laboratory chronic bioassay, and the results were not apparently due to food scarcity due to phytotoxicity.

4.4 Microtox Toxicity Testing

A total of five Microtox tests (AR226-0511, AR226-0515, AR226-0521, AR226-0522, AR226-0523) addressing the effect of PFOA (ammonium salt) on *Photobacterium phosphoreum* were reviewed by STS. The Microtox procedure is a screening test that measures the light output of the bacteria over a 5, 15 and 30 minute exposure period while exposed to a noxious agent. The percent light loss after the exposure period is the recorded endpoint. The Microtox procedure is not an EPA approved procedure for

incorporation into aquatic life standards at this time. *P. phosporeum* are saltwater bacteria. The toxicity data obtained from these tests were not used by STS in the calculation of water quality standards for PFOA. The tests are discussed in detail below.

AR226-0511

This Microtox test on the exposure of PFOA (ammonium salt) to *P. phosphoreum* was completed in April, 1987. A control and four nominal concentrations of PFOA were tested: 420, 560, 750 and 1000 mg/L. The exposure of PFOA (ammonium salt) to *P. phosphoreum* resulted in a 30-minute EC50 value of 870 mg/L.

AR226-0515

This Microtox test on the exposure of PFOA (ammonium salt) to *P. phosphoreum* was completed in March, 1990. A control and four nominal concentrations of PFOA were tested: 125, 250, 500 and 1000 mg/L. The exposure of PFOA (ammonium salt) to *P. phosphoreum* resulted in a 30-minute EC50 value of >1000 mg/L. We note that no calculation was made to adjust for the actual concentration of the test substance in the test sample.

AR226-0521

This Microtox test on the exposure of PFOA (ammonium salt) to *P. phosphoreum* was completed in April, 1996. A control and four nominal concentrations of PFOA were tested: 125, 250, 500 and 1000 mg/L. The exposure of PFOA (ammonium salt) to *P. phosphoreum* resulted in a 30-minute EC50 value of 730 mg/L. We note that no calculation was made to adjust for the actual concentration of the test substance in the test sample.

AR226-0522

This Microtox test on the exposure of PFOA (ammonium salt) to *P. phosphoreum* was completed in April, 1996. A control and four nominal concentrations of PFOA were tested: 625, 1250, 2500 and 5000 mg/L. The exposure of PFOA (ammonium salt) to *P. phosphoreum* resulted in a 30-minute EC50 value of 3150 mg/L. We note that no calculation was made to adjust for the actual concentration of the test substance in the test sample.

AR226-0523

This Microtox test on the exposure of PFOA (ammonium salt) to *P. phosphoreum* was completed in April, 1996. A control and four nominal concentrations of PFOA were tested: 416, 833, 1665 and 3330 mg/L. The exposure of PFOA (ammonium salt) to *P. phosphoreum* resulted in a 30-minute EC50 value of 1950 mg/L. We note that no calculation was made to adjust for the actual concentration of the test substance in the test sample.

4.5 Other Unused Toxicity Tests

4.5.1 Saltwater Species

No PFOA toxicity studies of saltwater species were obtained and/or reviewed by STS for this project (other than the Microtox testing of PFOA – ammonium salt on saltwater bacteria *Photobacterium phosphoreum* discussed in Section 4.4).

4.5.2 Non-Native Species

One PFOA toxicity study on a non-native species (other than the Microtox testing of PFOA – ammonium salt on saltwater bacteria *Photobacterium phosphoreum* discussed in Section 4.4) was obtained and/or reviewed by STS for this project:

Myriophyllum spicatum

One toxicity test (STS-155) on the effects of PFOS on *Myriophyllum spp. (*milfoil*)* was reviewed by STS and was discussed previously (see Section 4.1.1). STS-155 was generally observed as an acceptable test in terms of methodology and data quality. The toxicity data for *M. spicatum* (Eurasian milfoil) was not used because it is not native to North America.

5.0 SURFACE WATER CRITERIA DEVELOPMENT

As described in the Introduction to this document (Section 1.0), a variety of water quality criteria are developed for a chemical to be protective of both aquatic life and human health.

5.1 Aquatic Life Criteria

The first step in developing toxicity-based aquatic life criteria is to determine if there are sufficient data available from which to calculate the criteria using the USEPA national method -- Tier 1. According to this method, a minimum of eight acute toxicity studies representing each of the following groups must be available:

- salmonid
- osteichthyes
- chordate (fish, amphibian)
- phylum other than Arthropoda or Chordata
- planktonic crustacean
- benthic crustacean
- aquatic insect
- second insect or a phylum not already represented

In addition, there is a requirement for a minimum of three chronic toxicity studies for the chemical, from which the Acute Chronic Ratio (ACR) is to be developed.

Table 2a (Appendix C) provides the acceptable chronic toxicity data for PFOA on various aquatic species. As can be seen, the above minimum requirement of three species studies has not been met. Acceptable data from only one species O. mykiss (rainbow trout) exist.

Table 2b (Appendix C) lists all acceptable Acute to Chronic Ratios (ACRs). No acceptable ACRs were found. The generic ACR of 18 is used as a default. See Minn. R. Ch. 7050.0218, Subpart 5 relating to use of the generic ACR.

Table 3a (Appendix C) provides the acceptable acute toxicity data for PFOA on various aquatic species. As can be seen, the above minimum requirement of eight species studies also has not been met. Acceptable acute toxicity data on only three of the eight

species categories is currently available for PFOA -- fathead minnow (P. promelas), Daphnia magna and the midge (C. tentans). The midge study, however, did not have a definitive LC_{50} value and was not used in the final determination of the Final Acute Value (FAV) (Table 3b). Thus, it is concluded that there is insufficient toxicological data on PFOA from which to develop Tier 1 direct toxicity criteria. Therefore, for PFOA the Tier 2 method, as specified in Minnesota Rules Chapter 7050 Subp. 5.G, will be used to calculate the criteria.

According to the Tier 2 method, a minimum of two acute values in the following groups must be available:

- Osteichthyes (fish)
- Daphnidae

As shown in Table 3a, this criterion is met for PFOA. Table 3b ranks the GMAVs for these two organisms, as well as the final FAV of 30.692 mg/L.

5.1.1 Chronic Criterion (CC), Based on Toxicity to Aquatic Organisms

Per Minnesota Rules 7050 Subp 5, the chronic criterion (CC) is calculated by dividing the final FAV by the appropriate ACR. Table 3b presents the final FAV for PFOA, 30.692 mg/L. Since there are insufficient toxicological data available on PFOA from which to calculate a measured ACR, the default value of 18 is used. Thus, the CC is 1.705 mg/L.

It is important to recognize that this value is derived from a very limited toxicological dataset.

5.1.2 Chronic Criterion (CC), Based on Toxicity to Aquatic Plants

Table 4a presents all of the PFOA toxicity studies found with aquatic plants. The final plant value is based on the Northern milfoil (Myriophyllum sibricum). Northern milfoil had the most sensitive chronic endpoint of all acceptable plant data. The Northern milfoil had a NOEC of 23.9 mg/L (Table 4b). The animal derived toxicity-based chronic criteria of 1.705 mg/L will thus protect aquatic plants.

5.1.3 Maximum Criterion (MC)

Per Minnesota Rules Chapter 7050 Subp 5, the maximum criterion (MC) is calculated by dividing the final FAV by 2. The final FAV for PFOA is presented in Table 3b; 30.692 mg/L. Thus the MC is 15.346 mg/L.

5.2 Human Health-based Criteria

In order to develop both of the human health-based surface water criteria, a risk-based toxicity criterion is required, along with a chemical-specific bioconcentration/ bioaccumulation factor (BCF/BAF). Appendix D to this document provides the risk-based criterion for PFOA, as developed by the Minnesota Department of Health. Tables 5a (all BCF/BAF data) and 5b (usable BCF/BAF data) provide the BCF/BAF data obtained to date on PFOA. Table 5c presents the analysis used to obtain the site-specific BCF/BAFs for PFOA.

5.2.1 Drinking Water Plus Fish Consumption Criterion (dfCC) Based on the BAF from the Mississippi River at Pool 3

According to Minnesota Rules 7050 Subp 6.A. a dfCC criterion is calculated for a non-carcinogen using the following equation:

$$\text{dfCC (mg/L)} = \frac{\text{RfD (mg/kg-d)} \times 70\ \text{kg} \times \text{K}}{2\ \text{L/d} + [0.030\ \text{kg/d} \bullet \text{BAF}]}$$

Where: dfCC = drinking water plus fish consumption criterion (mg/L)

RfD = reference dose = 0.00014 mg/kg-d (see Appendix D)

70 kg = standard body weight of an adult

K = exposure fraction attributed to drinking water and fish consumption (0.2)

2L/d = amount of water assumed to be consumed per day

0.030 kg/d = amount of fish assumed to be consumed per day

BAF = final BAF (see Section 3.3 of report) = 24 L/kg

$$dfCC = \frac{(0.00014)\ (70)(\ 0.2)}{2 + [(0.030)(24)]} = 0.00072 \text{ mg/L}$$

5.2.1.a Drinking Water Plus Fish Consumption Criterion (dfCC) Based on the BAF from Lake Calhoun

$$dfCC\ (mg/L) = \frac{RfD\ (mg/kg\text{-}day) \times 70\ kg \times K}{2\ L/d + [0.030\ kg/day \times BAF]}$$

Where: dfCC = drinking water plus fish consumption criterion (mg/L)

RfD = reference dose = 0.00014 mg/kg-d (see Appendix D)

70 kg = standard body weight of an adult

K = exposure fraction attributed to drinking water and fish consumption (0.2)

2L/d = amount of water assumed to be consumed per day

0.030 kg/d = amount of fish assumed to be consumed per day

BAF = final BAF (see Section 3.3 of report) = 40 L/kg

$$dfCC = \frac{(0.00014)(70)(0.2)}{2 + [(0.03)(40)]} = 0.00061 \text{ mg/L}$$

5.2.2 Fish Consumption Criterion (fCC) Based on the BAF from the Mississippi River at Pool 3

According to Minnesota Rules 7050 Subp 6.B. a fCC is calculated for a non-carcinogen using the following equation:

$$fCC\ (mg/L) = \frac{RFD\ (mg/kg\text{-}d) \times 70\ kg \times K}{0.01\ L/d + [0.030\ kg/d \bullet BAF]}$$

Where: fCC = fish consumption criterion (mg/L)

RfD = reference dose = 0.00014 mg/kg-d (see Appendix D)

70 kg = standard body weight of an adult

0.01 L/d = assumed incidental ingestion of water

0.030 kg/d = amount of fish assumed to be consumed per day

BAF = final BAF (see Section 3.3 of report) = 24 L/kg

$$fCC = \frac{(0.00014)(70)(0.2)}{0.01 + [(0.030)(24)]} = 0.0027 \text{ mg/L}$$

5.2.2.a Fish Consumption Criterion (fCC) Based on the BAF from Lake Calhoun

$$fCC\ (mg/L) = \frac{RfD\ (mg/kg\text{-}day) \times 70\ kg \times K}{0.01\ L/d + [0.030\ kg/day \times BAF]}$$

Where: fCC = fish consumption criterion (mg/L)

RfD = reference dose = 0.00014 mg/kg-d (see Appendix D)

70 kg = standard body weight of an adult

0.01 L/d = assumed incidental ingestion of water

0.030 kg/d = amount of fish assumed to be consumed per day

BAF = final BAF (see Section 3.3 of report) = 40 L/kg

$$fCC = \frac{(0.00014)(70)(0.2)}{0.01 + [(0.030)(40)]} = 0.00162 \text{ mg/L}$$

APPENDIX A

Table of Contents for
Accompanying Database Binders

PFOA Chemical Properties

Biodegradation Studies

Article No.	Title	Year
226-0487	Ready Biodegradation of FC143	1977
226-0489	Biodegradation Studies of Fluorocarbons (FC143)	1978
226-0492	Ready Biodegradation of FC143	1980
226-0495	Ready Biodegradation of FC126	1987
226-0494	Ready Biodegradation of FX1001	1985
STS-156	18-Day Aerobic Biodegradation Study	2001
226-1796	Memo: Environ. Half-Life for C-8	1998

Abiotic Degradation Studies

Article No.	Title	Year
226-0490	FC143: Photolysis Study using Simulated Sunlight	1979
STS-157	Hydrolysis Reactions of PFOA	2001
STS-158	Publ. Study: Decomposition of PFOA	2004
STS-400	Phytolytic Degradation of PFOA	2001

Octanol-Water Coefficient

Article No.	Title	Year
226-0493	Calculated Octanol-Water Partition Coefficient: FC143	1981

Soil Binding Studies

Article No.	Title	Year
226-0488	Adsorption of FC95 and FC143 on Soil	1978
226-1783	Adsorption of FC95 and FC143 on Soil	1978
STS-401	Adsorption of PFOA to Soil	1978

Water Solubility

Article No.	Title	Year
226-0486	Water, Acetone, and Toluene Solubilities Estimates - FC143	1981
STS-159	3M Solubility Study	2001

Bioaccumulation Studies

Article No.	Title	Year
226-0491	Bioaccumulation Properties in Bluegill Sunfish	1978
226-0496	Assessments of Bioacc.Properties of APFO: Static Test	1995
STS-160	Publ. Study: Dietary Accum. of PFOA in Trout	2003
STS-134	Publ. Study: PFOS/PFOA in Mink and Otters in U.S.	2004

General Environment

Article No.	Title	Year
STS-163	Publ. Study: Sources, Fate and Transport to Perfluorocarb.	2006
226-1055	PFOA in Diets and Human Samples	2002
STS-164	Arctic PFOA Contamination	2006
STS-212	Isomers of PFs in Polar Bears	2005
STS-213	PFs in Biota of the Canadian Arctic	2004
226-8000	Publ. Study: PFCs in Aquatic Organisms in the Great Lakes Food Chain	2005
STS-135	Publ. Study: PFOS and Related Fluorinated Hydrocarbons in Marine Mammals	2002
STS-133	Publ. Study: Perfluorinated Acids in Livers of Birds from Japan and Korea	2002
STS-142	Perfluoroalkyl Contaminants in a Food Web from Lake Ontario	2004
STS-204	Publ. Study: PFOS and Other PFCs in Fish, Birds and Marine Mammals	2005
*STS-205	Publ. Study: Polyfluoroalkyl Compounds in Bottlenose Dolphins	2005

PFOA Chemical Properties

Vapor Pressure

* Note: Articles referred to in the PFOA text that are not in the Appendix here can be found in the Appendix of the PFOS document prepared by STS for the MPCA.

PFOA Aquatic Life Studies

Volume 1

Daphnia

Article No.	Title	Year
226-0507	48-Hour Acute Static Toxicity to *Daphnia magna* - FC143	1982
226-0512	48-Hour Acute Static Toxicity to *Daphnia magna* - FC126	1987
226-0517	Static Acute Toxicity of FX1003 to the Daphnid, *Daphnia magna*	1990
226-0520	Acute Toxicity of N2803-3 to the Daphnid, *Daphnia magna*	1996
226-0527	Acute Toxicity of FC-1015 to the Daphnid, *Daphnia magna*	1996
226-0508	Chronic Toxicity of Fluorochemicals to *Daphnia magna*	1998
STS-403	Wilbury Study 895-TH Acute Toxicity of *Daphnia magna*	1996
STS-404	Wilbury Study 889-TH Acute Toxicity of *Daphnia magna*	1996
STS-405	Wilbury Study 840-TH Acute Toxicity of *Daphnia magna*	1995

Fathead Minnow

Article No.	Title	Year
226-0498	96-Hour Acute Static Toxicity to Fathead minnow - FC26	1974
226-0497	96-Hour Acute Static Toxicity to Fathead minnow - FC143	1974
226-0504	Acute Toxicity to Fathead minnow (FC-143)	1980
226-0509	96-Hour Acute Static Toxicity to Fathead minnow	1985
226-0513	96-Hour Acute Static Toxicity to Fathead minnow - FC126	1987
226-0516	Static Acute Toxicity of FX1003 to the Fathead minnow	1990
226-0519	Acute Toxicity of N2803-3 to the Fathead minnow	1996
226-0525	Acute Toxicity of FC1015 to the Fathead minnow	1996
STS-150	Acute Toxicity to the Fathead minnow: Study 839-TH	1995
STS-151	Acute Toxicity to the Fathead minnow: Study 888-TH	1995
226-0501	Flow Through - Egg and Fry Exposure	1978
226-0502	Effects of Aqueous Exposure on Hatchability and Growth and Survival	1978
226-0503	Summary of Histopathological Exams of Fathead minnows	1978
STS-152	Publ. Study: PFOA Effect on Fathead minnow	2004

Bluegill

Article No.	Title	Year
226-0499	Acute Toxicity to Fish: 96-Hour Toxicity Test in Bluegills	1978

Rainbow Trout

Article No.	Title	Year
226-1803	Early Life-Stage Toxicity Test - Rainbow Trout	2003
226-1531	Bioconcentration and Tissue Distribution of Perfluorinated Acids in Rainbow Trout	2003

PFOA Aquatic Life Studies

Volume 2

Algae

Article No.	Title	Year
226-0506	Multi-Phase Exposure/Recovery Algal Assay Test with *Selenastrum capricornutum*	1981
226-0526	Growth and Reproduction Toxicity Test with FC1015 and the Freshwater Alga, *Selenastrum capricornutum*	1996
226-0518	Acute Toxicity of PFOA to the Freshwater Alga	1996
STS-153	Growth and Reproduction Toxicity Test: Study 841-TH	1995
STS-406	Growth and Reproduction Toxicity Test: Wilbury Study 890-TH	1995
STS-407	Growth and Reproduction Toxicity Test: Wilbury Study 896-TH	1996

Midge

Article No.	Title	Year
STS-110	Publ. Study: PFOs/PFOA Toxicity to *Chironomus tentans*	2004
STS-408	96-Hour Acute Toxicity of PFOA to *Chironomus tentans*	2007

Microcosm Effects

Article No.	Title	Year
STS-209	Publ. Study: PFOA Impact to Zooplankton Community	2002
STS-201	Publ. Study: Effects of PFOA to Zooplankton Community	2003

Microtox Assay

Article No.	Title	Year
226-0511	Microtox Test: PFOA	1987
226-0515	Microtox Test: PFOA	1990
226-0521	Microtox Test: PFOA	1996
226-0522	Microtox Test: PFOA	1996
226-0523	Microtox Test: PFOA	1996

Milfoil

Article No.	Title	Year
STS-155	Publ. Study: Microcosm Eval. PFOA to Aquatic Macrophytes	2005

APPENDIX B

Axys Laboratory Report:
PFOA Database for
Minnesota Waters and Fish

(Available Upon Request)

APPENDIX C

Toxicity-based Summary Tables on PFOA

Table 1: Toxicity Data
PFOA - Ammonium salt
Rainbow trout - *Onchorhynchus mykiss*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
O. mykiss	NOEC (juvenile mortality)	40	Juvenile	85	FM	FW	11.1-12.5 (embryo) 11.6-14.4 (larval and juvenile)	14.0-16.8	Statistical issues	AR226-1803	No Statistical issues
O. mykiss	NOEC (larval mortality)	40	Larval	85	FM	FW	11.1-12.5 (embryo) 11.6-14.4 (larval and juvenile)	14.0-16.8	GLP test	AR226-1803	Yes
O. mykiss	NOEC (mortality before hatch)	40	Egg	85	FM	FW	11.1-12.5 (embryo) 11.6-14.4 (larval and juvenile)	14.0-16.8	GLP test	AR226-1803	Yes
O. mykiss	NOEC (juvenile growth)	40	Juvenile	85	FM	FW	11.1-12.5 (embryo) 11.6-14.4 (larval and juvenile)	14.0-16.8	GLP test based on length and wt.	AR226-1803	Yes
O. mykiss	NOEC (larval growth)	40	Larval	85	FM	FW	11.1-12.5 (embryo) 11.6-14.4 (larval and juvenile)	14.0-16.8	GLP test	AR226-1803	Yes
O. mykiss	NOEC (time to hatch)	40	Egg	85	FM	FW	11.1-12.5 (embryo) 11.6-14.4 (larval and juvenile)	14.0-16.8	GLP test	AR226-1803	Yes

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data
PFOA - Ammonium salt
Bluegill sunfish - *Lepomis machrochirus*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
L. machrochirus	LC50	>420	Juvenile	4	SU	FW	18-19	NR	Non GLP study. Method questions. Temps. Out of range. No replicates. Fish weight questions.	AR226-0499	No Method questions

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
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RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data
PFOA - Acid Form
Fathead minnow - *Pimephales promelas*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
P. promelas	LC50	861	Juvenile (0.5g)	4	SU	FW	19-20	NR		AR226-0509	Yes
P. promelas	LC50	825	Juvenile (0.5g)	4	SU	FW	19-20	NR		AR226-0509	Yes
P. promelas	LC50	849	Juvenile (0.5g)	3	SU	FW	19-20	NR		AR226-0509	No Data point not used for criteria calculation
P. promelas	LC50	849	Juvenile (0.5g)	2	SU	FW	19-20	NR		AR226-0509	No Data point not used for criteria calculation
P. promelas	LC50	>930	Juvenile (0.5g)	1	SU	FW	19-20	NR		AR226-0509	No Data point not used for criteria calculation
P. promelas	LC50	440	Juvenile	4	SU	FW	20.5-21.1	NR	Gap between conc. Too wide. Only one replicate. Methodology questions.	AR226-0498	No Method questions
P. promelas	LC50	280 (as tested)	Juvenile	1	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	LC50	280 (as tested)	Juvenile	2	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	LC50	280 (as tested)	Juvenile	3	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	LC50	280 (as tested)	Juvenile	4	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	NOEC	220 (as tested)	Juvenile	4	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data (continued)
PFOA - Acid Form
Fathead minnow - *Pimephales promelas*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
P. promelas	LC50	140 (based on conc.)	Juvenile	1	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	LC50	140 (based on conc.)	Juvenile	2	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	LC50	140 (based on conc.)	Juvenile	3	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	LC50	140 (based on conc.)	Juvenile	4	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions
P. promelas	NOEC	110 (based on conc.)	Juvenile	4	SU	FW	21.9-22.6	40-48	Low pH at higher doses. No adverse respone at lower doses.	AR226-0519	No Method questions

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FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data
PFOA - Ammonium salt
Fathead minnow - *Pimephales promelas*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
P. promelas	LC50	290	Juvenile (0.3g)	4	SU	FW	21	NR		AR226-0513	Yes
P. promelas	LC50	312	Juvenile (0.3g)	4	SU	FW	21	NR		AR226-0513	Yes
P. promelas	LC50	776	Juvenile (0.4g)	4	SU	FW	18-20	272	Hardness measured on one day of test from one tank	AR226-0504	Yes
P. promelas	LC50	754	Juvenile (0.4g)	4	SU	FW	18-20	272	Hardness measured on one day of test from one tank	AR226-0504	Yes
P. promelas	Egg hatchability, survival and growth	>100	30 days post hatch	Eggs within 48 hours of fertilization	FU	FW	25	31-38	Non GLP test. Non standard test protocol. Test solution conc. not available.	AR226-0501	No Data point not used for criteria calculation
P. promelas	Egg hatchability, survival and growth	>100	30 days post hatch	Eggs within 48 hours of fertilization	FU	FW	25	31-38	Non GLP test. Non standard test protocol. Test solution conc. not available.	AR226-0502	No Data point not used for criteria calculation
P. promelas	Egg hatchability, survival and growth	>100	30 days post hatch	Eggs within 48 hours of fertilization	FU	FW	25	31-38	Non GLP test. Non standard test protocol. Test solution conc. not available.	AR226-0503	No Data point not used for criteria calculation
P. promelas	LC50	70	4	1.5g	SU	FW	21-22	NR	Non GLP test. Methodology questions. No replicates.	AR226-0497	No Method issues
P. promelas	LC50	>1000	4	Juvenile	SU	FW	21-22	88	Absolute value not determined	AR226-0516	No Absolute value not determined
P. promelas	LC50	>1000	3	Juvenile	SU	FW	21-22	88	Absolute value not determined	AR226-0516	No Absolute value not determined
P. promelas	LC50	>1000	2	Juvenile	SU	FW	21-22	88	Absolute value not determined	AR226-0516	No Absolute value not determined

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FW - Freshwater
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SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data (continued)
PFOA - Ammonium salt
Fathead minnow - *Pimephales promelas*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
P. promelas	LC50	>1000	1	Juvenile	SU	FW	21-22	88	Absolute value not determined	AR226-0516	No Absolute value not determined
P. promelas	NOEC	>1000	4	Juvenile	SU	FW	21-22	88	Absolute value not determined	AR226-0516	No Absolute value not determined
P. promelas	LC50	890	4	Juvenile	SU	FW	21.9-22.3	44	The actual concentration of the test sample is not known	STS-150	No Actual concentration of PFOA is unknown
P. promelas	NOEC	600	4	Juvenile	SU	FW	21.9-22.3	44	The actual concentration of the test sample is not known	STS-150	No Actual concentration of PFOA is unknown
P. promelas	LC50	890	3	Juvenile	SU	FW	21.9-22.3	44	The actual concentration of the test sample is not known	STS-150	No Actual concentration of PFOA is unknown
P. promelas	LC50	940	2	Juvenile	SU	FW	21.9-22.3	44	The actual concentration of the test sample is not known	STS-150	No Actual concentration of PFOA is unknown
P. promelas	LC50	1,000	1	Juvenile	SU	FW	21.9-22.3	44	The actual concentration of the test sample is not known	STS-150	No Actual concentration of PFOA is unknown
P. promelas	NOEC	630	4	Juvenile	SU	FW	21.6-22	40	The actual concentration of the test sample is not known	STS-151	No Actual concentration of PFOA is unknown
P. promelas	LC50	960	4	Juvenile	SU	FW	21.6-22	40	The actual concentration of the test sample is not known	STS-151	No Actual concentration of PFOA is unknown
P. promelas	LC50	970	3	Juvenile	SU	FW	21.6-22	40	The actual concentration of the test sample is not known	STS-151	No Actual concentration of PFOA is unknown

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data (continued)
PFOA - Ammonium salt
Fathead minnow - *Pimephales promelas*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
P. promelas	LC50	>1,000	2	Juvenile	SU	FW	21.6-22	40	The actual concentration of the test sample is not known	STS-151	No Actual concentration of PFOA is unknown
P. promelas	LC50	>1,000	1	Juvenile	SU	FW	21.6-22	40	The actual concentration of the test sample is not known	STS-151	No Actual concentration of PFOA is unknown
P. promelas	NOEC	830	4	Juvenile	SU	FW	21.8-22	40-48	The actual concentration of the test sample is not known - mixture concerns	AR226-0525	No Actual concentration of PFOA is unknown
P. promelas	LC50	2470	4	Juvenile	SU	FW	21.8-22	40-48	The actual concentration of the test sample is not known - mixture concerns	AR226-0525	No Actual concentration of PFOA is unknown
P. promelas	LC50	2470	3	Juvenile	SU	FW	21.8-22	40-48	The actual concentration of the test sample is not known - mixture concerns	AR226-0525	No Actual concentration of PFOA is unknown
P. promelas	LC50	2890	2	Juvenile	SU	FW	21.8-22	40-48	The actual concentration of the test sample is not known - mixture concerns	AR226-0525	No Actual concentration of PFOA is unknown
P. promelas	LC50	>3,330	1	Juvenile	SU	FW	21.8-22	40-48	The actual concentration of the test sample is not known - mixture concerns	AR226-0525	No Actual concentration of PFOA is unknown

NR - Not Recorded
FW - Freshwater
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SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data
PFOA - Acid Form
Cladoceran - *Daphnia magna*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
D. magna	EC50	840 (as-tested)	<24 hours	1	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	LC50	1,000 (as-tested)	<24 hours	1	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	EC50	720 (as-tested)	<24 hours	2	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	LC50	800 (as-tested)	<24 hours	2	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	NOEC	360 (as-tested)	<24 hours	2	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	EC50	420 (based on concentration of test substance in solution)	<24 hours	1	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	LC50	500 (based on concentration of test substance in solution)	<24 hours	1	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	EC50	360 (based on concentration of test substance in solution)	<24 hours	2	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	LC50	400 (based on concentration of test substance in solution)	<24 hours	2	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence
D. magna	NOEC	180 (based on concentration of test substance in solution)	<24 hours	2	SM	FW	19.4-20.2	160	Isopropanol may have influenced toxicity results	AR226-0520	No Possible isopropanol influence

NR - Not Recorded
FW - Freshwater
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SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data
PFOA - Ammonium Salt
Cladoceran - *Daphnia magna*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
D. magna	EC50	126	<24 hours	2	SU	FW	24	NR	Non-GLP test. Test method not described. Variance between substance conc. exceeds standard.	AR226-0507	No
D. magna	EC50	>1,000	<24 hours	2	SU	FW	24	NR	Non-GLP test. Test method not described. Variance between substance conc. exceeds standard.	AR226-0507	No
D. magna	EC50	221	<24 hours	2	SU	FW	21	NR		AR226-0512	Yes
D. magna	EC50	227	<24 hours	2	SU	FW	21	NR		AR226-0512	Yes
D. magna	EC50	584	<24 hours	2	SU	FW	19.5-20.1	180		AR226-0517	Yes
D. magna	EC50	>1,000	<24 hours	1	SU	FW	19.5-20.1	180		AR226-0517	No Data point not used in criteria calculation
D. magna	EC50	1790	<24 hours	1	SU	FW	20.3-20.8	176		AR226-0527	No Data point not used in criteria calculation
D. magna	EC50	1200	<24 hours	2	SU	FW	20.3-20.8	176		AR226-0527	No
D. magna	EC50	730	<24 hours	2	SU	FW	20.3-20.8	176		AR226-0527	No
D. magna	NOEC survival	60	<24 hours	14	RU	FW	22	240	Temp. out of range	AR226-0508	No Temperature not acceptable
D. magna	NOEC reproduction	8	<24 hours	14	RU	FW	22	240	Temp. out of range	AR226-0508	No Temperature not acceptable
D. magna	NOEC survival	22	<24 hours	21	RU	FW	22	240	Temp. out of range	AR226-0508	No Temperature not acceptable
D. magna	NOEC reproduction	22	<24 hours	21	RU	FW	22	240	Temp. out of range	AR226-0508	No Temperature not acceptable
D. magna	IC50 reproduction	40	<24 hours	14	RU	FW	22	240	Temp. out of range	AR226-0508	No Temperature not acceptable
D. magna	IC50 reproduction	43	<24 hours	21	RU	FW	22	240	Temp. out of range	AR226-0508	No Temperature not acceptable
D. magna	EC50	416	<24 hours	1	SU	FW	22	240	Temp. out of range	AR226-0508	No Temperature not acceptable
D. magna	EC50	266	<24 hours	2	SU	FW	22	240		AR226-0508	Yes
D. magna	LC50	>1000	<24 hours	1	SU	FW	19.1-20.6	164	GLP test	STS-403	No Data point not used for criteria calculation

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data (continued)
PFOA - Ammonium Salt
Cladoceran - *Daphnia magna*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
D. magna	LC50	720	<24 hours	2	SU	FW	19.1-20.6	164	GLP test	STS-403	Yes
D. magna	EC50	780	<24 hours	1	SU	FW	19.1-20.6	164	GLP test	STS-403	No Data point not used for criteria calculation
D. magna	EC50	720	<24 hours	2	SU	FW	19.1-20.6	164	GLP test	STS-403	Yes
D. magna	NOEC	360	<24 hours	2	SU	FW	19.1-20.6	164	GLP test	STS-403	No
D. magna	LC50	>100	<24 hours	1	SU	FW	19.3-20.4	176	Actual conc. Of PFOA unknown	STS-404	No Concentration of PFOA unknown
D. magna	LC50	93	<24 hours	2	SU	FW	19.3-20.4	176	Actual conc. Of PFOA unknown	STS-404	No Concentration of PFOA unknown
D. magna	EC50	72	<24 hours	1	SU	FW	19.3-20.4	176	Actual conc. Of PFOA unknown	STS-404	No Concentration of PFOA unknown
D. magna	EC50	62	<24 hours	2	SU	FW	19.3-20.4	176	Actual conc. Of PFOA unknown	STS-404	No Concentration of PFOA unknown
D. magna	NOEC	13	<24 hours	2	SU	FW	19.3-20.4	176	Actual conc. Of PFOA unknown	STS-404	No Concentration of PFOA unknown
D. magna	LC50	>100	<24 hours	1	SU	FW	20.4-20.7	164	Actual conc. Of PFOA unknown	STS-405	No Concentration of PFOA unknown
D. magna	LC50	77	<24 hours	2	SU	FW	20.4-20.7	164	Actual conc. Of PFOA unknown	STS-405	No Concentration of PFOA unknown
D. magna	EC50	89	<24 hours	1	SU	FW	20.4-20.7	164	Actual conc. Of PFOA unknown	STS-405	No Concentration of PFOA unknown
D. magna	EC50	34	<24 hours	2	SU	FW	20.4-20.7	164	Actual conc. Of PFOA unknown	STS-405	No Concentration of PFOA unknown
D. magna	NOEC	13	<24 hours	2	SU	FW	20.4-20.7	164	Actual conc. Of PFOA unknown	STS-405	No Concentration of PFOA unknown

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data
PFOA - Potassium Salt
Midge - *Chironomus tentans*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
C. tentans	NOEC	>100	Larval	10	RM	FW	23	NR	Generally good test with no usable data	STS-110	No Data point unusable

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 1: Toxicity Data
PFOA - Ammonium Salt
Midge - *Chironomus tentans*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
C. tentans	LC50	>1090	2nd to 3rd instar larvae (approx. 10-day old)	1	RM	FW	21.7-23	132-136	Std. = 48 hr. result	STS-408	No Data point not used in criteria calculation
C. tentans	LC50	>1090	2nd to 3rd instar larvae (approx. 10-day old)	2	RM	FW	21.7-23	132-136	Std. = 48 hr. result	STS-408	Yes
C. tentans	LC50	>1090	2nd to 3rd instar larvae (approx. 10-day old)	3	RM	FW	21.7-23	132-136	Std. = 48 hr. result	STS-408	No No definitive LC50 endpoint
C. tentans	LC50	>1090	2nd to 3rd instar larvae (approx. 10-day old)	4	RM	FW	21.7-23	132-136	Std. = 48 hr. result	STS-408	No No definitive LC50 endpoint
C. tentans	NOEC	277	2nd to 3rd instar larvae (approx. 10-day old)	4	RM	FW	21.7-23	132-136	Std. = 48 hr. result	STS-408	No Data point not used in criteria calculation
C. tentans	No-mortality conc.	277	2nd to 3rd instar larvae (approx. 10-day old)	4	RM	FW	21.7-23	132-136	Std. = 48 hr. result	STS-408	No Data point not used in criteria calculation

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 2a: Acceptable Chronic Data
PFOA - All Salts

Data Requirement Category	Species	Effect	Concentration (mg/L)	Life Stage	PFOA Salt	Ex Ty	Ref. No.	Used for Criteria Database/Comments
Salmonid	*O. mykiss*	NOEC (larval mortality)	40	Larval	Ammonium salt	FM	AR226-1803	No / no acceptable acute test reference for acute/chronic ratio identified
	O. mykiss	NOEC (mortality before hatch)	40	Egg	Ammonium salt	FM	AR226-1803	No / no acceptable acute test reference for acute/chronic ratio identified
	O. mykiss	NOEC (juvenile growth)	40	Juvenile	Ammonium salt	FM	AR226-1803	No / no acceptable acute test reference for acute/chronic ratio identified. Based on both length and weight
	O. mykiss	NOEC (larval growth)	40	Larval	Ammonium salt	FM	AR226-1803	No / no acceptable acute test reference for acute/chronic ratio identified
	O. mykiss	NOEC (time to hatch)	40	Egg	Ammonium salt	FM	AR226-1803	No / no acceptable acute test reference for acute/chronic ratio identified

Table 2b: Acceptable Acute to Chronic Ratios (ACRs)
PFOA - All Salts

No acceptable ACRs found
Generic ACR of 18 used. See Minn. R. ch. 7050.0218, subpart 5

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 3a: Acceptable Acute Data
PFOA - All Salts

Data Requirement Category	Species	Effect	Concentration (mg/L)	Life Stage	PFOA Salt	Ex Ty	Ref. No.	GMAV	Used for Criteria Database/Comments
Osteichthyes	*P. promelas*	LC50	861	Juvenile (0.5g)	Acid form	SU	AR226-0509	578.8	Yes
	P. promelas	LC50	825	Juvenile (0.5g)	Acid form	SU	AR226-0509		Yes
	P. promelas	LC50	312	Juvenile (0.3 g)	Ammonium salt	SU	AR226-0513		Yes
	P. promelas	LC50	290	Juvenile (0.3g)	Ammonium salt	SU	AR226-0513		Yes
	P. promelas	LC50	776	Juvenile (0.4g)	Ammonium salt	SU	AR226-0504		Yes
	P. promelas	LC50	754	Juvenile (0.4g)	Ammonium salt	SU	AR226-0504		Yes
Planktonic crustacean	*D. magna*	EC50	227	<24 hours	Ammonium salt	SU	AR226-0512	399.0	Yes
	D. magna	EC50	221	<24 hours	Ammonium salt	SU	AR226-0512		Yes
	D. magna	EC50	266	<24 hours	Ammonium salt	SU	AR226-0508		Yes
	D. magna	EC50	584	<24 hours	Ammonium salt	SU	AR226-0517		Yes
	D. magna	LC50	720	<24 hours	Ammonium salt	SU	STS-403		Yes
	D. magna	EC50	720	<24 hours	Ammonium salt	SU	STS-403		Yes
Aquatic insect	*C. tentans*	LC50	>1090	2nd to 3rd instar larvae (approx. 10-day old)	Ammonium salt	RM	STS-408	Not calculable	No definitive LC50 endpoint

NR - Not Recorded
FW - Freshwater
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SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 3b: GMAV Ranking of Acute Data and Final Acute Value
PFOA - All Salts

Species	GMAV (mg/L)
Pimephales promelas (Fathead minnow)	578.8
Daphnia magna (Water flea)	399.0

Final Acute Value [A] = 30.692 mg/L

[A] Calculated by dividing the lowest GMAV by 13.0
(see MN Rules 7050 Subp. 5. G(8)).

Table 4a: Toxicity Data
PFOA - Ammonium Salt
Photobacterium phosphoreum

Species	Effect	Concentration (mg/L)	Life Stage	Duration	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
P. phosphoreum	EC20	810	NR	5 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC50	>1000	NR	5 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC80	>1000	NR	5 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC20	520	NR	15 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC50	>1000	NR	15 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC80	>1000	NR	15 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC20	420	NR	30 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC50	870	NR	30 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC80	>1000	NR	30 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0511	No Saltwater test/species
P. phosphoreum	EC50	>1000	NR	5 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0515	No Saltwater test/species
P. phosphoreum	EC50	>1000	NR	15 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0515	No Saltwater test/species
P. phosphoreum	EC50	>1000	NR	30 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0515	No Saltwater test/species
P. phosphoreum	EC50	>1000	NR	5 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0521	No Saltwater test/species
P. phosphoreum	EC50	800	NR	15 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0521	No Saltwater test/species
P. phosphoreum	EC50	730	NR	30 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0521	No Saltwater test/species
P. phosphoreum	EC50	4460	NR	5 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0522	No Saltwater test/species
P. phosphoreum	EC50	3360	NR	15 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0522	No Saltwater test/species
P. phosphoreum	EC50	3150	NR	30 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0522	No Saltwater test/species
P. phosphoreum	EC50	2300	NR	5 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0523	No Saltwater test/species
P. phosphoreum	EC50	1960	NR	15 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0523	No Saltwater test/species
P. phosphoreum	EC50	1950	NR	30 minutes	SU	SW	NR	NR	Microtox Procedure	AR226-0523	No Saltwater test/species

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RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data
PFOA - Acid
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC50 (cell density)	180 (as tested)	10-day old culture	3	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	EC50 (growth rate)	180 (as tested)	10-day old culture	3	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	EC50 (cell density)	180 (as tested)	10-day old culture	4	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	EC50 (growth rate)	180 (as tested)	10-day old culture	4	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	NOEC	125 (as tested)	10-day old culture	4	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	EC50 (cell density)	90 (based on conc. of test substance in solution)	10-day old culture	3	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	EC50 (growth rate)	90 (based on conc. of test substance in solution)	10-day old culture	3	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	EC50 (cell density)	90 (based on conc. of test substance in solution)	10-day old culture	4	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Acid
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC50 (growth rate)	90 (based on conc. of test substance in solution)	10-day old culture	4	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues
S. capricornutum	NOEC	63 (based on conc. of test substance in solution)	10-day old culture	4	SU	FW	23.5-24	NR	Organisms too old, low pH at test outset due to acid form. Ideal temp. = 25 C. Std. test duration = 4 days.	AR226-0518	No Method issues

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RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data
PFOA - Ammonium Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC50 (dry weight)	149	7-day old culture	4	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Not lowest value
S. capricornutum	EC50 (dry weight)	70	7-day old culture	7	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC50 (dry weight)	49	7-day old culture	10	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC50 (dry weight)	73	7-day old culture	14	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC50 (cell count)	49	7-day old culture	4	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC50 (cell count)	30	7-day old culture	7	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC50 (cell count)	27	7-day old culture	10	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC50 (cell count)	43	7-day old culture	14	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC10 (cell count)	5.3	7-day old culture	4	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC10 (cell count)	3.3	7-day old culture	7	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC10 (cell count)	2.9	7-day old culture	10	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC10 (cell count)	5	7-day old culture	14	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC90 (cell count)	624	7-day old culture	4	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC90 (cell count)	283	7-day old culture	7	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC90 (cell count)	386	7-day old culture	10	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation

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Table 4a: Toxicity Data (continued)
PFOA - Ammonium Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC90 (cell count)	307	7-day old culture	14	SU	FW	23 +/- 2	NR	Ideal temp. 25, std. test = 4 days	AR226-0506	No Data point not used for criteria calculation
S. capricornutum	EC50 (cell count)	2510	8-day old culture	1	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues
S. capricornutum	EC50 (cell count)	>3330	8-day old culture	2	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues
S. capricornutum	EC50 (cell count)	2040	8-day old culture	3	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues
S. capricornutum	EC50 (cell count)	1980	8-day old culture	4	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues
S. capricornutum	EC50 (growth rate)	1700	8-day old culture	1	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues
S. capricornutum	EC50 (growth rate)	>3330	8-day old culture	2	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues
S. capricornutum	EC50 (growth rate)	>3330	8-day old culture	3	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues
S. capricornutum	EC50 (growth rate)	>3330	8-day old culture	4	SU	FW	24-24.2	NR	Organisms too old, sample was mixture, 48 hr. values exceeded 24 hr. values	AR226-0526	No Method issues

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Table 4a: Toxicity Data
PFOA - Unknown Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC10 (cells)	4.1	7-day old culture	1	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (cells)	>16	7-day old culture	1	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC90 (cells)	>16	7-day old culture	1	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC10 (cells)	1.2	7-day old culture	2	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (cells)	7.1	7-day old culture	2	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC90 (cells)	>16	7-day old culture	2	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC10 (cells)	<0.99	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (cells)	2.8	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC90 (cells)	8.4	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues

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FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Unknown Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC10 (cells)	1.4	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (cells)	2.9	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC90 (cells)	6	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	NOEC (cells)	0.99	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	LOEC (cells)	2	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (growth rate)	>16	7-day old culture	1	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (growth rate)	>16	7-day old culture	2	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC10 (growth rate)	2.2	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (growth rate)	11	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues

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FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Unknown Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC90 (growth rate)	>16	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC10 (growth rate)	2.3	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC50 (growth rate)	8.4	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC90 (growth rate)	>16	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	NOEC (growth rate)	2	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	LOEC (growth rate)	4	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-406	No Method issues
S. capricornutum	EC10 (cells)	310	8-day old culture	3	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC50 (cells)	520	8-day old culture	3	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC90 (cells)	>1000	8-day old culture	3	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues

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FM - Flow-through Measured
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Table 4a: Toxicity Data (continued)
PFOA - Unknown Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC10 (cells)	97	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC50 (cells)	310	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC90 (cells)	>1000	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	NOEC (cells)	62	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	LOEC (cells)	130	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC10 (growth rate)	470	8-day old culture	3	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC50 (growth rate)	>1000	8-day old culture	3	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC90 (growth rate)	>1000	8-day old culture	3	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC10 (growth rate)	220	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues

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RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Unknown Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC50 (growth rate)	>1000	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC90 (growth rate)	>1000	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	NOEC (growth rate)	500	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	LOEC (growth rate)	1000	8-day old culture	4	SU	FW	23.5-23.7	NR	Ideal temp is 25 C, organisms too old. Standard test duration = 4 days.	STS-407	No Method issues
S. capricornutum	EC10	<1.0	7-day old culture	1	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC50	15	7-day old culture	1	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC90	>16	7-day old culture	1	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC10	>1	7-day old culture	2	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC50	14	7-day old culture	2	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Unknown Salt
Alga - *Selenastrum capricornutum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
S. capricornutum	EC90	>16	7-day old culture	2	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC10	>1	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC50	7.1	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC90	>16	7-day old culture	3	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC10	>1	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC50	4.9	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	EC90	>16	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	NOEC	1	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues
S. capricornutum	LOEC	2	7-day old culture	4	SU	FW	23.4-23.7	NR	Actual conc. of substance not known. Ideal temp. = 25 C and standard test duration = 4 days	STS-153	No Method issues

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	EC10 (plant length)	23	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (plant length)	30.4	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (plant length)	23.7	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (plant length)	51.7	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (plant length)	50	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (plant length)	41.3	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	NOEC (plant length)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	NOEC (plant length)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (plant length)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	EC10 (root number)	20.9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (root number)	8.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (root number)	29.2	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (root number)	43.2	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (root number)	44.6	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (root number)	48.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	NOEC (root number)	23.9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (root number)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (root number)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	EC10 (root length)	25	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation

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SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	EC10 (root length)	8.4	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (root length)	24.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (root length)	40.9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (root length)	42.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (root length)	40	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	NOEC (root length)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (root length)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (root length)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	EC10 (longest root)	9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (longest root)	25.7	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (longest root)	30	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (longest root)	44.9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation

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SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	EC50 (longest root)	43.3	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (longest root)	52	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	NOEC (longest root)	23.9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (longest root)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (longest root)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	EC10 (Node number)	13.9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (Node number)	37.8	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (Node number)	7.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Node number)	69.6	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Node number)	55.2	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Node number)	39.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	NOEC (Node number)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation

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SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	NOEC (Node number)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (Node number)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	EC10 (Wet mass)	29.2	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (Wet mass)	27	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (Wet mass)	21.6	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Wet mass)	45.6	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Wet mass)	70.4	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Wet mass)	37.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	NOEC (Wet mass)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (Wet mass)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (Wet mass)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value
M. sibricum	EC10 (Dry mass)	8.7	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	EC10 (Dry mass)	7.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 (Dry mass)	24.7	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Dry mass)	43.5	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Dry mass)	39.6	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 (Dry mass)	35.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	NOEC (Dry mass)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (Dry mass)	74.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC (Dry mass)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	EC10 Chlorophyll-a	17.5	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 Chlorophyll-a	17.2	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 Chlorophyll-a	21.4	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Chlorophyll-a	87.3	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation

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SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	EC50 Chlorophyll-a	86.2	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Chlorophyll-a	106.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	NOEC Chlorophyll-a	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC Chlorophyll-a	74.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC Chlorophyll-a	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	EC10 Chlorophyll-b	26.7	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 Chlorophyll-b	20	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 Chlorophyll-b	not calculated	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Chlorophyll-b	133.6	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Chlorophyll-b	99.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Chlorophyll-b	not calculated	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Unspecified data point
M. sibricum	NOEC Chlorophyll-b	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum sibricum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	NOEC Chlorophyll-b	74.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC Chlorophyll-b	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	EC10 Catenoids	27.3	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 Catenoids	27	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC10 Catenoids	not calculated	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Catenoids	136.3	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Catenoids	135.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	EC50 Catenoids	not calculated	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not calculated
M. sibricum	NOEC Catenoids	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC Catenoids	74.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not used in criteria calculation
M. sibricum	NOEC Catenoids	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	No Not lowest value

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SM - Static Measured
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FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data
PFOA - Sodium Salt
Milfoil - *Myriophyllum spicatum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. spicatum	EC10 (plant length)	24.2	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (plant length)	5.7	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (plant length)	31.5	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (plant length)	121.2	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (plant length)	31.8	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (plant length)	52.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (plant length)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (plant length)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (plant length)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (root number)	51.6	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (root number)	16.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (root number)	10.2	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (root number)	258.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (root number)	80.5	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (root number)	51	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (root number)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (root number)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (root number)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (root length)	18.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (root length)	11.4	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (root length)	8.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (root length)	90.5	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum spicatum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. spicatum	EC50 (root length)	56.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (root length)	43.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (root length)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (root length)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (root length)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (longest root)	19.7	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (longest root)	13.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (longest root)	24.3	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (longest root)	98.3	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (longest root)	69.3	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (longest root)	62.7	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (longest root)	23.9	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (longest root)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (longest root)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Node number)	13.2	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Node number)	21.8	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Node number)	8.3	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Node number)	66.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Node number)	44.8	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Node number)	41.7	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Node number)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Node number)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum spicatum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. spicatum	NOEC (Node number)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Wet mass)	33.7	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Wet mass)	10.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Wet mass)	22.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Wet mass)	112.8	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Wet mass)	37.3	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Wet mass)	38.7	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Wet mass)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Wet mass)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Wet mass)	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Dry mass)	18.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Dry mass)	13.5	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 (Dry mass)	19.7	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Dry mass)	90.3	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Dry mass)	40.2	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 (Dry mass)	33.5	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Dry mass)	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Dry mass)	23.9	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC (Dry mass)	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Chlorophyll-a	nc	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Chlorophyll-a	nc	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Chlorophyll-a	22.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum spicatum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. spicatum	EC50 Chlorophyll-a	nc	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Chlorophyll-a	nc	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Chlorophyll-a	110.4	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Chlorophyll-a	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Chlorophyll-a	74.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Chlorophyll-a	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Chlorophyll-b	nc	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Chlorophyll-b	nc	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Chlorophyll-b	31.7	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Chlorophyll-b	nc	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Chlorophyll-b	nc	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Chlorophyll-b	117.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Chlorophyll-b	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Chlorophyll-b	74.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Chlorophyll-b	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Catenoids	nc	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Catenoids	nc	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC10 Catenoids	58.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Catenoids	nc	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Catenoids	nc	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	EC50 Catenoids	294.2	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Catenoids	74.1	Apical shoots (4 cm)	14	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4a: Toxicity Data (continued)
PFOA - Sodium Salt
Milfoil - *Myriophyllum spicatum*

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. spicatum	NOEC Catenoids	74.1	Apical shoots (4 cm)	21	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species
M. spicatum	NOEC Catenoids	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Eurasian milfoil	STS-155	No Non-native species

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 4b: Usable Plant Toxicity Data
PFOA - All salts

Species	Effect	Concentration (mg/L)	Life Stage	Duration (days)	Ex Ty	Salt/Fresh	Temperature (C)	Hardness (mg/L)	Comments	Ref. No.	Used for Criteria Calculation
M. sibricum	EC50 (plant length)	41.3	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	NOEC (plant length)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	EC50 (Dry mass)	35.8	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	NOEC (Dry mass)	23.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	EC50 Chlorophyll-a	106.9	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	NOEC Chlorophyll-a	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes
M. sibricum	NOEC Chlorophyll-b	74.1	Apical shoots (4 cm)	35	SM	FW	17.9-22	218	Outdoor Microcosms	STS-155	Yes

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 5a: All Bioconcentration/Bioaccumulation Data
PFOA

Species Latin Name/Species Common Name	Effect Type	BCF/BAF Value (L/kg)	Tissue Type	Life Stage/Age	Duration (days)	Exp. Type	Salt/Fresh	Comments	Ref. No.
Oncorhynchus mykiss/ rainbow trout	BCF	0.038	Edible portion	Juveniles	34-day uptake/41-day depuration	FM	FW	Laboratory test, kinetic extrapolation	STS-160
Lepomis macrochirus/ bluegill sunfish	BAF	24.011316 - 25 (geometric mean = 24)	Edible portion	3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Mississippi River Pool 3)	MPCA, 2006
Morone chrysops / white bass	BAF	24.34211 - 41.28289 (geometric mean = 26)	Edible portion	Juveniles	variable	Field survey	FW	Minnesota Site-Specific Study (Mississippi River Pool 3)	MPCA, 2006
Lepomis macrochirus/ bluegill sunfish	BAF	35.17588 - 37.9397 (geometric mean = 35)	Edible portion	2-3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Lake Calhoun)	MPCA, 2006
Catostomus commersonii / white sucker	BAF	35.42714 - 120.1005 (geometric mean = 46)	Edible portion	2-3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Lake Calhoun)	MPCA, 2006
Salvelinus namaycush/ lake trout	BAF	2,000	Whole fish	4 years	variable	Field survey	FW	Lake Superior	STS-330
	BAF	2,500	Whole fish	4 years	variable	Field survey	FW	Lake Michigan	STS-330
	BAF	4,000	Whole fish	4 years	variable	Field survey	FW	Lake Huron	STS-330
	BAF	800	Whole fish	4 years	variable	Field survey	FW	Lake Erie	STS-330
	BAF	400	Whole fish	4 years	variable	Field survey	FW	Lake Ontario	STS-330
Pimephales promelas/ fathead minnow	BCF	1.8	Whole fish	64 days	13-day uptake/15-day depuration	SM	FW	Laboratory test	AR226-0496
Trachemys scripta elegans and *Chinemys reevesii* / turtles	BCF	3.2 (geometric mean)	Serum	variable	variable	Field survey	FW	Ai River, Japan	STS-314

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 5b: Usable Bioconcentration/Bioaccumulation Data
PFOA

Species Latin Name/Species Common Name	Effect Type	BCF/BAF Value (L/kg)	Tissue Type	Life Stage/Age	Duration (days)	Exp. Type	Salt/Fresh	Comments	Ref. No.
Oncorhynchus mykiss/ rainbow trout	BCF	0.038	Edible portion	Juveniles	34-day uptake/ 41-day depuration	FM	FW	Laboratory test, kinetic extrapolation	STS-160
Lepomis macrochirus/ bluegill sunfish	BAF	24.011316 - 25 (geometric mean = 24)	Edible portion	3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Mississippi River Pool 3)	MPCA, 2006
Morone chrysops / white bass	BAF	24.34211 - 41.28289 (geometric mean = 26)	Edible portion	Juveniles	variable	Field survey	FW	Minnesota Site-Specific Study (Mississippi River Pool 3)	MPCA, 2006
Lepomis macrochirus/ bluegill sunfish	BAF	35.17588 - 37.9397 (geometric mean = 35)	Edible portion	2-3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Lake Calhoun)	MPCA, 2006
Catostomus commersonii / white sucker	BAF	35.42714 - 120.1005 (geometric mean = 46)	Edible portion	2-3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Lake Calhoun)	MPCA, 2006
Salvelinus namaycush/ lake trout	BAF	2,000	Whole fish	4 years	variable	Field survey	FW	Lake Superior	STS-330
	BAF	2,500	Whole fish	4 years	variable	Field survey	FW	Lake Michigan	STS-330
	BAF	4,000	Whole fish	4 years	variable	Field survey	FW	Lake Huron	STS-330
	BAF	800	Whole fish	4 years	variable	Field survey	FW	Lake Erie	STS-330
	BAF	400	Whole fish	4 years	variable	Field survey	FW	Lake Ontario	STS-330
Pimephales promelas/ fathead minnow	BCF	1.8	Whole fish	64 days	13-day uptake/ 15-day depuration	SM	FW	Laboratory test	AR226-0496

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 5c: Final Chosen Bioconcentration/Bioaccumulation Data
PFOA

Species Latin Name/Species Common Name	Effect Type	Individual BCF/BAF Value (L/kg)	BCF/BAF Value(L/kg) by species	Site Specific BCF/BAF Value (L/kg)	Tissue Type	Life Stage/Age	Duration (days)	Exp. Type	Salt/Fresh	Comments	Ref. No.
Lepomis macrochirus/ bluegill sunfish	BAF	35.17588 * (geometric mean = 35)	35	40	Edible portion	2-3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Lake Calhoun)	MPCA, 2006
		35.67839 *(geometric mean = 35)			Edible portion	2-3 years	variable	Field survey	FW		
		36.68342 *(geometric mean = 35)			Edible portion	2-3 years	variable	Field survey	FW		
		37.68844 * (geometric mean = 35)			Edible portion	2-3 years	variable	Field survey	FW		
		37.9397 * (geometric mean = 35)			Edible portion	2-3 years	variable	Field survey	FW		
Catostomus commersonii / white sucker	BAF	35.42714 *(geometric mean = 46)	46		Edible portion	2-3 years	variable	Field survey	FW		
		36.93467 * (geometric mean = 46)			Edible portion	2-3 years	variable	Field survey	FW		
		38.44221 * (geometric mean = 46)			Edible portion	2-3 years	variable	Field survey	FW		
		38.69347 * (geometric mean = 46)			Edible portion	2-3 years	variable	Field survey	FW		
		120.1005 (geometric mean = 46)			Edible portion	2-3 years	variable	Field survey	FW		

Note:

* Derived from 1/2 of the less than dection limit on the individual fish tissue. See section 3.3 in the report.

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

Table 5c: Final Chosen Bioconcentration/Bioaccumulation Data (continued)
PFOA

Species Latin Name/Species Common Name	Effect Type	Individual BCF/BAF Value (L/kg)	BCF/BAF Value(L/kg) by species	Site Specific BCF/BAF Value (L/kg)	Tissue Type	Life Stage/Age	Duration (days)	Exp. Type	Salt/Fresh	Comments	Ref. No.
Lepomis macrochirus/ bluegill sunfish	BAF	24.011316 * (geometric mean = 24)	24	24	Edible portion	3 years	variable	Field survey	FW	Minnesota Site-Specific Study (Mississippi River Pool 3)	MPCA, 2006
		24.83553 * (geometric mean = 24)			Edible portion	3 years	variable	Field survey	FW		
		25 * (geometric mean = 24)			Edible portion	3 years	variable	Field survey	FW		
Morone chrysops / white bass	BAF	24.34211 * (geometric mean = 26)	26		Edible portion	Juveniles	variable	Field survey	FW		
		24.34211 * (geometric mean = 26)			Edible portion	Juveniles	variable	Field survey	FW		
		24.50658 * (geometric mean = 26)			Edible portion	Juveniles	variable	Field survey	FW		
		24.83553 * (geometric mean = 26)			Edible portion	Juveniles	variable	Field survey	FW		
		41.28289 * (geometric mean = 26)			Edible portion	Juveniles	variable	Field survey	FW		

Note:

* Derived from 1/2 of the less than dection limit on the individual fish tissue. See section 3.3 in the report.

NR - Not Recorded
FW - Freshwater
SW - Saltwater
SM - Static Measured
SU - Static Unmeasured
RM - Renewal Measured
RU - Renewal Unmeasured
FM - Flow-through Measured
FU - Flow-through Unmeasured

APPENDIX D

Health Risk-based Criterion for PFOA

Memo

Date: February 26, 2007

To: John Stine, Environmental Health Division Director 3/1/07

Via: Larry Gust, Environemental Surveillance and Assessment Section Manager
Pamela Shubat, Health Risk Assessment Unit Supervisor

From: Helen Goeden, Health Risk Assessment Unit staff

Subject: Health Based Values for Perfluorooctanoic acid (PFOA)

In 2002 the Minnesota Department of Health (MDH) developed a HBV of 7 ppb for PFOA. Since 2002 additional toxicity data, toxicokinetic data, and reviews of preexisting data have been produced. After a careful review of this information the Health Risk Assessment Unit staff recommends that the HBV for PFOA be lowered to 0.5 ug/L (ppb).

The following information was utilized in generating the revised HBV:

Chemical	CAS #	Endpoint	RfD (mg/kg-d)	HBV (ug/L)	Source
PFOA	335-67-1	hepatic (liver) system, hemotopoietic (blood) system, developmental, and immune system	0.00014	0.5	MDH 2007

More detailed information, supporting the development of the HBV, is attached. Please be advised that, although we believe that this number will provide an adequate level of protection, there is a degree of uncertainty associated with all HBVs, and they should be considered provisional. Professional judgment should be used in implementing this HBV. MDH will review this HBV if and when additional studies have been conducted.

The MDH's authority to promulgate health risk limits under the Groundwater Protection Act is limited to situations where degradation has already occurred. Similarly, health-based values, which are un-promulgated exposure values, serve as interim advice issued for specific sites where a contaminant has been detected. As such, neither health risk limits nor health-based values are developed for the purpose of providing an upper limit for degradation.

cc: Larry Gust, MDH
Pam Shubat, MDH
Rita Messing, MDH
Cathy Villas-Horns, MDA
Shelley Burman, MPCA
Paul Hoff, MPCA
DougWetzstein, MPCA

ATTACHMENT

DATA FOR DERIVATION OF GROUND WATER HEALTH BASED VALUE (HBV)

Chemical Name: Perfluorooctanoic Acid (PFOA)
CAS: 335-67-1(acid)
3825-26-1 (ammonium salt, APFO)
2395-00-8 (potassium salt)
335-95-5 (sodium salt)

Non-Cancer Health Based Value (HBV) = 0.5 ug/L

$$= \frac{\text{(toxicity value, mg/kg/d) x (relative source contribution) x (1000 ug/mg)}}{\text{(intake rate, L/kg-d)}}$$

$$= \frac{\text{(0.00014 mg/kg/d) x (0.2) x (1000 ug/mg)}}{\text{(0.053 L/kg/day)}}$$

= 0.5 ug/L

Toxicity value:	0.00014 mg/kg-d (Cynomolgus monkeys)
Source of toxicity value:	MDH 2007 (RfD derived by MDH)
Point of Departure:	LOAEL, 3 mg/kg-d
Dose Metric Adjustment:	70 (to adjust for half-life duration of 3.8 years in humans versus 20 days in male Cynomolgus monkeys)
Total uncertainty factor:	300
UF allocation:	3 interspecies toxicodynamic differences, 10 intraspecies variability; and 10 LOAEL-to-NOAEL (for lack of a no effect dose in the critical study)
Critical effect(s)*:	Increased relative liver weight
Co-critical effect(s)*:	Reduced number of erythrocytes, reduced body weight and body weight gain, developmental effects (decreased weight gain, delayed developmental progress, hypoactive response in nicotine-induced behavior test), suppressed IgM titers
Additivity endpoint(s):	Hepatic (liver) system, hematopoietic (blood) system, developmental, immune system
Secondary effect(s)*:	Decreased postnatal survival, increase in the incidence of full litter resorptions, altered mammary gland development, decreased thyroid hormones (T4 & T3), disruption of spontaneous behavior, changes in the adrenal cortex

* for explanation of terms see Glossary located at: http://www.health.state.mn.us/divs/eh/groundwater/hrlgw/glossary.html

Cancer Health Risk Limit (HRL) = N/A

Volatile: No

Summary of changes since 2002 HBV:
Toxicity Value (RfD):
Improved toxicokinetic (e.g., half-life) information allowed for the incorporation of a 70-fold dose-metric adjustment based on half-life differences between humans and monkeys and a 10-fold decrease in the total UF. In 2002 a 30-fold factor (3 interspecies extrapolation + 10 subchronic-to-chronic) was used to address uncertainties around toxicokinetics.

Intake rate:
PFOA, unlike most ground water contaminants, has a long half-life and therefore will accumulate in the body if repeated exposure occurs over long-periods of time. Eventually the internal concentration of PFOA will reach a plateau (steady-state). The length of time to reach steady state conditions is equivalent to approximately 5 half-lives. In the case of PFOA the time to steady-state would be approximately 19 years (5 x human half-life of 3.8 years). The intake rate selected for the revised HBV was a time-weighted average intake of an upper-end consumer over the first 19 years of life (0.053 L/kg-d). This intake rate incorporates the higher intake rates early in life (i.e., infants and children) as well as the accumulation of the chemical over time.

Consideration of Sensitive Populations:
Delayed development and growth deficits in the offspring of females mice exposed during pregnancy have been reported at dose levels similar to the LOAEL of the critical study (3 mg/kg-d). Studies have shown that the developmental effects are mainly due to exposure during pregnancy rather than after birth. Possible HBVs, based on protection of a pregnant woman and her fetus, were also calculated. Two scenarios were evaluated: 1) a long-term exposure – exposure to the mother from birth to age 19 years, and 2) a short-term exposure – exposure to an infant. The long-term exposure scenario incorporated accumulation over time and utilized a time-weighted intake rate 0.053 L/kg-d. The short-term exposure scenario did not incorporate accumulation over time but did utilize a young infant intake rate of 0.221 L/kg-d. The resulting potential HBVs for both scenarios were higher than the HBV based on the selected critical study in monkeys.

Summary of toxicity testing for health effects identified in the Health Standards Statute:

	Endocrine	Immunotoxicity	Development	Reproductive	Neurotoxicity
Tested?	Sec. Observations[1]	Yes	Yes	Yes	Yes
Effects?	Yes	Yes[2]	Yes[3]	Unclear[4]	Yes[5]

Note: Even if testing for a specific health effect was not conducted for this chemical, information about that effect may be available from studies conducted for other purposes. Most chemicals have been subject to multiple studies in which researchers identify a dose where no effects were observed, and the lowest dose that caused one or more effects. A toxicity value based on the effect observed at the lowest dose across all available studies is considered protective of all other effects that occur at higher doses.

Comments on extent of testing or effects:

[1] Hormonal perturbations (e.g., decreased thyroxine (T4) and triiodothyronine (T3) levels) have been observed in laboratory animals at dose levels approximately 3-fold higher than the LOAEL and have been identified as secondary effects.

[2] Short-term immunotoxicity studies have shown that PFOA exposure suppresses humoral immunity and may adversely affect cell mediated immunity at doses similar to the critical study LOAEL. These effects have been identified as co-critical effects.

[3] Developmental delays, lower body weight/weight gain and behavior in offspring have been observed at dose levels similar to the LOAEL. These effects have been identified as co-critical effects. At doses 3-fold higher than the LOAEL additional developmental effects (decreased pup viability, delays in eye opening, increased incidence of full-litter resorption, alterations in mammary gland development) are observed. Effects occurring at doses approximately 3 fold higher have been identified as secondary effects.

[4] The results of the 2-generational study indicate that fertility is not affected by treatment. Full-litter resorption was observed at dose levels 3-fold higher than the LOAEL, however, it is unclear whether this resulted from maternal toxicity or a direct effect on the developing organism. Altered mammary gland development during the lactational period was observed in mice exposed to dose levels slightly higher than the critical study LOAEL during pregnancy. Increased incidence of full-litter resorption and alterations in mammary gland development have been identified as a secondary effects.

[5] Hypoactive response to nicotine has been observed in neonatal mice and has been included in the list of co-critical effects. A dose-related increase in ataxia in the female rats was reported in the chronic 2 year study at dose levels greater than the LOAEL, however, this effect was not observed in males with higher body burdens or in 90 day studies utilizing higher doses. Disruption of spontaneous behavior following acute neonatal exposure to doses approximately 3-fold higher than the critical study LOAEL have been observed and are identified as a secondary effect. The SAB has recommended additional neurological testing.

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