APPENDIX G: TECHNICAL BASIS FOR PRELIMINARY REMEDIATION GOALS FOR FISH TISSUE IN ONONDAGA LAKE

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TECHNICAL BASIS FOR PRELIMINARY REMEDIATION GOALS FOR FISH TISSUE IN ONONDAGA LAKE

G.1 INTRODUCTION

This appendix describes the calculation of target tissue concentration (TTC) ranges to be considered as preliminary remediation goals (PRGs) for fish tissue in Onondaga Lake based on assumptions presented in the Baseline Ecological Risk Assessment (BERA), the Human Health Risk Assessment (HHRA), and Attachment 3 of comments from New York State Department of Environmental Conservation (NYSDEC) on the draft Onondaga Lake Feasibility Study Report (TAMS, 2002a; TAMS, 2002b; NYSDEC, 2003; Parsons, 2003; respectively). The TTC ranges were calculated using exposure assumptions developed in the HHRA and BERA through application of a target risk estimate (i.e., a hazard quotient of 1.0 [in the case of ecological receptors and noncancer risk for humans] and cancer risk estimates of 10^{-6}, 10^{-5}, and 10^{-4} for human receptors). The methods and chemical parameters of interest (CPOIs) used to calculate TTC ranges for fish tissue that would be protective of human and ecological receptors that consume fish are described below.

G.2 CALCULATION OF ECOLOGICAL TARGET TISSUE CONCENTRATIONS FOR FISH CONSUMPTION

The BERA identified fish consumption as a pathway of concern for the following ecological receptors: belted kingfisher, great blue heron, osprey, mink, and river otter. The BERA reported hazard quotients for each of these receptors based on both no-observed-adverse-effect levels (NOAELs) and lowest-observed-adverse-effect levels (LOAELs) at the mean and 95 percent upper confidence limit (UCL) on the mean concentrations in fish. The LOAEL represents the lowest CPOI concentration shown to produce adverse effects on specific receptors exposed to a range of doses. In contrast, the NOAEL is the highest CPOI concentration shown to produce no adverse effects on specific receptors exposed to a range of doses. For Onondaga Lake, key CPOIs contributing to risk related to fish consumption by wildlife were identified in Section 1 of the feasibility study (FS) report as those with mean LOAEL hazard quotients greater than 1.0. These CPOIs are methylmercury, DDT, and polychlorinated biphenyls (PCBs).

Attachment 3 of NYSDEC's comments (NYSDEC, 2003) on the draft feasibility study report (Parsons, 2003) provided an example of how to calculate target tissue concentration ranges for fish tissue that would be protective of piscivorous wildlife. The method described in Attachment 3 was used to calculate target concentration ranges for the additional CPOIs listed above. Specifically, the mean exposure concentration for each piscivorous receptor was derived by back-calculating the food web equations used to calculate risk in the BERA. In calculating the target tissue concentrations, CPOI exposure was assumed to be exclusively from fish

consumption, and the calculations were based on a threshold exposure rate equivalent to either the NOAEL or LOAEL toxicity reference values (TRVs).

For receptors with a 100 percent aquatic diet (i.e., belted kingfisher, great blue heron, osprey, and river otter), a diet of 100 percent fish was assumed. Mink were assumed to have both a 50 percent fish diet with no exposure from the terrestrial component of their diet and a 100 percent fish diet. Dry weights (DW) were converted to a wet weight (WW) basis assuming 24 percent dry weight content as specified in NYSDEC (2003). The equation used to calculate the mean target concentrations is as follows:

$$TTC = \frac{1.0 \times TRV}{NFIR \times Frac} \times 0.24$$

where:

TTC = target tissue concentration in whole fish (mg/kgWW)

TRV = toxicity reference value (mg/kg body weight (BW)-day)

NFIR = normalized fish ingestion rate (kgDW/kgBW-day)

Frac = fraction of fish or other source in the diet (unitless)

0.24 = conversion of WW fish data to DW fish data (kgDW/kgWW)

Exposure parameters for the ecological receptors considered were as follows:

Factors	Units	Belted Kingfisher	Great Blue Heron	Osprey	Mink	River Otter
BW	**Grams**	136	2,200	1,568	600	5,450
Food ingestion rate	**kg/kg-day**	0.137	0.045	0.048	0.0643	0.044

Source: TAMS (2002a)

In addition, the following TRVs were applied:

CPOI	Mammalian TRV (mg/kg-day)		Avian TRV (mg/kg-day)	
	NOAEL	LOAEL	NOAEL	LOAEL
Methylmercury	0.0025	0.025	0.0064	0.064
DDT	0.8	4	0.0028	0.028
Total PCBs	0.0034	0.034	0.18	1.8

Source: TAMS (2002a)

NOAEL and LOAEL TTCs for each CPOI were calculated by applying the LOAEL TRV and the NOAEL TRV for all relevant receptors. The TTCs for ecological receptors are as follows:

CPOI	Receptor	NOAEL target tissue concentration (ppm wet)	LOAEL target tissue concentration (ppm wet)
Methylmercury	Belted kingfisher	0.0112	0.112
	Great blue heron	0.0341	0.341
	Mink (50 percent fish diet)	0.0187	0.187
	Mink (100 percent fish diet)	0.0093	0.093
	Osprey	0.032	0.32
	River otter	0.0136	0.136
DDT	Belted kingfisher	0.0049	0.049
	Great blue heron	0.015	0.15
	Osprey	0.014	0.14
	River otter	4.4	21.8
Total PCBs	Belted kingfisher	0.315	3.15
	Great blue heron	0.96	9.6
	Mink (50 percent fish diet)	0.0254	0.254
	Mink (100 percent fish diet)	0.0127	0.127
	River otter	0.0185	0.185

For comparison, Table G.1 presents whole fish tissue data from Onondaga Lake and a national survey of uncontaminated lakes conducted by the United States Environmental Protection Agency (USEPA) (2002). Mercury is the only CPOI for which the mean background concentration exceeds the lowest LOAEL for mercury. The mean background concentration for DDT is approximately equal to the lowest LOAEL for DDT.

A range of mean TTCs for each CPOI was established based on the lowest NOAEL value and the highest LOAEL value, consistent with NYSDEC (2003). The target ranges are presented in Table G.2. The target concentration ranges are applicable to prey fish of both size classes considered in the BERA (i.e., less than 18 cm and greater than 18 cm in length). DDT was not included because current fish tissue concentrations are only slightly elevated above the lowest LOAEL. Furthermore, an examination of DDT concentrations in the littoral sediment of Onondaga Lake indicates that DDT concentrations in the lake are below background (i.e., lower than the mean DDT concentration in Otisco Lake sediment) (Appendix I, risk of remedy). DDT was also undetected in all analyses of Onondaga Lake surface water. DDT concentrations in fish in Onondaga Lake are likely reflective of background conditions; therefore, TTC ranges for DDT were not developed for use as PRGs.

G.3 CALCULATION OF HUMAN HEALTH TARGET TISSUE CONCENTRATIONS FOR FISH CONSUMPTION

The HHRA (TAMS, 2002b) identified fish consumption as the pathway with the highest risk estimates for human health. Estimates were derived for adults, young children, and older children. Risk estimates for carcinogenic CPOIs were highest for adult recreational anglers, whereas for noncarcinogenic CPOIs, the highest hazard indices were calculated for young children. Therefore, the TTC ranges for carcinogenic CPOIs were based on exposure assumptions for adults and the target concentration ranges for noncarcinogens were based on exposure assumptions for young children. All exposure assumptions are those presented in the HHRA. The primary carcinogenic CPOIs contributing to risk via fish consumption, as determined in the HHRA, are polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDFs), PCBs, and arsenic. The primary noncarcinogenic CPOIs are PCBs and mercury (as methylmercury).

TTC ranges were developed for each of the primary CPOIs except arsenic. Arsenic concentrations in fish tissue appear to be consistent with background concentrations of 0.177 mg/kg determined in the national survey of U.S. Lakes (USEPA, 2002). Specifically, the HHRA (TAMS, 2002b) identified a mean total arsenic concentration of 0.33 mg/kg in Onondaga Lake fish tissue. Although the mean concentration calculated for the lake was above the U.S. background concentration, the estimate was based primarily on undetected values in Onondaga Lake fish tissue samples. Arsenic was detected two times in 11 samples. Detected concentrations were 1.00 and 1.05 mg/kg, and undetected samples had detection limits ranging from 0.14 to 0.5 mg/kg. The mean was calculated assuming arsenic was present at half of the detection limit. Thus, although the mean was higher than the background concentration, it is likely that site concentrations were consistent with background. Furthermore, surface-weighted average arsenic concentrations in the littoral sediment of Onondaga Lake are below background (i.e., lower than the mean arsenic concentration in Otisco Lake sediment), as discussed in Appendix I, implementation and residual risk. Therefore, TTC ranges for arsenic were not developed for use as PRGs.

TTC ranges were developed for each of the remaining CPOIs for both reasonable maximum exposure (RME) and central tendency exposure (CTE) scenarios. For carcinogenic CPOIs, the following equation was applied:

$$TTC = \frac{TR \times AT_c \times BW_a}{EF \times ED \times FI \times 1 - CL \times IR_{fa} \times 0.001 \times CSF}$$

where:

TTC = target tissue concentration in fish tissue fillet (mg/kg WW)

TR = target risk 10^{-6}, 10^{-5}, and 10^{-4} applied for carcinogens to calculate a range of TTCs

ATc = averaging time (carcinogens; 25,550 days)

BWa = body weight (70 kg adult)

EF = exposure frequency (365 days/year)

ED = exposure duration (30 years for adults RME and 9 years for adults CTE)

FI = fraction of intake assumed from site – 100 percent (unitless)

CL = cooking loss ([unitless] none assumed for RME and a 0.33 loss factor applied for CTE for PCBs and PCDD/Fs)

IRfa = ingestion rate for fish (25 g/day in RME and 8 g/day in CTE for adults)

0.001 = conversion of grams fish to kg fish (kg/g)

CSF = carcinogenic slope factor (mg/kg-day)−1: includes 2 (mg/kg-day)−1 for PCBs (RME scenario), 1 (mg/kg-day) −1 for PCBs (CTE scenario) and 150,000 (mg/kg-day)−1 for PCDD/Fs (RME and CTE scenarios).

The TTCs for PCBs and PCDD/Fs derived based on cancer risks are as follows:

Chemical of Concern / Target Cancer Risk	CTE TTC 18 meals per year	RME TTC 54 meals per year
PCBs - Carcinogenic Risk		
$1x10^{-4}$	10	0.3
$1x10^{-5}$	1.0	0.03*
$1x10^{-6}$	0.10	0.003*
PCDD/Fs - Carcinogenic Risk		
$1x10^{-4}$	$7x10^{-5}$	$4x10^{-6}$
$1x10^{-5}$	$7x10^{-6}$	$4x10^{-7}$*
$1x10^{-6}$	$7x10^{-7}$*	$4x10^{-8}$*

Concentrations in mg/kg wet weight. *Value is lower than the respective mean background concentrations in U.S. freshwater, i.e., 0.04 mg/kg wet weight for total PCBs and $8x10^{-7}$ for PCDD/Fs (see Table G.1). Meals are assumed to be 6 ounces in size.

For noncarcinogenic CPOIs, the following equation was used to derive target concentrations ranges for fish tissue:

$$TTC = \frac{THQ \times BW_c \times AT_n \times RfD}{EF \times ED \times FI \times (1 - CL) \times IR_{fc} \times 0.001}$$

where:

TTC = target tissue concentration in fish tissue fillet (mg/kg wet weight)

THQ = target hazard quotient of 1

BWc = body weight (15 kg young child)

ATn = averaging time (noncarcinogens; 2,190 days)

RfD = reference dose for noncancer effects (mg/kg-day): including RfDs of 0.0001 (mg/kg-day) for mercury, 0.00007 (mg/kg-day) for low molecular weight (MW) PCBs, and 0.00002 (mg/kg-day) for high MW PCBs

EF = exposure frequency (365 days/year)

ED = exposure duration (6 years, young child)

FI = fraction of intake assumed from site – 100 percent (unitless)

CL = cooking loss ([unitless] none assumed for RME and a 0.33 loss factor assumed for CTE for PCBs)

IRfc = ingestion rate for fish (8.3 g/day for RME, and 2.7 for CTE scenario, young child)

0.001 = conversion of grams fish to kg fish (kg/g)

The TTCs for PCBs and mercury derived based on noncancer risks are as follows:

Chemical of Concern	CTE TTC 18 meals per year	RME TTC 54 meals per year
Noncancer endpoints, hazard index of 1		
PCBs		
Sum of low MW PCBs	0.6	0.1
Sum of high MW PCBs	0.2	0.04
Mercury (total as methyl)	0.6	0.2*

Concentrations in mg/kg wet weight. *Value is lower than the mean background concentration of methyl mercury in U.S. freshwater, i.e., 0.221 mg/kg wet weight (see Table G.1). Child meals are assumed to be as frequent as adult meals, but smaller.

Consistent with ecological TTC ranges, a range of values was calculated, termed upper end and lower end. The lower end was set as the lowest of the target concentrations and represented an RME risk estimate of $1x10^{-6}$ for carcinogenic CPOIs or the RME target for non-carcinogenic CPOIs. The upper end of the target range was set as the CTE risk estimate of $1x10^{-5}$ for carcinogenic CPOIs or the CTE target for noncarcinogenic CPOIs. In the case of PCBs, which are both carcinogens and noncarcinogens, the lowest value of the carcinogenic and noncarcinogenic targets was selected.

G.4 APPLICATION TO ONONDAGA LAKE FEASIBILITY STUDY REPORT

One of the PRGs for the feasibility study report is:

- "Achieve CPOI concentrations in fish tissue that are protective of humans and wildlife that consume fish."

Table G.2 shows the target tissue concentration ranges for human health and ecological receptors to be considered as preliminary remediation goals in the feasibility study report. Separate ranges were established for wildlife and humans for the following CPOIs: mercury (wildlife and human health), PCBs (wildlife and human health), and PCDD/PCDFs (human health). Definition of separate ranges allows the risk manager to understand how current and future CPOI concentrations in fish tissue may impact wildlife and humans differently. The distinction is also important because wildlife receptors consume whole prey fish while humans consume fillets of larger "sport" fish.

The lower ends of the TTC ranges are lower than background concentrations for mercury, PCBs, and PCDD/PCDFs, as reported in Table G.1. Thus, these lower-end TTCs will not likely be achievable without reductions in overall background sources and are not a representative measure of the effectiveness of site remedial actions.

The PCB target range for protection of wildlife that consume fish is from 0.01 to 8 mg/kg (whole body). Within this range for wildlife, the lowest LOAEL target is 0.1 mg/kg for the mink with a 100 percent fish diet. This value is considerably lower than the LOAEL target developed for protection of the mink in the Hudson River (0.7 mg/kg) (TAMS, 2000).

The PCB target range for protection of humans who consume fish is 0.003 to 0.2 mg/kg (fillet). This range encompasses two of the target goals established for the Hudson River (TAMS, 2000). The PCB targets for Hudson River fish are 0.05, 0.2, and 0.4 mg/kg and correspond to approximately 52, 12, and six meals per year. The upper-end target for Onondaga Lake is based on the noncarcinogenic CTE risk estimate (18 meals per year), which is approximately equivalent to a cancer risk estimate of 6×10^{-5} in the RME scenario (54 meals per year).

The mercury target range is from 0.01 to 0.3 mg/kg for protection of wildlife and from 0.2 to 0.6 mg/kg for protection of human health. The target range for human health encompasses the USEPA water quality criterion for mercury of 0.3 mg methylmercury/kg fish (USEPA, 2001), which is based on a consumption rate of 17 g/day. The USEPA criterion is higher than the lower-end TTC calculated here because the fish consumption rate used by USEPA is less than the 25g/day fish consumption rate used in the HHRA (TAMS, 2002b).

The PCDD/PCDF target range for protection of humans who consume fish is from 4×10^{-8} to 7×10^{-6} mg/kg (whole body). The upper-end target for Onondaga Lake is based on a cancer risk estimate of 1×10^{-5} in the CTE scenario (18 meals per year) and corresponds approximately to a cancer risk estimate of 1×10^{-4} in the RME scenario (54 meals per year). Target ranges for

protection of wildlife were not reported because mean LOAEL hazard quotients for wildlife receptors did not exceed 1.0 in the BERA (TAMS, 2002a).

In application of TTC ranges, it is essential to recognize that the values, for both wildlife and humans, represent thresholds for the mean of data on CPOI concentrations in fish tissue. Therefore, the TTCs should only be compared to appropriate estimates of the mean and not to single sample results in a "not to exceed value" manner. Application of these mean target concentrations as "not to exceed values" would result in a significant over-prediction of the risk associated with the specific exposure concentration. Again, it must be also be noted that the ecological and human health TTCs are distinguished from each other in that the ecological TTCs are to be applied to whole body data from prey fish and the human health thresholds are to be applied to fillet data from sport fish.

G.5 REFERENCES

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APPENDIX G

TABLES

TABLE G.1
CPOI CONCENTRATIONS IN FISH FROM BACKGROUND U.S. LAKES AND ONONDAGA LAKE

	Background Concentration in U.S. Lakes[a]		Concentration in Onondaga Lake Prey Fish < 18 cm (Ecological)[b]	Concentration in Onondaga Lake Prey Fish > 18 cm (Ecological)[b]	Concentration in Onondaga Lake Sport Fish (Human Health)[c]	
CPOI	Mean	95 Percent UCL	Mean	Mean	Mean	95 Percent UCL
Metals						
Mercury/methylmercury	0.221	0.224	0.216	0.67	1.05	1.08
Organic Compounds						
DDT	0.0408	0.0573	0.048	0.096	NA	NA
Total PCBs	0.0404	0.0618	0.983	1.57	0.67	0.91
Sum of low MW PCBs	NA	NA	NA	NA	0.27	0.48
Sum of high MW PCBs	NA	NA	NA	NA	0.42	0.58
PCDD/PCDFs (human TEQ)	8.10×10^{-7}	9.78×10^{-7}	--	--	1.01×10^{-5}	1.95×10^{-5}

Note: All units in mg/kg wet weight

--	-	not relevant
MW	-	molecular weight
NA	-	not available
PCB	-	polychlorinated biphenyl
PCDD/PCDF	-	polychlorinated dibenzo-*p*-dioxin and dibenzofuran
TEQ	-	toxic equivalency
UCL	-	upper confidence limit

[a] Mean and 95 percent UCL on the mean CPOI concentration in fish from uncontaminated lakes (U.S. EPA, 2002).

[b] Mean CPOI concentration in fish as reported in Tables H-5 and H-6 of the BERA (TAMS, 2002a). Wet weight concentrations were determined assuming a 24 percent dry weight content. Methylmercury data are reported in this table.

[c] 95 percent UCL on the mean concentration of Onondaga Lake fish tissue data from fish of edible size as reported in the HHRA (TAMS, 2002b).

TABLE G.2
TARGET FISH TISSUE CONCENTRATION RANGES FOR ONONDAGA LAKE

	Target Tissue Concentration for Piscivorous Wildlife		Target Tissue Concentration for Humans	
CPOI	NOAEL	LOAEL	Lower-End	Upper-End
Metals				
Mercury/methylmercury	0.01	0.3	0.2	0.6
Organic Compounds				
Total PCBs	0.01	9.6	0.003	0.2
PCDD/PCDFs (human TEQ)	--	--	4×10^{-8}	5×10^{-5}

Note: All units in mg/kg wet weight

--	-	not relevant
LOAEL	-	lowest-observed-adverse-effect level
NOAEL	-	no-observed-adverse-effect level
PCB	-	polychlorinated biphenyl
PCDD/PCDF	-	polychlorinated dibenzo-p-dioxin and dibenzofuran
TEQ	-	toxicity equivalent