APPENDIX D MERCURY RISK EVALUATION

ASSOCIATED ELECTRIC COOPERATIVE, INC.

DRAFT MERCURY RISK ASSESSMENT REPORT

Norborne, Missouri

Prepared for

Associated Electric Cooperative Inc

October 17, 2006

URS

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EXECUTIVE SUMMARY

Associated Electric Cooperative, Inc. (AECI) is proposing to develop a new coal-fired Electric Generation Unit (EGU) in Carroll County, Missouri. The proposed EGU property is located west-northwest of Norborne, Missouri. The construction of the EGU is classified as a major federal action, since AECI has asked the United States Department of Agriculture/Rural Development (USDA/RD) to assist with project financing. This classification requires USDA/RD to review the project under the National Environmental Policy Act (NEPA) by completing an Environmental Impact Statement (EIS). RUS's review of comments provided in the EIS scoping process identified the usefulness for AECI to assess the mercury risk associated with the EGU operation. AECI contracted URS Corporation (URS) to conduct a mercury risk assessment for the EGU's operations.

The purpose of this document is to evaluate whether mercury emissions from the proposed Norborne coal-fired power plant could pose a potentially unacceptable risk to local populations by entering the human food chain. Inorganic mercury released in power plant emissions can be converted to a toxic organic form, methyl mercury, once it enters water bodies via deposition and runoff. Methyl mercury is highly bioaccumulative in fish, and anglers who catch and consume fish can be at risk if too much mercury enters a watershed. This evaluation is not intended to address regional cumulative loading of mercury from all mercury sources throughout the Midwest.

A number of conservative assumptions are made throughout the evaluation process to ensure that risks are more likely to be overestimated than underestimated. The evaluation is performed using the multi-step process listed below:

1. Obtain and evaluate fish advisories issued by the Missouri Department of Health and Senior Services (DHSS). Also obtain from the Missouri Department of Natural Resources (MDNR)

mercury concentrations in fish fillets and whole fish tissue from streams within a 50 mile radius.

2. Estimate mercury emissions from the proposed power plant based upon coal data, control technology efficiencies, and speciated mercury stack test data from other power plants.
3. Perform air modeling to predict mercury air concentrations from the proposed power plant and subsequent deposition to the surrounding vicinity.
4. Identify watersheds in the area with highest potential to be impacted by mercury deposition.
5. Calculate the total deposition of mercury for the most-impacted watersheds. Based on a review of the deposition modeling results, the Wakenda Creek and Moss Creek watersheds were identified as the most-impacted watersheds.
6. Calculate representative (e.g., worst-case) surface water concentrations of methyl mercury in both watersheds.
7. Use the bioaccumulation factor (BAF) for methyl mercury to calculate fish tissue concentrations.
8. Use fish tissue concentrations to evaluate the incremental impact on fish samples obtained from MDNR in step 1.
9. Calculate hazard indices for anglers who catch and consume fish from the two watersheds.

Based upon this risk evaluation, mercury emissions from the proposed facility would not pose a hazard to anglers who consume fish from either of the most-impacted watersheds. Additionally, the incremental mercury increase in fish tissue would not decrease the number of meals anglers could safely consume based upon existing levels of mercury in fish tissue, USEPA guidance and DHSS fish advisory levels.

Associated Electric Cooperative Inc. (AECI) is proposing to develop a new 660 megawatt baseload coal-fired electric generation unit (EGU). The subject property is located near the town of Norborne, in northwest Missouri.

AECI's proposed construction of the Norborne facility is classified as a major federal action, given that AECI has applied for project financing through the United States Department of Agriculture / Rural Development (USDA/RD}. The project, thus, necessitates review under the National Environmental Policy Act (NEPA).

This report presents an evaluation of environmental impacts associated with the mercury emissions associated with combusting coal in the power plant. Mercury, a trace element in coal, is released in the flue gas upon combustion. The mercury is released in three forms: elemental mercury, reactive gas mercury, and particulate bound mercury. Conventional emission control technologies can reduce mercury emissions to some degree, depending on the type of coal fired and the emission control system. In addition to conventional emission control systems, AECI will inject activated carbon into the air stream before the particulate control system. The activated carbon will bind the mercury and then be captured by the particulate control system, further reducing the amount of mercury released into the atmosphere.

1.1 Project Location

The proposed site is located northwest of Norborne, Missouri in Carroll County, Missouri. The proposed facility property measures approximately 1,500 acres in size. It consists primarily of farmed corn and soybean fields. Several drainage ditches traverse the farmed fields. The Missouri River lies approximately six miles south of the facility property. **Figure 1-1** is a site vicinity map, which depicts the site relative to the community of Norborne and the Missouri River.

1.2 Project Description

The major components of the proposed new 660 megawatt baseload, coal-fired EGU will include a pulverized coal-fired boiler, steam turbine generator, cooling tower, emission control equipment and stack. Coal will be delivered to the plant via rail. A rotary railcar dumper will unload the coal, where it will then be conveyed to either a coal yard for storage or directly to the power block area.

1.3 Report Purpose

The purpose of this report is to document the evaluation of the potential health related impacts of mercury emissions from the proposed Norborne coal-fired power plant. Specifically, this study is intended to determine if mercury emissions for the proposed EGU could pose an unacceptable risk to local populations by entering the human food chain. In particular, inorganic mercury released in power plant emissions can be converted to a toxic organic form, methyl mercury, once it enters water bodies via deposition and runoff. Methyl mercury is highly bioaccumulative in fish, and anglers who catch and consume fish can be at risk if too much mercury enters a watershed. This evaluation is not intended to address cumulative loading of mercury from all mercury sources throughout the Midwest nor is it intended to address the impacts of future mercury emission reductions that will be required by the Environmental Protection Agency's Clean Air Mercury Rule (CAMR) at existing power plants across the country.

The Missouri Department of Health and Senior Services (DHSS) and USEPA have issued nationwide and statewide[1] fish advisories relating to mercury. The Missouri Department of Natural Resources (MDNR) has a database of information about whole fish and fish filet mercury levels which serves as a foundation for the DHSS fish advisory. The existing fish advisory and the information in this database will be described as it relates to the geographic area surrounding the proposed power plant. To the extent that there are data showing changes in fish flesh mercury concentrations over time, these data will also be presented.

2.1 DHSS Fish Advisory

The fish advisory issued by DHSS consists of several advisories including the three advisories for two populations associated with mercury. These advisories are for non-commercial fish.

2.1.1 Sensitive Populations

Sensitive populations are women who are pregnant, women of childbearing age, nursing mothers, and children under 13 years of age. The sensitive populations may have health-protective restriction recommendations because growth and development happens rapidly in young children. These restriction recommendations are designed to protect children.

1. No more that one meal a month for Largemouth Bass, Smallmouth Bass, and Spotted Bass over 12 inches in total length
2. No more than two meals a week for Carp species over 21 inches in total length.
3. No more than one meal a week for any other species of fish.

[1] Missouri Department of Health and Senior Services "2006 Fish Advisory, A Guide to Eating Fish in Missouri", available at http://www.dhss.mo.gov/NewsAndPublicNotices/06FishAdvisory.pdf.

One meal is 11 ounces of uncooked fish for a 150-pound person and 3 ounces for a 40-pound child. The 11-ounce meal is approximately equal to the size of two decks of cards[2].

2.1.2 General Populations

No more than one meal a week for any other species of fish.

2.2 MDNR Fish Tissue Database

In conjunction with MDNR, the USEPA and the Missouri Department of Conservation have been obtaining fish samples and analyzing for mercury content since 1985. This is the database that the DHSS uses to determine which fish advisory levels apply to what areas of the state.

URS obtained a current copy of this database for the area surrounding the proposed EGU from MDNR[3]. The data were filtered so that fish samples farther than 50 miles were removed from the database. A copy of this filtered database is provided in Appendix B.

[2] Missouri Department of Health and Senior Services "2006 Fish Advisory, A Guide to Eating Fish in Missouri", available at http://www.dhss.mo.gov/NewsAndPublicNotices/06FishAdvisory.pdf.
[3] Email from Rich Burge, MDNR to Ken Hagg, URS dated 23 May 2006.

SECTION THREE Emission Estimate and Speciation

Mercury is a trace element in coal and is released upon combustion. During combustion, the mercury (Hg) in coal is volatilized and converted to elemental mercury (Hg^0) vapor in the high temperature regions of coal-fired boilers. As the flue gas is cooled, a series of complex reactions begin to convert Hg^0 to ionic mercury (Hg^{2+}) compounds and/or Hg compounds (Hg_p) that are in a solid-phase at flue gas cleaning temperatures or Hg that is adsorbed onto the surface of other particles. The presence of chlorine gas-phase equilibrium favors the formation of mercuric chloride ($HgCl_2$) at flue gas cleaning temperatures. However, Hg^0 oxidation reactions are kinetically limited and, as a result, Hg enters the flue gas cleaning device(s) as a mixture of Hg^0, Hg^{2+}, and Hg_p. This partitioning of Hg into Hg^0, Hg^{2+}, and Hg_p is known as mercury speciation, which can have considerable influence on selection of mercury control approaches. The majority of gaseous mercury in PRB fired boilers is Hg^0 [4].

Control of mercury emissions from coal-fired boilers is currently achieved via existing controls used to remove particulate matter (PM), sulfur dioxide (SO_2), and nitrogen oxides (NO_x). Besides these conventional emission control technologies, AECI will inject activated carbon into the air stream before their particulate control technology (baghouse). The activated carbon will bind mercury emissions which will then be captured by the particulate control system, reducing the amount of mercury released into the atmosphere.

The emission estimation calculation begins with the type of coal combusted in the EGU. AECI's engineer, Sargent & Lundy, specified a range of acceptable coal that could be used in the power plant[5]. Using these parameters, URS assumed a worst case coal (in terms of mercury emissions)

[4] United States Environmental Protection Agency (USEPA). Control of Mercury Emissions from Coal-Fired Electric Utility Boilers. Research Triangle Park, NC: February 2004.
[5] Sargent & Lundy, LLC. "Associated Electric Cooperative, Inc. New Coal Plan Turnkey Specification for Engineering, Procurement and Construction Services", Addendum No. 3, October 18, 2005, pages. I-27 through I-58.

would be combusted in the EGU. This coal would have a higher heating value (HHV) of 8,000 Btu/lb and would contain 0.21 ppm of mercury. The net plant heat rating in the specification is 8,963 Btu/kilowatt-hour. The uncontrolled total mercury emissions would be:

$$Hg^{T}{}_{uncontrolled} = \left(\frac{0.21 lbHg}{10^{6} lbcoal}\right)\left(\frac{1 lbcoal}{8{,}000 Btu}\right)\left(\frac{8{,}953 Btu}{kW - hr}\right)\left(\frac{1{,}000 kW - h}{MWh}\right) = 235.0x10^{-6}\ lb/MWh$$

Assuming the power plant is running at full load, 660,000 KW_{net}, the uncontrolled mercury emissions on a pound per hour basis is:

$$Hg^{T}{}_{uncontrolled} = \left(\frac{235.0x10^{-6} lb}{MWh}\right)\left(\frac{660 MWh}{hr}\right) = 0.1551 lbHg^{T}{}_{uncontrolled}/hr$$

Based upon previous source testing overseen by URS, we assumed that one percent of the total mercury emissions are particulate bound[6]. Furthermore from other data, the removal efficiency of activated carbon adsorption followed by a filter fabric for particulate bound mercury is 97%[7]. Therefore, the controlled particulate bound mercury emissions are:

$$Hg^{P}{}_{controlled} = \left(\frac{0.1551 lbHg^{T}}{hr}\right)\left(\frac{0.01 lbHg^{P}{}_{uncontrolled}}{lbHg^{T}{}_{uncontrolled}}\right)\left(\frac{0.03 lbHg^{P}{}_{controlled}}{lbHg^{P}{}_{uncontrolled}}\right) = 46.5x10^{-6}\ lbHg^{P}{}_{controlled}/hr$$

The technical specifications for the EGU call for a 90% control efficiency for all mercury emissions. Therefore, the total controlled mercury emissions are:

[6] Lower Colorado River Authority (LCRA). Results of Flue Gas Mercury Measurements at Sam K. Seymour Station, Unit 3. May 1999. Austin, TX. Radian International, LLC.
[7] United States Environmental Protection Agency (USEPA). Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: An Update. Research Triangle Park, NC: February 2005. Page 38.

$$Hg^{T}{}_{controlled} = \left(\frac{0.1551 lbHg^{T}{}_{uncontrolled}}{hr}\right)\left(\frac{0.10 lbHg^{T}{}_{controlled}}{lbHg^{T}{}_{uncontrolled}}\right) = 0.0155\, lbHg^{T}{}_{controlled}/hr$$

Mercury emissions are in one of the three forms discussed above. The elemental and reactive gas forms of mercury emissions are both gaseous. The gaseous mercury emitted is the difference between the total mercury emitted and the particulate bound mercury emitted:

$$Hg^{G}{}_{controlled} = 0.0155\, lbHg^{T}{}_{controlled}/hr - 46.5x10^{-6}\, lbHg^{P}{}_{controlled}/hr = 0.01546\, lbHg^{G}{}_{controlled}/hr$$

From source testing conducted by URS/EPRI/DOE on Stanton Unit No. 10 with activated carbon injection followed by a baghouse, all of the gaseous mercury was elemental mercury, Hg^0. The reactive gas mercury, Hg^{+2}, was below the detection limit of the Ontario Hydro test method[8]. This detection limit was 2% of the total gas phase for one set of measurements and 4% for the other set. We assume that the actual reactive gas concentration is one-half of the detection limit of the test sets. This equals 1.5% of the total gas phase mercury[9]. So the reactive gas emission rates are:

$$Hg^{+2}{}_{controlled} = \left(0.01546 \frac{lbHg^{G}{}_{controlled}}{hr}\right)\left(\frac{0.015 lbHg^{+2}{}_{controlled}}{lbHg^{G}{}_{controlled}}\right) = 0.00023 lbHg^{+2}{}_{controlled}/hr$$

The elemental gaseous mercury emission rate is the difference between the total gaseous mercury emission rate and the reactive gas emission rate:

$$Hg^{0}{}_{controlled} = 0.01546\, lbHg^{G}{}_{controlled}/hr - 0.00023\, lbHg^{+2}{}_{controlled}/hr = 0.01523 lbHg^{0}{}_{controlled}/hr$$

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[8] U.S. Department of Energy National Energy Technology Laboratory. Enhancing Carbon Reactivity in Mercury Control in Lignite-Fired Systems – Technical Progress Report for the Period October 1 – December 31, 2004. February 2005. Grand Forks, ND. Energy & Environmental Research Center – University of North Dakota, page 9.

[9] U.S. Department of Energy National Energy Technology Laboratory. Enhancing Carbon Reactivity in Mercury Control in Lignite-Fired Systems – Technical Progress Report for the Period October 1 – December 31, 2004. February 2005. Grand Forks, ND. Energy & Environmental Research Center – University of North Dakota, page 10-11.

In summary the controlled mercury emission rates used in this effort are:

Hg^0 = 0.01523 lb/hr

Hg^{+2} = 0.00023 lb/hr

Hg^P = 0.00005 lb/hr

Total Hg = 0.01551 lb/hr

4.1 Model Selection and Parameters

This modeling effort was intended to dovetail with the air dispersion modeling required by the Missouri Department of Natural Resources Department of Environmental Quality Air Program to obtain an air construction and operating permit. Therefore the modeling was conducted using the USEPA AERMOD air dispersion model, which is the same model used in the air permit application. While a number of parameters remained the same, there are several additional parameters needed for this modeling effort.

The air permit application modeling requires air dispersion modeling to estimate air concentrations of selected criteria pollutants. While the modeling effort undertaken for this project required air dispersion modeling to estimate both air concentrations as well as total deposition for three types of mercury emissions as discussed in Section Three. In mercury risk assessment, the deposition of mercury into watersheds has a higher impact than mercury concentrations in the ambient air.

In order to conduct deposition modeling, a non-regulatory default had to be used. This default is the Toxics Option, which allows portions of AERMOD dealing with deposition to be activated.

Another change required by the EGU's mercury emission rate, is the conversion of deposition rates from grams per square meter (g/m^2) to micrograms per square meter ($\mu g/m^2$).

4.1.1 Parameters used from Air Permit Application

The physical parameters of the facility and surrounding area were obtained from the air permit application modeling files. This included stack parameters, facility property line, digital elevation maps, and an initial set of receptor locations.

4.1.2 Additional Parameters

After an initial screening run for a single year, additional receptors were added to the model so the point of maximum impact was in a 50 meter receptor grid for both air concentration as well as deposition.

4.1.2.1 Meteorological Data

The meteorological data used in the air permit application was not sufficient as it did not include precipitation data needed to conduct depositional modeling. Therefore two types of meteorological data were obtained from the National Climatic Data Center (NCDC) for surface observational data and upper air data. Data files were obtained for the years 2001 through 2005. The Integrated Surface Hourly Observation data used were collected from the Kansas City International Airport Weather Bureau Airport Station. Upper Air data used were collected from the Topeka Weather Meteorological Observation Station.

These data sets were then processed through AERMET. In this process, URS provided seasonal daytime bowen ratios, surface roughness lengths, and albedos[10]. The surface roughness lengths and albedos were an average of the two predominate land uses around the EGU: cultivated land and grassland. The daytime bowen ratios are dependent not only upon season and land use, but also by precipitation (wet, normal or dry moisture conditions). Based upon the actual annual precipitation for the five years of meteorological data and the historical annual average precipitation, URS classified 2001 as a wet year, 2002 and 2003 as dry years, and 2004 and 2005 as average years. The table below shows the values used in AERMET.

[10] United States Environmental Protection Agency (USEPA). User's Guide for the Aermod Meteorological Preprocessor (AERMET). Washington, D.C.: NTIS, November 2004. EPA-454/B-03-002.

Table 4-1
AERMET Preprocessing Variables

Variable	Season			
	Spring	Summer	Autumn	Winter
Surface Roughness Length (m)	0.04	0.15	0.03	0.006
Albedo	0.16	0.19	0.19	0.60
Daytime Bowen Ratio (wet)	0.25	0.35	0.45	0.47
Daytime Bowen Ratio (dry)	1.0	1.75	2.0	2.0
Daytime Bowen Ratio (normal)	0.35	0.65	0.85	1.18

4.1.2.2 Gaseous Wet Deposition Variables

There are four additional factors that AERMOD uses to calculate gas deposition. They are the gases' volatilization factor in water and air also called diffusivity in air and diffusivity in water and are measured in square centimeters per second. The cuticular resistance term, measured in seconds per centimeter, is a function of the relative humidity and the plant type. The last factor is the Henry's Law coefficient measured in Pascal cubic meters per mol. Both the elemental and the reactive gas mercury phase deposition modeling use these variables. URS used the following in the model.

Table 4-2
Gaseous Wet Deposition Variables

Mercury Phase	Diffusivity in Air[11]	Diffusivity in Water	Cuticular Resistance Term[5]	Henry's Law Coefficient[5]
Elemental	7.23E-6	6.30E-6[12]	1E7	150
Reactive Gas	6.00E-6	3.256E-4[13]	1E7	6E-6

4.1.2.3 Gas Dry Deposition Variables

There are two factors used by AERMOD to calculate gaseous dry deposition. The first factor is a seasonal category as listed below[14]:

1. Midsummer with lush vegetation
2. Autumn with unharvested cropland
3. Late autumn after frost and harvest or winter with no snow
4. Winter with snow on the ground
5. Transitional Spring with partial green coverage or short annuals.

URS used season category one for May, June and July; category two for August and September; category three for February, October, November, and December; category 4 for January; and category five for March and April.

The second factor is a land use type as listed below[15]:

[11] Wesely, M.L. Doskey, P.V., Shannon, J.D. United States Department of Energy, Office of Science, Office of Biological and Environmental Research. Deposition Parameterizations for the Industrial Source Complex (ISC3) Model Appendix B. Washington, D.C.: GPO, 2002. ANL/ER/TR-01/003.
[12] Indiana Department of Environmental Management, RISC Technical Guide – Appendix 1 Table B, February 5, 2001, page A.1-22.
[13] United States Environmental Protection Agency (USEPA). Mercury Study Report to Congress, Volume III Fate and Transport of Mercury in the Environment. Washington, D.C.: NTIS, December 1997. EPA-452/R-97-005.
[14] United States Environmental Protection Agency (USEPA). Addendum to User's Guide for the AMS/EPA Regulatory Model – AERMOD. Washington, D.C.: NTIS, October 2004, page 3.

1. Urban land, no vegetation
2. Agricultural land
3. Rangeland
4. Forest
5. Suburban areas, grassy
6. Suburban areas, forested
7. Bodies of water
8. Barren land, mostly desert
9. Non-forested wetlands

URS used the agricultural land use type for this project. In addition, default reference parameters for gas dry deposition were used.

4.1.2.4 Scavenging Variables

There are two factors used by AERMOD to calculate particle wet scavenging. The first is a liquid precipitation scavenging coefficient (hr/s-mm) for each of the three mercury phases. The second is a frozen precipitation scavenging coefficient (hr/s-mm) for each of the three mercury phases.

4.1.2.5 Method 2 Particle Deposition Parameters

Method 2 algorithms are used when the particle size distribution is not well known and when a small fraction (less than 10% of the mass) is in particles with a diameter of 10 µm or larger[16]. There are two factors used by AERMOD to calculate Method 2 particle dry deposition. The first is the fine mass fraction (less than 2.5 micron) and the second is the representative

[15] United States Environmental Protection Agency (USEPA). Addendum to User's Guide for the AMS/EPA Regulatory Model – AERMOD. Washington, D.C.: NTIS, October 2004, page 4.
[16] United States Environmental Protection Agency (USEPA). AERMOD Deposition Algorithms – Science Document (Revised Draft). March 19, 2004, page 4.

mass mean particle diameter in microns. URS used a fine mass fraction of 0.5[17] and mean particle diameter of 0.4 microns[18].

4.2 Results

AERMOD returned data for air concentration (µg/m^3) and total deposition (µg/m^2/year) for each of the five years modeled for the three mercury phases and two averaging periods. The maximum results for each of these are presented in **Table 4-3**.

Table 4-3
AERMOD Air Dispersion Model Results

Year	Mercury Phase	Highest Air Concentration (µg/m^3)		Highest Total Deposition (µg/m^2/year)	
		1-hour maximum	Annual average	1-hour maximum	Annual average
2001					
	Hg (0)	0.00082	0.00001	0.00002	0.00053
	Hg (+2)	0.00001	<0.00001	<0.00001	0.00027
	Hg (P)	0.00004	<0.00001	0.06669	0.24337
2002					
	Hg (0)	0.00077	0.00001	0.00008	0.00047
	Hg (+2)	0.00001	<0.00001	<0.00001	0.00045
	Hg (P)	0.00004	<0.00001	0.03564	0.26498
2003					
	Hg (0)	0.00062	0.00001	0.00010	0.00048

[17] United States Environmental Protection Agency (USEPA). Compilation of Air Pollutant Emission Factors, Fifth Edition (AP-42) External Combustion Boiler burning subbituminous coal, Table 1.1-6.
[18] Wesely, M.L. Doskey, P.V., Shannon, J.D. United States Department of Energy, Office of Science, Office of Biological and Environmental Research. Deposition Parameterizations for the Industrial Source Complex (ISC3) Model Appendix B. Washington, D.C.: GPO, 2002. ANL/ER/TR-01/003.

Table 4-3
AERMOD Air Dispersion Model Results

Year	Mercury Phase	Highest Air Concentration (µg/m^3)		Highest Total Deposition (µg/m^2/year)	
		1-hour maximum	Annual average	1-hour maximum	Annual average
	Hg (+2)	0.00001	<0.00001	<0.00001	0.00029
	Hg (P)	0.00005	<0.00001	0.05325	0.23230
2004					
	Hg (0)	0.00088	0.00001	0.00010	0.00052
	Hg (+2)	0.00001	<0.00001	<0.00001	0.00032
	Hg (P)	0.00005	<0.00001	0.04808	0.29014
2005					
	Hg (0)	0.00079	0.00001	0.00012	0.00060
	Hg (+2)	0.00001	<0.00001	<0.00001	0.00035
	Hg (P)	0.00004	<0.00001	0.04914	0.30303

5.1 Drainage Areas

Watershed drainage areas were delineated using USGS 7.5 minute quadrangles and 1 minute by 2 minute quadrangles. Working from the major water body, the Missouri River, URS identified major tributaries that drain the area within 30 miles of the proposed power plant site. In the case of larger tributaries (i.e. Grand River), their tributaries leading from the area of concern were delineated.

Once delineated on print-outs of the maps, the delineations were transferred to an electronic format (AutoCad®) that allows the further manipulation of these data. The delineated drainage areas are shown in **Figure 5-1**.

5.2 Deposition Isopleths

The model provides maximum individual receptor deposition rates for each of the three types of mercury phases in µg/m^2/year. These deposition rates include both wet and dry deposition. The model also provided the maximum deposition rates for each year as shown in **Table 4-1**. Based upon the results in this table and experience with mercury risk analysis, URS determined the annual deposition would be the controlling variable. We chose to use 2005 data in the risk assessment as it had the highest maximum deposition rate.

The three mercury phase deposition rates were added to determine the maximum mercury deposition rate for each receptor. The dates for each mercury phase had the maximum deposition rate for any receptor does not necessarily happen on the same date. Therefore, by adding the maximum deposition rates for each phase, URS was being conservative.

This total deposition rate for each receptor was then used in a computer program that plots isopleths, Surfer version 8.0. It was determined that the annual deposition rate is the controlling element in the risk assessment, so the daily deposition rate and the air concentration rates were not plotted.

Surfer was then used to export the isopleths into AutoCad®. The 2005 annual isopleth is shown in **Figure 5-2**.

These deposition isopleths are then used with the watershed boundaries to determine total mercury deposition rates per watershed. The depositional isopleths are overlaid onto the watershed areas, see **Figure 5-3**. Examining the watershed areas and the distribution of the isopleths, URS evaluated the Wakenda Creek and Moss Creek watersheds in the risk assessment. For each of these watersheds, the area (square meters) within the watershed between two isopleth lines is calculated using Autocad®. This area is multiplied by the larger of the two deposition rates (µg/square meter/year) represented by the two isopleth lines, which provides a conservative calculation of the total deposition between the isopleth lines. This is continued for the entire watershed area and each deposition is added for the total deposition (grams/year) for the watershed.

5.3 Surface water concentrations of methyl mercury

Surface water concentrations of methyl mercury are calculated separately for each watershed by calculating the total mercury load to the watersheds, then calculating the methyl mercury surface water load, and finally calculating the concentration of methyl mercury in the waterbodies.

5.3.1 Total Mercury Load Calculation

URS calculated the load of total mercury (LT_m) to Moss Creek and to Wakenda Creek. The following equation from USEPA (2005) can be used to calculate mercury loading to Moss and Wakenda Creeks, taking into account partial loss of mercury to soils, sediments, and pervious soils:

$$LT_m = L_{dep} + L_{df} + L_{ri} + L_R + L_E + L_I$$

Where:

LT_m = Total load to water body (gm)

L_{dep} = Deposition to water

L_{dif} = Diffusion to water

L_{ri} = Runoff from impervious surfaces

L_R = Runoff from pervious surfaces

L_E = load from soil erosion

L_I = Load from internal transfer

As a conservative, simplifying step for initial screening, it can be assumed that all mercury deposited throughout the watershed enters the surface water (i.e., no loss is assumed). Using this approach, LT_m is equal to total amount of mercury deposited throughout the entire watershed. Worst-case historical meteorological data, based on the year 2005 (annual data that would result in the highest predicted mercury deposition), were used to predict LT_m values.

LT_m Wakenda Creek watershed = 10.310 grams/year total mercury

LT_m Moss Creek watershed = 4.098 grams/year total mercury

5.3.2 Methyl Mercury Load Calculation

URS then converted the load of total mercury in surface water (LT_m) to the load of methyl mercury in surface water (LT_{mm}) (i.e., the form that is bioaccumulative). USEPA (2005) recommends applying a fifteen percent (15%) conversion efficiency.

LT_{mm} Wakenda Creek watershed = 10.310 gm/yr total mercury * 0.15
= 1.547 gm/yr methyl mercury

LT_{mm} Moss Creek watershed = 4.098 gm/yr total mercury * 0.15
= 0.615 gm/yr methyl mercury

5.3.3 Methyl Mercury Concentration

URS calculated the water body methyl mercury concentration. USEPA (2005) provides the following equation:

$$C_{wtot} = \frac{LT_{mm}}{V_{fx} * f_{wc} + k_{wt} * A_w * (d_{wc} + d_{bs})}$$

Where:

C_{wtot} = concentration in water (ug/m^3)
V_{fx} = flow rate (m^3/yr)
f_{wc} = fraction of methyl mercury that is in the water column
k_{wt} = water body mercury dissipation rate constant
A_w = water body surface area
D_{wc} = depth of water column
D_{bs} = depth of upper benthic sediment layer

This equation can be simplified by assuming that 100% of the methyl mercury is in the water column. This is a conservative assumption, as the bioaccumulation factors used to estimate bio-uptake in fish assume all uptake into fish occurs from water, none from sediment. Assuming any portion of the total methyl mercury is partitioned to sediments would thus result in lower calculated fish tissue concentrations. The resulting simplified equation is:

$$C_{wtot} = \frac{LT_{mm}}{V_{fx}}$$

In this evaluation, V_{fx} values are calculated in Moss and Wakenda Creeks near the confluence of the creeks with the Missouri River (i.e., portions of the creeks that are assumed to be large enough to support a harvestable fishery). As no ponds or lakes large enough to support a large, sustainable harvest of fish are present in either watershed, the use of the creek outfalls is considered a reasonably representative fishing location. Using these assumptions, the flow rate (V_{fx}) can be calculated using the following equation:

$$V_{fx} = P_{yr} * A_{ws}$$

Where:

P_{yr} = annual precipitation (m/year); 44.14 in/year (1.12 m/year) for the year of maximum predicted mercury deposition (2005)

A_{ws} = Area of watershed (m^2); 951,797,017 m^2 Wakenda Creek; 235,904,803 m^2 Moss Creek

Calculated V_{fx} values are as follows:

V_{fx} Wakenda Creek = 951,797,017 m^2 * 1.12 m/year = 1,066,031,980 m^3/year

V_{fx} Moss Creek = 235,904,803 m^2 * 1.12 m/year = 264,218,168 m^3/year

Resulting surface water methyl mercury concentrations are:

C_{wtot} Wakenda Creek = 1.547 gm/yr methyl mercury / 1,066,031,980 m^3/yr = 1.5E-9 gm/m^3 = 1.5E-3 ug/m^3

C_{wtot} Moss Creek = 0.615 gm/yr methyl mercury / 264,218,168 m^3/yr = 2.3E-9 gm/m^3 = 2.3E-3 ug/m^3

Converting to ug/L:

C_{wtot} Wakenda Creek = 1.5E-3 ug/m^3 * 0.001 m^3/L = 1.5E-6 ug/L

C_{wtot} Moss Creek = 2.3E-3 ug/m^3 * 0.001 m^3/L = 2.3E-6 ug/L

5.4 Calculate fish tissue concentrations

Calculate fish tissue concentrations using the following equation:

$$C_{fish} = C_{dw} * BAF_{fish}$$

Where:

C_{fish} = concentration of methyl mercury in fish tissue, assuming the chemical partitions uniformly in both edible tissue (muscle tissue) and inedible tissues (bone, skin, scales, organs)
C_{dw} = Concentration of dissolved methyl mercury in water (conservatively assumed to be equal to total concentration, C_{wtot})
BAF_{fish} = Bioaccumulation Factor in fish

Note that USEPA provides a wide range of BAF_{fish} values for evaluating fish bio-uptake. These values reflect differences in size, age, sex, feeding preferences and trophic level (i.e., position on the food chain) among different species of fish. In general, large adults of top predator species, such as largemouth bass, tend to bioaccumulate more mercury than smaller individuals, or species that are more intermediate in the food chain, such as two other species often sought by anglers, crappie and bluegill. For purposes of classifying the bioaccumulation potential of various types of fish, USEPA has developed a series of BAF_{fish} values to reflect differences between fish based on their position in the food chain, referred to as their “trophic level”. The following table summarizes the USEPA (2006) recommended 50th percentile BAF_{fish} values for Trophic Level 2, 3 and 4 fish species, with Trophic Level 4 species being the top predator species. As noted in the Water Quality Criterion documentation for methyl mercury (USEPA, 2001), anglers typically consume a mixture of fish species from these three trophic levels.

Recommended BAF_{fish} for Methyl mercury (USEPA, 2006)

Trophic Level 2	Trophic Level 3	Trophic Level 4

117,000	680,000	2,670,000

The calculated fish tissue methyl mercury concentrations for Trophic Level 4 fish (i.e., the worst-case example) are:

C_{fish} Wakenda Creek = 1.5E-6 ug/L * 2.67E+6 L/kg = 3.9 ug/kg
C_{fish} Moss Creek = 2.3E-6 ug/L * 2.67+6 L/kg = 6.2 ug/kg

As a point of comparison, these fish tissue concentrations are considerably below the USEPA (2001) Water Quality Criterion comparison fish tissue value of 300 ug/kg, which is the concentration USEPA considers safe for human consumption.

5.5 Calculate cancer risks and hazard indices

Calculate cancer risk and non-cancer hazard index, using standard USEPA (1989) risk assessment protocols. Given that methyl mercury is not a carcinogen, only the non-cancer hazard index is relevant. USEPA (2005) recommends evaluating adult and child anglers separately. The equation used to calculate the non-cancer hazard index is the same for both adults and children, and is:

$$HI = \frac{C_{fish} * IR_{fish} * CF * EF * ED}{BW * AT_{nc} * RfD}$$

Where:

HI = Hazard Index (unitless)
IR_{fish} = Ingestion rate of fish (kg/day) (0.087 kg/day adult; 0.013 kg/day child) (USEPA, 2005)
CF = Conversion factor (0.001 mg/ug)
EF = Exposure Frequency (365 days/year, consistent with IR which is a daily average value)

ED = Exposure Duration (years); (30 years adult; 6 years child) (USEPA, 1989, 2005)

BW = Body Weight (kg); (70 kg adult; 15 kg child) (USEPA, 1989, 2005)

AT_{nc} = Non-cancer averaging time (days) (10,950 days for adult; 2,190 days for child)

RfD = Reference Dose[19] (0.0001 mg/kg-day)

The resulting Hazard Indices, based on Trophic Level 4 fish, are:

HI_{adult} Wakenda Creek = (3.9*0.087*0.001*365*30) / (70*10,950*0.0001) = 0.05

HI_{child} Wakenda Creek = (3.9*0.013*0.001*365*6) / (15*2,190*0.0001) = 0.03

HI_{adult} Moss Creek = (6.2*0.087*0.001*365*30) / (70*10,950*0.0001) = 0.08

HI_{child} Moss Creek = (6.2*0.013*0.001*365*6) / (15*2,190*0.0001) = 0.05

As shown in these calculations, all calculated Hazard Indices are substantially below 1.0. A Hazard Index of less than 1.0 indicates the lack of any potential hazard.

5.6 Impacts on Missouri Fish Advisory

URS evaluated the impact the increased mercury deposition in local waterbodies would have on historic fish mercury levels as analyzed by Missouri Department of Natural Resources (MDNR), Missouri Department of Conservation (MDC), and the United States Environmental Protection Agency (USEPA). As discussed in Section Two, these agencies have been collecting fish and analyzing the amount of mercury found in these collected fish.

[19] The reference dose for methyl mercury of 0.0001 mg/kg-day is per USEPA's IRIS database, verified on Sept. 18, 2006.

These data are used by the Missouri Department of Health and Senior Services (DHSS) to determine what level of fish advisory will be issued for areas within Missouri.

There are no historical fish analyses from the two watersheds that have the highest mercury impact (Wakenda Creek and Moss Creek). URS calculated mercury fish tissue concentrations using the same methodology discussed in Section 5.1 through 5.4. Because the historical fish tissue data included samples from watersheds are beyond the air quality deposition receptor grid, URS conservatively assumed that the lowest depositional isopleth plotted (0.00125 $\mu g/m^2/year$) applied to the entire watershed. If a watershed fell within the air dispersion receptor field, the deposition rate was calculated using a weighted average as discussed in Section 5.2.

SECTION SIX **Conclusions**

A screening level risk evaluation was performed to determine whether the placement of a coal-fired EGU in Norborne, Missouri would be likely to pose a health threat to the local community due to mercury emissions from the plant. Consistent with the screening nature of this evaluation, a number of assumptions, which are likely to overestimate the potential impacts, were used throughout the evaluation process. In particular, the following conservative assumptions were made:

- Predicted mercury deposition rates were calculated based on worst-case historical meteorological data for the years 2001-2005 (i.e., 2005 data, which produced the highest predicted mercury deposition rates).
- Assumption that all mercury deposited in a watershed ends up in surface water. In reality, much of the mercury would be either lost from the watershed from subsequent volatilization, leach to the subsurface, or be sequestered in soils and sediments, where it would not be available for bio-uptake into fish.
- The ingestion rates used in the risk calculations are based on the assumption that an adult eats an average of 5.4 fish meals per week, and that all of that fish originates from the impacted watershed (i.e., individuals do not eat fish from any other source). Likewise, the assumption is made that a very young child, aged 0-6, eats an average of 0.8 fish meals per week from the impacted watershed. In reality, most anglers consume fish that originate from a variety of sources.
- The bioaccumulation factor used to estimate representative methyl mercury concentrations in fish was based on species with the highest bioaccumulation potential, Trophic Level 4 fish (i.e., it was assumed that only large individuals of top predator species such as large mouth bass were consumed). This is a worst-case scenario, as most anglers

would be expected to eat a variety of fish from different trophic levels, with a lower overall methyl mercury concentration.

- The reference dose used in the risk calculations includes a 10X uncertainty factor (similar in concept to a safety factor) to ensure that the hazard index is not underestimated.

In combination, these assumptions undoubtedly resulted in a substantial overestimation of the potential health impacts from mercury emissions. Even with the use of these conservative assumptions, the predicted hazard indices were well below the threshold value of 1.0, indicating that mercury emissions from the proposed power plant should not pose any health threat to the surrounding community.

This evaluation evaluates the current mercury levels in fish samples taken by MDNR, MDC, and USEPA within 50 miles of the proposed plant and what incremental effect the mercury released by the proposed plant would have on mercury levels in those fish as provided by the fish advisory issued by MDSS. There would be no change in limits on recommended fish consumption based upon the incremental increase in mercury in the fish, as evaluated by MDSS and USEPA.