Site-Specific Methylmercury Water Quality Criterion Stream Study Report:

Unnamed Tributary to Rambo Run and Unnamed Tributary to Ebaughs Creek
York County, Pennsylvania

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Acronym List

Acronym	Explanation
µg/L	Micrograms per Liter
AWQC	Ambient water quality criteria
$AWQC_{MeHg}$	Ambient Water Quality Criteria for filtered Methylmercury
$AWQC_{THg}$	Ambient Water Quality Criteria for Total Mercury
BAF	Bioaccumulation factor
C_t	Mercury concentration in tissue
C_w	Mercury concentration in a waterbody
cfs	Cubic feet per second
COA	Consent Order and Agreement
COC	Chain-of-Custody
Department	Pennsylvania Department of Environmental Protection
EPA	United States Environmental Protection Agency
f_d	Water column translation factor
fMeHg	Filtered Methylmercury
ft.	Feet
Landfill	York County Sanitary Landfill
L/kg	Liters per Kilogram
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MeHg	Methylmercury
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MGD	Million gallons per day
mm	Millimeters
ng/L	Nanograms per liter
NPDES	National Pollutant Discharge Elimination System
PADEP	Pennsylvania Department of Environmental Protection
QA/QC	Quality assurance/Quality control
QAPP	Quality Assurance Project Plan
THg	Total Mercury
TL	Trophic level
TMDL	Total maximum daily load
TRC	Tissue residue concentration
µg/L	Microgram/Liter
UNT	Unnamed Tributary
WQBEL	Water quality based effluent limits
YCSWRA	York County Solid Waste and Refuse Authority

Executive Summary

The York County Solid Waste and Refuse Authority (YCSWRA) owns and operates the York County Sanitary Landfill (Landfill) located in Hopewell Township, York County, Pennsylvania. This landfill was in operation from 1974 to 1997 receiving municipal and industrial waste. In 1983, volatile organic compounds thought to be associated with unlined cells were detected in groundwater; in 1985 a pump and treat system (treatment system) was established with multiple wells and two air stripping towers. The treatment system discharges treated groundwater effluent from two outfalls under National Pollutant Discharge Elimination System (NPDES) Permit Number PA0081744 to unnamed tributaries (UNT) of Rambo Run and Ebaughs Creek. Both outfalls are at the head waters to these tributaries. Historically the outfalls have had total mercury (THg) concentrations above the Pennsylvania surface water quality, human health criterion of 0.05 micrograms/liter (µg/L), yet are consistently below the Pennsylvania Fish and Aquatic Life Continuous (0.77 µg/L) and Maximum (1.4 µg/L) water quality criteria as outlined in 25 Pa. Admin. Code Chapter 93.8c (PADEP, 2009), as well as below the Maximum Contaminant Level (i.e., drinking water standard; MCL) of 2.0 µg/L. As part of the routine NPDES permit renewal process, the Pennsylvania Department of Environmental Protection (PADEP; the Department) has required that the YCSWRA either:

1. Meet the Human Health Criteria for Hg of 0.05 ug/L as listed in Table 5 of Title 25 Chapter 93 of the Pennsylvania Code, or
2. Conduct a study to develop a site-specific methylmercury criterion and translation factor for the unnamed tributaries to Rambo Run and Ebaughs Creek that would be used to establish NPDES THg permit limits.

The YCSWRA chose to conduct a Site-Specific study (Stream Study), and entered into a Consent Order and Agreement (COA) on August 20, 2015 with the Department to conduct the Stream Study. The Stream Study as outlined in the COA is generally consistent with the United States Environmental Protection Agency (EPA) guidance (2010) for establishing a scientifically defensible water-column translation of the EPA tissue-based Ambient Water Quality Criterion for Methylmercury ($AWQC_{MeHg}$). As stated in Section 7.4 of the above referenced EPA (2010) guidance document, the water column translation of the fish tissue criterion is to be used in determining reasonable potential and for deriving numeric water-quality based effluent limits (WQBELs). In October, 2016, the YCSWRA commenced surface water and fish tissue sampling for the Stream Study in accordance with the COA and the later approved work plan.

Part of the process to develop a site-specific methylmercury criterion is determining a site-specific bioaccumulation factor (BAF) which relates the concentration of dissolved methylmercury (MeHg) in the water column to the concentration of THg in fish tissue present in the surface waterbody. The BAF is used to determine the quantity of dissolved MeHg in the water-column (e.g., the $AWQC_{MeHg}$) which can be present without fish tissue THg concentrations exceeding thresholds that are protective of human health. Surface water and fish tissue data used in the calculation of site-specific BAF and $AWQC_{MeHg}$ were collected at stations located approximately two miles downstream of the subject outfalls (Stream Stations); these locations were the closest stations to the Outfalls where suitable populations of legal sized gamefish were documented in a fish population survey (AECOM, 2016b) conducted prior to commencement of the Stream Study. Concentrations of dissolved MeHg in surface water collected during the Stream Study at these locations were below method detection limits (MDLs) and the respective site-specific $AWQC_{MeHg}$ for each stream. Fish tissue THg concentrations in samples collected during the Stream Study were consistently below the EPA recommended tissue-based AWQC (0.3 mg/kg), and also the Department's unrestricted consumption threshold of 0.12 mg/kg. These results indicate that methylation of outfall THg is not contributing to unsafe MeHg levels in surface water or fish.

Data collected during the Stream Study demonstrates that the UNT-Rambo Run and UNT-Ebaughs Creek achieve all designated uses. They are fishable, swimmable, and meet the Department's existing 25 Pa. Admin. Code Chapter 93 aquatic life (acute/chronic) water quality standards and MCL (i.e., drinking water standard) for THg. These data sets also demonstrate that there is no unacceptable risk

to human health associated with exposure to site-related sources of mercury through ingestion of surface water and fish tissue from the UNT-Rambo Run and Ebaughs Creek. It is reasonable to conclude that the YCSWRA Outfalls 001 and 002 do not have reasonable potential to cause or contribute to an exceedance of the applicable water-column translation of the site-specific fish tissue water quality criterion (i.e., the $AWQC_{THg}$) at the point where a complete exposure pathway exists. It is important to note that these discharges have been ongoing since the mid-1980's and that fish tissue and surface water data are reflective of long-term exposure conditions.

In accordance with the COA, a site-specific translation factor was developed during the Stream Study to facilitate conversion of the $AWQC_{MeHg}$, to an $AWQC_{THg.}$ This requirement was set forth in the COA as NPDES permit limits typically rely on the total recoverable concentration of THg to determine compliance, which is analytically simpler to measure, but less biologically relevant than the filtered MeHg concentration in surface water. The location where surface water samples are collected for use in the calculation of the translation factor is of critical importance when it is to be used to establish a scientifically defensible translation of a site-specific $AWQC_{MeHg}$, as fish accumulation of mercury is dependent on the form and concentration of mercury at the location where habitat is capable of supporting edible sized fish. Surface water data for the calculation of the translation factor were collected approximately 25 feet downstream of each subject Outfall as required by the Department. However, edible sized fish were collected approximately two miles from the outfalls. Mercury concentrations in surface water were substantially lower at locations where fish samples were collected than at the outfall locations.

Based upon the multiple lines of evidence presented in this report, it is reasonable to conclude that the YCSWRA Outfalls 001 and 002 do not have reasonable potential to cause or contribute to an exceedance of the applicable water-column translation of the site-specific fish tissue water quality criterion (i.e., the $AWQC_{THg}$) at the point where a complete exposure pathway exists. Consistent with Section 7 of the EPA (2010) Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion, it is recommended that the YCSWRA develop and implement a voluntary mercury minimization plan and conduct effluent monitoring to ensure that the discharges will continue to have no reasonable potential to cause or contribute to an exceedance of the applicable site-specific water quality standards with a re-opener clause if future monitoring data demonstrate that the discharges have reasonable potential. It is important to note that these discharges have been ongoing since the mid-1980's and that fish tissue and surface water data are reflective of long-term exposure conditions; therefore, establishing a THg permit limit that is more restrictive than existing effluent quality would be unduly restrictive based upon the results of the Stream Study.

1.0 Introduction

The York County Solid Waste and Refuse Authority (YCSWRA) owns and operates the York County Sanitary Landfill (Landfill) located in Hopewell Township, York County, Pennsylvania. The Landfill operated from 1974 to 1997 receiving municipal and industrial waste which was placed into lined (40 acres) and unlined (135 acres) cells at the 306 acre facility. Various volatile organic compounds associated with the unlined cells were detected in groundwater in 1983; a pump and treat system (treatment system) was initiated in 1985 with three wells and two air stripping towers. The system has expanded over the years in response to evaluations of containment and treatment performance to its current configuration of 18 wells and three air stripping towers. The air stripping towers discharge treated groundwater effluent from two outfalls under National Pollutant Discharge Elimination System (NPDES) Permit Number PA0081744. Outfall 001 discharges into an Unnamed Tributary (UNT) to Rambo Run (UNT-Rambo Run), while Outfall 002 discharges into an UNT to Ebaughs Creek (UNT-Ebaughs Creek). Each of these two receiving streams has limited watershed area and stream discharge above the YCSWRA outfalls. In the absence of the outfalls, stream flow would be greatly reduced within the headwaters of the streams. Both outfalls have documented total mercury (THg) concentrations above the Pennsylvania surface water quality, human health criterion of 0.05 micrograms/liter (µg/L), yet are consistently below the Pennsylvania Fish and Aquatic Life Continuous (0.77 µg/L) and Maximum (1.4 µg/L) water quality criteria as outlined in 25 Pa. Code Chapter 93.8c (PADEP, 2009), as well as below the MCL (drinking water standard) of 2.0 µg/L.

On May 25, 2011, the YCSWRA submitted an application for renewal of NPDES Permit No. PA0081744 to the Pennsylvania Department of Environmental Protection (the Department). After numerous correspondence and several meetings, on November 1, 2012, the Department sent a letter to the YCSWRA regarding the application where they informed YCSWRA that they would need to either:

1. *Meet the Human Health Criteria for Hg of 0.05 ug/L as listed in Table 5 of Title 25 Chapter 93 of the Pennsylvania Code, or*
2. *Submit a Site-Specific study for the Department's review utilizing the document titled Site-Specific Methyl Mercury Fish Tissue Based Water Quality Criterion — Quality Assurance Project Plan / Bioaccumulation Factor (BAF) Determination dated February 27, 2012 provided to the Authority during the meeting on March 22, 2012. This option will be accompanied by a Consent Order and Agreement. Please note that the criteria developed utilizing this option would have to be used even if it is calculated to be more stringent than the existing Human Health Criteria.*

The YCSWRA chose Option 2, to conduct a site-specific study, hence, on August 20, 2015 the YCSWRA and the Department entered into a Consent Order and Agreement (COA). The COA gave the YCSWRA 60 days to submit a Site-specific Stream Study Plan (Stream Study) that identified and described the methodology to be utilized to develop a site-specific methylmercury criterion and translation factor for the unnamed tributaries to Rambo Run and Ebaughs Creek that will be used by the Department to set THg permit limits for the YCSWRA Outfalls 001 and 002. YCSWRA submitted the Stream Study Work Plan to the Department on September 23, 2015; the final Stream Study was formally approved by the Department on October 6, 2016 (AECOM, 2016a).

1.1 Background

The United States Environmental Protection Agency (EPA) publishes recommended ambient water quality criteria (AWQC) guidance under Section 304(a) of the Federal Clean Water Act, which are intended to be protective of designated uses including aquatic life and human health (EPA, 2010). In 2001, the EPA published a tissue-based $AWQC_{MeHg}$ (0.3 milligrams per kilogram [mg/kg]) and encourages states and authorized tribes to adopt this criterion or any sound, scientifically-based approach for MeHg or THg into their water quality standards (EPA, 2010). EPA recommends this approach for the following reasons (EPA, 2010):

- *"A criterion expressed as a fish tissue concentration is closely tied to the "fishable" designated use goal applied to nearly all waterbodies in the United States.*
- *A fish tissue concentration value is expressed in the same form (fish tissue), through which humans are exposed to methylmercury.*
- *A fish tissue concentration value is more consistent with how fish advisories are issued.*
- *At environmentally relevant concentrations, methylmercury is currently easier to detect in fish tissue than in water samples."*

The Department has not yet adopted the EPA (2010) recommended $AWQC_{MeHg}$ as a fish tissue criterion into its statewide water quality standards. As outlined in the COA and presented in the previous section, the Department permitted YCSWRA to conduct the Stream Study as a mechanism to determine a scientifically defensible THg NPDES discharge limit for Outfalls 001 and 002 under the authority of 25 Pa. Code Chapter 93.8d. The primary objective of the Stream Study set forth in the COA was to develop a site-specific, water column translation of the tissue-based 2001 EPA Water Quality Criterion for methylmercury (i.e., $AWQC_{MeHg}$ = 0.3 mg/kg) for each of the receiving waters below the YCSWRA Outfall 001 and Outfall 002. This approach is consistent with the EPA *Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion* (EPA, 2010). Section 7.2 of the above referenced EPA (2010) guidance document outlines the recommended NPDES permitting approach for methylmercury after a determination has been made regarding how the methylmercury criterion is expressed in the applicable water quality standard (e.g., fish tissue criterion, or water column translation of the fish tissue criterion). The process for determining reasonable potential and appropriate permit conditions based upon the site-specific water-column methylmercury criterion is briefly summarized below; Figure 1-1 provides the complete EPA NPDES Permitting approach flow chart (EPA, 2010).

- Determine reasonable potential based upon the water column translation of the fish tissue criterion ($AWQC_{MeHg}$);
    - Is there a quantifiable amount of mercury in the discharge using a sufficiently sensitive method?
    - Is the fish tissue concentration of methylmercury (or the water column translation of the fish tissue criterion) in the receiving water close to or exceed the criterion?
- If reasonable potential does not exist – Implement anti-degradation;
- If reasonable potential exists – establish water quality based effluent limits (WQBEL) that are consistent with the site-specific water column translation of the fish tissue criterion.

The following sections of this report presents the results of the Stream Study and provides the required data and calculations to determine reasonable potential and establish scientifically defensible permit conditions for THg.

2.0 Environmental Setting

Rambo Run and Ebaughs Creek can be generally described as high gradient, cold water, headwater streams with largely undisturbed riparian corridors consisting of mature forested areas and early successional habitats within agricultural lands. Each of the stream segments included in the 2014 Pennsylvania Integrated Waters Report for the Rambo Run and Ebaughs Creek watersheds were listed as Category 2, or non-impaired waters with one exception (PADEP, 2014). One stream segment of Ebaughs Creek downstream of the Stewartstown wastewater treatment plant was designated as a Category 5 or, Impaired Stream requiring development of a total maximum daily load (TMDL) for chlorine.

2.1 Rambo Run

Rambo Run is a first order high-gradient stream designated as Exceptional Value, located in Hopewell Township, Pennsylvania (Figure 2-1; PSIE, 2013). Land use within the Rambo Run watershed is largely comprised of deciduous and coniferous forests, agricultural and residential lands with less than 1% of the area mapped as wetlands (Table 2-1, Figure 2-2). The YCSWRA Outfall 001 is located at the headwaters of the UNT-Rambo Run with limited upstream watershed area. Upstream of the outfall a culvert provides limited discharge associated with a storm water retention basin on the northern portion of the closed and capped Landfill and an intermittent spring which once provided water for a farm house located on the Naylor Winery property. The average daily flow for Outfall 001 is 0.066 million gallons per day (MGD) which is equivalent to a stream discharge of approximately 0.103 cubic feet per second (CFS). Outfall 001 discharges into a small (i.e., less than 0.1 acres) emergent wetland/stream complex and then flows for approximately eight miles in a northeasterly direction until the confluence with the North Branch of Muddy Creek.

Aquatic habitats capable of supporting robust populations of legal sized gamefish in the UNT-Rambo Run are not present immediately below Outfall 001. A qualitative fish community survey conducted at four locations on Rambo Run in March 2016 identified brown trout (*Salmo trutta*) as the dominant apex predator species in the UNT-Rambo Run and Rambo Run (Figure 2-4). Of the 91 brown trout collected at these stations, 65.9% were of legal harvest size (i.e., > 7 inches). Complete details of the qualitative fish community survey are provided in the Qualitative Fish Community Survey Summary memorandum (Appendix A; AECOM, 2016b).

2.2 Ebaughs Creek

Ebaughs Creek is a first-order, high gradient stream designated as a Cold Water Fishery located in Hopewell Township, Pennsylvania (Figure 2-1). Land use within the Ebaughs Creek watershed is largely comprised of deciduous and coniferous forests, agricultural and residential lands with less than 1% of the area mapped as wetlands (Table 2-1, Figure 2-3). YCSWRA Outfall 002 is located at the headwaters of the UNT-Ebaughs Creek with a limited upstream watershed and minimal flow upstream of the point of discharge. The average daily flow for Outfall 002 is 0.118 MGD which is equivalent to a stream discharge of approximately 0.183 CFS. Below Outfall 002, the stream flows north to south from the point of discharge approximately six miles before crossing the Maryland state line. At the point of discharge the stream is very narrow and shallow; no more than four feet (ft.) wide and less than six inches in depth. A 2-acre private impoundment is located approximately 0.12 miles downstream of Outfall 002. Below the impoundment, stream width, depth and discharge increase from base flow as the main stem of Ebaughs creek, a second order stream, multiple first order streams, and the discharge from the Stewartstown wastewater treatment plant join the UNT-Ebaughs Creek. By the time Ebaughs Creek crosses into Maryland, it has an average width of 15-20 ft. wide with water depths of 1-2 ft. deep in the deepest pools and runs.

Similarly to Rambo Run, aquatic habitats capable of supporting robust populations of legal-sized gamefish in the UNT-Ebaughs Creek and Ebaughs Creek start below Bridgeview Road, approximately 2 miles downstream of Outfall 002. Three stream reaches were evaluated during the qualitative fish community survey conducted the week of March 14, 2016 (Figure 2-5; AECOM, 2016b). Brown trout was the most common apex predatory fish species documented at each sampling reach with 62.5% of

the 32 brown trout collected from Ebaughs Creek of legal size (> 7”). American eel (*Anguilla rostrata*) were also present in low densities at Ebaughs Creek. Complete details of the qualitative fish community survey are provided in the Qualitative Fish Community Survey Summary memorandum (AECOM, 2016b).

3.0 Methodology

Surface water and fish tissue data to derive the site-specific BAF and methylmercury criterion were collected at the sampling stations closest to each permitted outfall where a potentially complete exposure pathway to site-related sources of mercury through ingestion of surface water and fish tissue were present. These data were collected at stations RR-01 on the UNT-Rambo Run and at EC-02 on Ebaughs Creek (Figure 2-4 and Figure 2-5). Monthly surface water sampling began in October 2016 and continued for twelve consecutive months, concluding in September 2017. Fish tissue samples were collected in October 2016 and September 2017, during the first and last surface water sampling events for the Stream Study. As required in the February 27, 2012 PADEP document referenced in Section 1.0, surface water samples used in the calculation of the site-specific translation factor were collected monthly at locations (approximately 25') downstream of each subject outfall from the well mixed effluent and receiving water (Figure 2-4 and Figure 2-5). The sections below provide a brief summary of field sampling procedures and analytical methodology; Appendix A provides a summary of the data validation and quality assurance/quality control (QA/QC) review. Complete details of sampling procedures, including standard operating procedures are provided in the Work Plan (AECOM, 2016a).

3.1 Surface Water Sampling

The surface water sampling was conducted in accordance with the approved Work Plan (AECOM, 2016c) as well as the guidance and principles outlined in EPA Method 1669 *Sampling Ambient Water for Determination of Metals at EPA Water Quality Criteria Levels* (EPA, 1996), using the "clean hands-dirty hands" technique.

Surface water samples collected for use in the calculation of the site-specific methylmercury criterion were collected at the stations where fish tissue samples were collected (stream stations); samples collected for the translation factor were collected approximately 25 feet downstream of each outfall in the well mixed effluent (i.e., Rambo-down and Ebaughs Down; Figure 2-4 and Figure 2-5). Samples were collected with a pump and field filtered (0.45 micrometer [µm] pore size) as necessary before being placed into laboratory supplied unpreserved bottleware. Immediately after collection, surface water samples were carefully packaged, placed on wet ice in a cooler and shipped under chain-of-custody (COC) via overnight courier to Brooks Applied Laboratories, a Pennsylvania accredited laboratory. Samples were preserved at the analytical laboratory within 48 hours of collection and analyzed for both unfiltered THg and filtered (i.e., dissolved) methylmercury (fMeHg) in accordance with EPA Methods 1631 and 1630, respectively (EPA 2002; EPA 1998). Further details regarding project QA/QC are provided in Section 3.3 below and in the Quality Assurance Project Plan (QAPP; Appendix A of the Work Plan; AECOM 2016a).

Water quality parameters and stream discharge were measured *in situ* during surface water sample collection; Table 3-1 presents a summary of water quality parameters collected during the Stream Study. Discharge measurements were also collected concurrent with the surface water samples using an OTT MF-Pro electro-magnetic flow meter.

3.2 Fish Tissue Sampling

Fish tissue samples used in determination of the site-specific bioaccumulation factor and subsequent site-specific MeHg criterion were collected at the Ebaughs Creek EC-02 (Figure 2-5) and the Rambo Run RR-01 stations (Figure 2-4), based upon the results of the qualitative fish community survey. These stations were the closest locations to the YCSWRA outfalls where adequate densities of apex predatory fish (i.e., brown trout and American eel) of legal harvest size were documented. Native gamefish species[1] other than brown trout and American eel were not observed during the survey.

[1] One rainbow trout (*Oncorhynchus mykiss)* was collected at RR-03, however it was likely a stocked fish; wild populations of rainbow trout have not been documented in York County (PFBC 2015a and 2015b).

Target fish species were collected using two, Smith-Root LR-24 backpack electrofishers. All likely habitats were sampled until the required number of target species (i.e., brown trout and American eel [only found in Ebaughs Creek]) were obtained. Three composite fish tissue samples made up of 2 to 5 individual fish per composite were targeted for collection at the stations identified above. Total length and weight were recorded prior to separating fish into composite samples that were grouped such that the smallest fish in the composite was at least 75% of the length of the largest fish in the composite.

Individual fish were wrapped in aluminum foil with the dull side toward the sample and labeled prior to being placed into a sealable plastic bag with the other fish in the composite. Samples were shipped frozen on dry ice under proper COC procedures via overnight courier to Brooks Applied Laboratories. Specific details regarding sample collection, field QA/QC and health and safety are provided in the Fish Tissue Standard Operating Procedure, FT-01 (Appendix A of the Work Plan; AECOM, 2016a).

Fish tissue samples were prepared for analysis at Brooks Applied Laboratories by methods consistent with those outlined in the EPA *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (EPA, 2000a). Fish tissue samples were prepared as skinless fillets as mercury is differentially concentrated in muscle tissue and few consumers in the general population eat the skin of the fish (EPA, 2000a). Samples were analyzed for THg by EPA Method 1631 E (EPA, 2002). The use of THg concentrations in fish tissue is a conservative surrogate for methylmercury concentrations is consistent with EPA guidance and other studies documenting that 80-100% of THg in adult fish tissue is in the form of methylmercury (Bloom, 1992; EPA, 2000b; EPA, 2001; EPA, 2010).

4.0 Data Evaluation

The site-specific methylmercury criterion, as referenced in the COA, is calculated using the same method as the EPA recommended tissue-based, ambient water quality criteria for MeHg ($AWQC_{MeHg;}$ EPA, 2001). The February 27, 2012 Department document titled *Site-Specific Methyl Mercury Fish Tissue Based Water Quality Criterion — Quality Assurance Project Plan / BAF Determination*, also refers to the $AWQC_{MeHg}$. Even though an $AWQC_{MeHg}$ has specific regulatory connotations, the Stream Study work plan and the following equations used by the EPA use the term $AWQC_{MeHg}$. In the following contexts the two terms are transposable.

In January 2001, EPA published a methylmercury ambient water quality criterion of 0.3 mg/kg, expressed as a tissue residue concentration (TRC), which is protective of human health (EPA, 2001). The TRC was based upon EPA's 2000 Human Health Methodology to calculate a water quality criterion; however, it was rearranged to solve for a protective concentration in fish tissue (EPA, 2001). The equation for the TRC does not include a BAF or drinking water intake value as exposure to MeHg through drinking water is negligible (EPA 2001). The equations below were included in the Stream Study approved by the Department on October 6, 2016, and have been unmodified.

The equation used to calculate the EPA tissue-based $AWQC_{MeHg}$ equation is provided below:

$$\boldsymbol{TRC} = \frac{\boldsymbol{BW\ X\ (RfD - RSC)}}{\sum_{i=2}^{4} \boldsymbol{FI_i}}$$

Where:

$\boldsymbol{TRC}$	=	Tissue residue concentration; the fish tissue-based water quality criterion for methylmercury in fish tissue (mg/kg)
$\boldsymbol{RfD}$	=	Reference dose (based on non-cancer human health effects) of 0.0001 mg MeHg/kg body weight-day
$\boldsymbol{RSC}$	=	Relative source contribution (subtracted from the RfD to account for marine fish consumption) estimated to be 2.7×10^{-5} mg MeHg/kg body weight-day
$\boldsymbol{BW}$	=	Human body weight default value of 70 kg for adults
$\boldsymbol{FI}$	=	Fish intake at trophic level (TL) i (i = 2, 3, 4); total default intake is 17.5 g fish/day for general adult population.

At the request of the Department, the current EPA $AWQC_{MeHg}$, based on the TRC, was modified using revised national default inputs and by incorporating a drinking water component and a BAF. The following equation was used to calculate a water concentration-based $AWQC_{MeHg}$ using a site-specific BAF:

$$\boldsymbol{AWQC}_{MeHg} = \frac{[\boldsymbol{BW\ X\ (RfD - RSC)}]}{[\boldsymbol{DI} + (\boldsymbol{FI\ X\ BAF})]}$$

Where:

$\boldsymbol{AWQC}_{\boldsymbol{MeHg}}$	=	Water concentration-based ambient water quality criterion for methylmercury in milligrams per liter (mg/L)

Rfd = Reference dose (based on non-cancer human health effects) of 0.0001 mg MeHg/kg body weight-day

RSC = Relative source contribution (subtracted from the RfD to account for marine fish consumption) estimated to be 2.7 x 10^{-5} mg MeHg/kg body weight-day

BW = Human body weight default value of 80 kg for adults

FI = Fish intake at trophic level (TL) i (i = 2, 3, 4); total default intake is 0.022 kg fish/day for general adult population.

DI = Water consumption, 2.4 L/day

BAF = Bioaccumulation factor for the apex predatory fish in the system (i.e. trophic level 3 of 4) in liters per kilogram (L/kg)

As stated above, this equation also included drinking water ingestion; however, exposure to MeHg through drinking water is considered negligible (EPA, 2001). With the other inputs to the equation remaining the same, using the updated national default values for body weight, fish consumption and the inclusion of a drinking water exposure source, results in an $AWQC_{MeHg}$ that is more conservative than the current EPA promulgated TRC of 0.3 mg/kg.

In order to develop the water concentration-based site-specific $AWQC_{MeHg}$, the site-specific BAF was calculated. The BAF is the ratio of the concentration of THg in the edible tissue of fish that people eat (C_t) to the concentration of dissolved methylmercury in the surrounding waterbody (C_w) occupied by the fish. The BAF was calculated using the geometric mean of the dissolved methylmercury concentrations in surface water at stream stations and the geometric mean of the THg concentration in fish tissue. As discussed in Section 3.3 above, using THg concentrations in fish tissue as a conservative surrogate for methylmercury concentrations is consistent with EPA guidance as 80-100% of THg in adult fish tissue is in the form of methylmercury (EPA, 2000b; EPA, 2001; EPA, 2010; Bloom, 1992).The equation used to calculate the BAF was as follows:

$$BAF = \frac{Ct}{Cw}$$

Where:

BAF = Bioaccumulation factor for apex predatory fish within the system (i.e. trophic levels 3 or 4) in liters per kilogram (L/kg)

Ct = Concentration of THg (it is assumed that 100% of THg is in the form of methylmercury) in fish tissue in mg/kg, wet tissue weight, from tissue samples collected within the stream sections identified in Figure 2-4 as RR-01 and in Figure 2-5 as EC-02.

Cw = Dissolved concentration of methylmercury in water at stream stations in mg/L from water samples collected within the stream sections identified in Figure 2-4 as RR-01 and in Figure 2-5 as EC-02.

NPDES permit limits typically rely on the total recoverable concentration of THg to determine compliance as opposed to the dissolved MeHg form. The COA does not prescribe calculation of a site-specific AWQC for THg; however, it states that the Department will calculate a discharge limit based on the AWQC for MeHg through the use of a site-specific translation factor (f_d). The site-specific water concentration-based $AWQC_{THg}$ was calculated using the following equation:

$$AWQC_{THg} = \frac{AWQC_{MeHg}}{f_d}$$

Where:

$AWQC_{THg}$ = Water concentration-based ambient water quality criterion for THg in mg/L

$AWQC_{MeHg}$ = Water concentration-based ambient water quality criterion for methylmercury in mg/L

f_d = Site-specific water column translation factor

The translation factor is the fraction of the total recoverable metal that is in the dissolved form. Total mercury and dissolved methylmercury data collected monthly for the duration of the study (12 consecutive monthly samples) were used to calculate the translation factor. A translation factor was calculated for each sample individually, and the final translation factor was calculated as the geometric mean of the individual translation factors. The following equation was used to determine the translation factor:

$$f_d = \frac{Cd_{MeHg}}{Ct_{Hg}}$$

Where:

f_d = Site-specific water column translation factor

$C_{d\ MeHg}$ = The dissolved concentration of methylmercury at outfall stations in mg/L from water samples collected in the well mixed zone approximately 25 ft. downstream of the NPDES effluents

$C_{t\ Hg}$ = The total recoverable mercury concentration in mg/L from water samples collected in the well mixed zone approximately 25 ft. downstream of the NPDES effluents.

5.0 Results and Discussion

The primary objective of the Stream Study was to develop a site-specific, water column translation of the tissue-based on the 2001 EPA Water Quality Criterion for methylmercury (i.e., $AWQC_{MeHg}$ = 0.3 mg/kg) for each of the receiving waters below the YCSWRA NPDES 001 and NPDES 002 outfalls. Sections 5.1 and 5.2 below present the results of the surface water and fish tissue analyses respectively. Section 5.3 presents the results of the $AWQC_{MeHg}$ calculations and provides a discussion of the findings.

5.1 Surface Water

Total mercury concentrations measured in surface water from the UNT-Rambo Run and UNT-Ebaughs Creek decreased with distance downstream of the respective YCSWRA Outfalls (Table 5-1 and Figure 5-1). The geometric mean THg concentrations for the UNT-Rambo Run decreased from 286 nanograms per liter (ng/L) at NPDES Outfall-001, to 168 ng/L at the Rambo-down location (approximately 25' downstream of the outfall) to 0.81 ng/L at the stream location RR-01 (Table 5-1). The geometric mean THg concentration for NPDES-002 is 178 ng/L which is slightly lower than that found at Ebaughs-down, 185 ng/L. As with Rambo Run, the geometric mean THg concentration was substantially lower at the Ebaughs Creek stream station EC-02, (1.44 ng/L) than at either of the upstream locations (Table 5-1; Figure 5-1). These results are expected as each receiving water essentially originates at or shortly upstream of the permitted outfalls. For example, the average daily discharge rate for NPDES-001 during the period of study was 0.102 cubic feet per second (cfs). In contrast, the average stream discharge at RR-01 during the Stream Study was 2.23 cfs. Similarly, average daily discharge rates for NPDES-002 and EC-02 located on the UNT-Ebaughs Creek were 0.183 cfs and 3.36 cfs respectively. Throughout the study period, THg concentrations in surface water samples collected just below the outfalls and the stream stations were relatively consistent (Figure 5-2).

THg loading rates decreased with distance downstream of Outfall 001 and Outfall 002 (Table 5-2 and Table 5-3). The THg load from Outfall 001 was 71.9 mg/day (geometric mean), compared with the 4.34 mg/day at RR-02 where the surface water and fish tissue samples were collected for determination of the BAF and $AWQC_{MeHg}$ (Table 5-2). Similarly, THg loading from Outfall 002 was 79.5 mg/day (geometric mean), compared with 11.3 mg/day at EC-02 (Table 5-3).

Concentrations of fMeHg were at or below the detection limits (e.g., approximately 0.02 ng/L) for most samples collected during the study, with the exception of those collected at the Rambo-down station (Table 5-1). Only one sample collected at either station on Ebaughs Creek had a fMeHg result (0.028 n/L) above the detection limit. At the Rambo-down sampling station the geometric mean fMeHg concentration was 0.098 ng/L, with a maximum concentration of 0.498 ng/L measured in the July, 2017 sample. Increased MeHg concentrations at this location are hypothesized to be the result of methylation of Hg(II) within the small stream/wetland complex below NPDES-001. Increased production of MeHg (i.e., methylation) by bacteria present in wetland environments is well documented (Wentz et al., 2014). Concentrations of fMeHg at RR-01, which is downstream of the wetlands at Rambo-down, were either non-detect, or J-qualified (i.e., estimated result between the MDL and the reporting limit) results (Table 5-1). Only samples from the wetland were detected above the MDL or not qualified.

5.2 Fish Tissue

Concentrations of THg in fish tissue samples collected during each of the two sampling events (Table 5-4) were below the EPA fish-tissue based $AWQC_{MeHg}$ (i.e., 0.3 mg/kg) and the

Department unrestricted consumption threshold limit of 0.12 mg/kg (Figure 5-3; PADEP 2001). THg concentrations in brown trout composite samples collected from the UNT-Rambo Run ranged from 0.035 mg/kg to 0.061 mg/kg, with a geometric mean concentration of 0.048 mg/kg. These concentrations are similar to those previously documented in brown trout collected by the Department in 2012 (average 0.037 mg/kg) in the UNT-Rambo Run. THg concentrations in brown trout composite samples from Ebaughs Creek ranged from 0.003 mg/kg to 0.055 mg/kg, while American eel composite samples ranged higher at 0.065 mg/kg to 0.119 mg/kg. Higher concentrations in American eel samples is likely attributable to their dietary habits as they are more piscivorous than brown trout < 250 millimeter (mm) in length. When brown trout and American eel data are combined for Ebaughs Creek, the resulting geometric mean THg concentration is 0.046 mg/kg. Overall, fish tissue mercury concentrations in the UNT-Rambo Run and Ebaughs Creek are consistent with other data for trout collected from Pennsylvania waters as well as regional and state commercial hatcheries (Brightbill et al., 2004; Horowitz et al., 2007).

5.3 Discussion

Calculation of the Stream Study results discussed below are consistent with the equations provided in Section 4.0 above; Table 5-5 and Table 5-6 provide these calculations.

The site-specific $AWQC_{MeHg}$ calculated with the equations provided in Section 4.0 above for the UNT-Rambo Run (1.19E-07 mg/L) and Ebaughs Creek (1.16E-07 mg/L) were similar (Table 5-5 and Table 5-6). During the period of the Stream Study, all surface water data points collected at the locations where the AWQC and BAF were calculated, were below the calculated AWQC. However, the f_d calculated using data collected at the Rambo-down location approximately 25' downstream of the NPDES-001 was five times greater (f_d =1.11E-04) than the f_d for Ebaughs Creek (f_d =5.84E-04). Localized MeHg production within the emergent wetland below the NPDES-001 appears to be driving the increased translation factor, however; the elevated fMeHg concentrations dissipate to non-detect levels at the stream study location on the UNT-Rambo Run, RR-01. As discussed in Section 5.1 above, not only do THg concentrations in surface water decrease with distance from the outfalls, but there is also a significant loss of THg mass due to natural processes, including photodegradation (Table 5-2 and Table 5-3; Jeremiason et al., 2015). Additionally, THg concentrations in surface water samples collected at the locations where the BAF and AWQC were calculated (i.e., RR-01 and EC-02), are not only similar to one another, but also to groundwater concentrations measured in the Appalachian basin (approximately 1 ng/L; Siegel et al., 2015). Determining the translation factor at/near the locations of the Outfalls as outlined in Section 4.0 above does not take into account in-stream physical and biological processes (e.g., methylation/de-methylation, photo-degradation) which may influence mercury cycling and uptake by aquatic receptors. Therefore, establishing a translation factor based upon hypothetical exposure conditions (i.e., ratios of MeHg to THg) that are substantially different from actual exposure conditions is not justified.

Using a translation factor that calculated at a point upstream of where site-specific BAFs were calculated introduces problematic uncertainty and variability in the resulting $AWQC_{THg.}$ Using the translation factors identified above results in an $AWQC_{THg}$ of 204 ng/L for Rambo Run and an $AWQC_{THg}$ of 1,043 ng/L for Ebaughs Creek (Table 5-5 and 5-6). If the assumed relationship between surface water samples used in the f_d and surface water and fish tissue concentrations downstream used to determine the BAF (i.e., a complete exposure pathway) were correct, it is expected that THg concentrations in fish tissue would be close to, or even exceed 0.3 mg/kg at RR-01 in Rambo Run. This result would be expected given that the geometric mean THg concentration (286 ng/L) for NPDES-001 surface water samples during the period of study was above the calculated $AWQC_{THg}$ of 204 ng/L. However, THg concentrations in brown trout

collected from the UNT-Rambo Run are below the Department's unrestricted consumption threshold (i.e., 0.12 mg/kg), which indicates an incomplete exposure pathway to locally elevated fMeHg in surface water within the wetland complex below Outfall 001.

Data collected during the Stream Study demonstrates that the UNT-Rambo Run and UNT-Ebaughs Creek achieve all designated uses. They are fishable, swimmable, and meet the Department's existing aquatic life (acute/chronic) water quality standards and MCL (i.e., drinking water standard) for THg. These data sets also demonstrate that there is no unacceptable risk to human health associated with exposure to site-related sources of mercury through ingestion of surface water and fish tissue from the UNT-Rambo Run and Ebaughs Creek. At the locations where the site-specific BAF and $AWQC_{MeHg}$ were calculated (i.e., RR-01 and EC-02), all surface water samples collected during the Stream Study were below the $AWQC_{MeHg}$. When the translation factor is applied using data from RR-01 and EC-02, the corresponding $AWQC_{THg}$ were also achieved for the UNT-Rambo Run (4.5 ng/L) and Ebaughs Creek[2] (8.26 ng/L) (Table 5-5 and Table 5-6). Fish tissue samples collected at RR-01 and EC-02 were below the EPA TRC (0.3 mg/kg) and also the Department's unrestricted consumption threshold (0.12 mg/kg; PADEP, 2001).

Site-specific BAFs ($Log_{10}BAF$) calculated with the equations outlined in Section 4.0 above, using fish tissue (THg) and fMeHg concentrations in surface water from the UNT-Rambo Run ($Log_{10}BAF$ = 6.35 L/kg; Table 5-5) and Ebaughs Creek ($Log_{10}BAF$ 6.36 L/kg; Table 5-6) Stream Stations (i.e., RR-01 and EC-02) are consistent with literature reported $Log_{10}BAFs$ for brown trout across the United States. Literature reported $Log_{10}BAFs$ for brown trout collected from riverine systems range from 5.93 L/kg to 6.04 L/kg (Scudder et al., 2009; Scudder-Eikenberry et al., 2015). This result is expected based upon the low fMeHg surface water concentrations (mostly below detection limits) present at the fish tissue sampling locations.

As noted in Section 5.1, THg loading rates at fish sampling locations were much lower than the loading rates of THg from the outfalls, which suggests that little, if any of the THg loaded from outfalls is reaching the locations where edible-sized fish are collected. Most of the mercury loaded from the outfalls is probably lost to the atmosphere by photoreduction of Hg(II) to Hg(0), which is volatile and evades rapidly to the gas phase. Half-lives for Hg(II) (i.e., the time it takes for half of the Hg(II) in a system to be photoreduced) ranged from 1.5 to 5 hours in laboratory studies (Jeremiason et al., 2015). It is estimated that it takes approximately 16 hours for the water from NPDES-01 to reach RR-01 and 6 hours to reach EC-02[3], resulting in losses of ~95%. This is consistent with what is known about the biogeochemical cycling of mercury in watersheds, where the majority of THg deposited via atmospheric deposition is re-emitted to the atmosphere (Wentz et al., 2014; Grigal, 2002; Hartman et al., 2009).

Geometric mean THg concentrations in surface water collected at the same locations were also consistently low (RR-01: 0.81 ng/L; EC-02 1.44 ng/L; Figure 5-1); as a point of reference the geometric mean THg concentration on precipitation measured at the Mercury Deposition Network Station PA00 in Arendtsville, PA for 2016 was 8.13 ng/L (NADP, 2017). Watershed processes, such as soil percolation (Krabbenhoft and Babiarz, 1992) can also contribute to the losses of mercury from atmospheric sources, reducing THg concentrations in precipitation to

[2] The February, 2017 THg result at EC-02 exceeded the $AWQC_{THg}$, however; it was identified as an outlier. The result was retained/included in all calculations.

[3] Based on a distance between NPDES-1 and RR-01 of 12,280 feet and an average velocity of 0.21 ft/second, and a distance between NPDES-02 and EC-02 of 12,301 feet and an average velocity of 0.57 ft/s.

levels observed at fish sampling locations. This suggests that the THg concentration at the fish sampling locations appears to reflect mercury from atmospheric deposition.

Based upon the multiple lines of evidence presented above, it is reasonable to conclude that the YCSWRA Outfalls 001 and 002 do not have reasonable potential to cause or contribute to an exceedance of the applicable water-column translation of the site-specific fish tissue water quality criterion (i.e., the $AWQC_{THg}$) at the point where a complete exposure pathway exists. The flow chart in Section 7 of the EPA (2010) *Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion* suggests that it is appropriate to (i) conduct routine effluent monitoring to ensure that the discharges continue to have no reasonable potential to cause or contribute to an exceedance of the applicable site-specific water quality standards and (ii) include in affected NPDES permits a re-opener clause if future monitoring data demonstrate that the discharges have such reasonable potential. The EPA (2010) guidance also recommends developing and implementing a voluntary mercury minimization plan. It is important to note that these discharges have been ongoing since the mid-1980's and that fish tissue and surface water data are reflective of long-term exposure conditions; therefore, establishing a THg permit limit that is more restrictive than existing effluent quality would be unduly restrictive based upon the results of the Stream Study.

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