APPENDIX D MERCURY RISK EVALUATION

A S S O C I A T E D   E L E C T R I C
C O O P E R A T I V E ,   I N C .

MERCURY RISK ASSESSMENT REPORT

Norborne, Missouri

Prepared for

Associated Electric Cooperative Inc

June 21, 2007

URS

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EXECUTIVE SUMMARY

Associated Electric Cooperative, Inc. (AECI) is proposing to develop a new 660 megawatt (net) 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 an unacceptable risk to local populations by entering the human food chain. A portion of the inorganic mercury emissions from the power plant are converted to a toxic organic form, methylmercury, once inorganic mercury enters water bodies via deposition and runoff. Methylmercury is highly bioaccumulative and anglers who catch and consume fish may be at risk. This evaluation is not intended to address regional cumulative loading of mercury from all mercury sources throughout the Midwest, although the evaluation does include an element to determine whether the existing fish advisory issued by the Missouri Department of Health and Senior Services (MHSS) would be made more severe in consideration of the mercury emissions from the proposed plant.

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 was performed using the multi-step process listed below:

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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 100 mile radius within Missouri.
2. Estimate maximum allowable mercury emissions from the proposed power plant based upon New Source Performance Standards (NSPS) limits.
3. Perform air modeling to predict mercury air concentrations from the proposed power plant and subsequent deposition rates to the surrounding vicinity.
4. Identify where fish sampling occurred and the associated watersheds lay mainly within a 50 kilometer radius of the Norborne site. Separately identify watersheds 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 watersheds Wakenda Creek and Moss Creek watersheds were identified as the most-impacted. Additionally, fish sampling occurred in Cooley Lake and the Lamine River, which includes Davis Creek, Salt Fork, Finney Creek, Muddy Creek, Flat Creek and Blackwater River watersheds.
6. Calculate surface water concentrations of methylmercury in the watersheds.
7. Use the bioaccumulation factor (BAF) for methylmercury to calculate mercury concentrations in fish tissue.
8. Use fish tissue concentrations to evaluate the incremental impact on fish samples obtained from MDNR in step 1.

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9. Calculate hazard indices for anglers who catch and consume fish from the evaluated watersheds.

Based upon this risk evaluation, the additional mercury emissions from the proposed facility would not pose a significant hazard to anglers who consume fish from the evaluated 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 (net) 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 have the ability to inject activated carbon into the air stream before the particulate control system. The activated carbon will bind the reactive gas and particulate 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 encompasses approximately 1,500 acres. Currently, 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 (net) 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, methylmercury, once it enters water bodies via deposition and runoff. Methylmercury is highly bioaccumulative and anglers who catch and consume fish may be at risk. 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 includes three advisories for two populations associated with mercury. These advisories are for non-commercial fish caught in Missouri.

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 than one meal a month for Largemouth Bass, Smallmouth Bass, and Spotted Bass over 12 inches in total length.
2. No more than one meal 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 "2007 Fish Advisory, A Guide to Eating Fish in Missouri", available at http://www.dhss.mo.gov/NewsAndPublicNotices/07FishAdvisory.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 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 facility from MDNR[3]. The data were filtered so that fish samples farther than 100 miles were removed from the database. A copy of this filtered database is provided in **Appendix B**. **Figure 2-1** shows the locations where fish samples were taken.

[2] Missouri Department of Health and Senior Services "2007 Fish Advisory, A Guide to Eating Fish in Missouri", available at http://www.dhss.mo.gov/NewsAndPublicNotices/07FishAdvisory.pdf.
[3] Email from Rich Burge, MDNR to Ken Hagg, URS dated 23 May 2006.

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 that are in a solid-phase at flue gas cleaning temperatures or Hg that is adsorbed onto the surface of other particles (Hg_p). 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 be able to inject activated carbon into the air stream before their particulate control technology (baghouse). The activated carbon binds the reactive gas and particulate mercury emissions which can then be captured by the particulate control system, reducing the amount of mercury released into the atmosphere.

Whatever the control scheme used by AECI, the plant must meet current mercury emission standards. The current emission standard for an Electric Utility Steam Generating Unit constructed after September 18, 1978 is codified in 40 CFR 60.45Da (a)(2)(i). Mercury emissions from any unit may not exceed 66 x 10^{-6} lb/MWh gross. The proposed Norborne facility is rated at 688 MW (gross). Therefore the total allowable mercury emission rate is:

[4] United States Environmental Protection Agency (USEPA). Control of Mercury Emissions from Coal-Fired Electric Utility Boilers. Research Triangle Park, NC: February 2004.

$$688 MW(gross) * 66x10^{-6} \,{}^{lb}\!/_{MWh} = 0.0454 \,{}^{lb}\!/_{hr}\, Hg^{T}$$

For inclusion into AERMOD, the emission rate is converted to grams/sec:

$$0.0454 \frac{lb}{hr} Hg^{T} * \frac{453.59\,gram}{lb} * \frac{1hr}{3{,}600\sec} = 0.00572 \frac{grams}{\sec} Hg^{T}$$

On an annualized basis the emission rate is:

$$0.0454 \frac{lb}{hr} Hg^{T} * \frac{8760\,hrs}{yr} = 398 \frac{lbs}{yr} Hg^{T}$$

Based upon previous source testing overseen by URS, we assumed that one percent of the total mercury emissions are particulate bound[5].

$$Hg^{P} = 0.00572 \frac{grams}{\sec} * \frac{0.01 Hg^{P} lb}{1 Hg^{T}} = 0.0000572 \frac{grams}{\sec} Hg^{P}$$

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:

$$Hg^{G} = 0.00572 \frac{grams}{\sec} Hg^{T} - 0.0000572 \frac{grams}{\sec} Hg^{P} = 0.00566 \frac{grams}{\sec} Hg^{G}$$

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[6]. This detection

[5] 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.
[6] 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.

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[7]. So the reactive gas emission rates are:

$$Hg^{+2} = 0.00566\frac{grams}{\sec} * \frac{0.015Hg^{+2}lb}{1Hg^{G}} = 0.0000849\frac{grams}{\sec}Hg^{+2}$$

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

$$Hg^{0} = 0.00566\frac{grams}{\sec}Hg^{G} - 0.0000849\frac{grams}{\sec}Hg^{+2} = 0.00558\frac{grams}{\sec}Hg^{0}$$

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

Hg^0 = 0.00558 grams/sec = 0.0443 lb/hr

Hg^{+2} = 0.0000849 grams/sec = 0.000674 lb/hr

Hg^P = 0.0000572 grams/sec = 0.000454 lb/hr

Total Hg = 0.00572 grams/sec = 0.0454 lb/hr

[7] 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.

4.1 Model Selection and Parameters

This modeling effort was intended to dovetail with the air dispersion modeling required by MDNR to obtain an air construction and operating permit. Therefore the modeling was conducted using USEPA's AERMOD air dispersion model, 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 requires air dispersion modeling to estimate air concentrations of selected criteria pollutants. While the Mercury modeling required air dispersion modeling to estimate both air concentrations as well as deposition rates for the three types of mercury emissions discussed in **Section Three**.

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. The stack height in the Draft Risk Assessment was 600ft and was changed to 500 feet (ft) for this effort to match the current planned stack height.

4.1.2 Additional Parameters

The following sections discuss the additional parameters used in this modeling effort to obtain deposition rates.

4.1.2.1 Meteorological Data

The meteorological data used in the air permit application was not sufficient for this risk assessment effort 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[8]. 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 following table shows the values used in AERMET.

[8] 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[9]	Diffusivity in Water	Cuticular Resistance Term[5]	Henry's Law Coefficient[5]
Elemental	7.23E-6	6.30E-6[10]	1E7	150

[9] 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.

[10] Indiana Department of Environmental Management, RISC Technical Guide – Appendix 1 Table B, February 5, 2001, page A.1-22.

Table 4-2
Gaseous Wet Deposition Variables

Mercury Phase	Diffusivity in Air[9]	Diffusivity in Water	Cuticular Resistance Term[5]	Henry's Law Coefficient[5]
Reactive Gas	6.00E-6	3.256E-4[11]	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[12]:

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[13]:

1. Urban land, no vegetation
2. Agricultural land
3. Rangeland
4. Forest
5. Suburban areas, grassy
6. Suburban areas, forested

[11] 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.
[12] 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.
[13] 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.

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[14]. 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 mass mean particle diameter in microns. URS used a fine mass fraction of 0.5[15] and mean particle diameter of 0.4 microns[16].

4.1.2.6 Receptors

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. Additional

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[14] United States Environmental Protection Agency (USEPA). AERMOD Deposition Algorithms – Science Document (Revised Draft). March 19, 2004, page 4.

[15] 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.

[16] 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

receptors were also added to cover drainage areas where fish tissue samples were collected. Receptors were not added beyond 50 km, as that is the distance to which AERMOD is effective per USEPA[17]. These receptors will provide data to estimate mercury deposition rates in these watersheds.

4.2 Results

AERMOD returned data for air concentration (µg/m^3), wet and dry 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 (ug/m³)		Highest Deposition Rate (ug/m²/yr)			
		1-hour Maximum	Annual Average	Wet 1-hour Maximum	Wet Annual Average	Dry 1-hour Maximum	Dry Annual Average
2001							
	Hg(0)	0.00348	0.00002	0.00068	0.00178	<0.00001	0.00020
	Hg(+2)	0.00005	<0.00001	0.00001	0.00002	0.00001	0.00115
	Hg(p)	0.00004	<0.00001	0.00016	0.00052	0.00108	0.03257
2002							
	Hg(0)	0.00269	0.00004	0.00027	0.00151	<0.00001	0.00028
	Hg(+2)	0.00004	<0.00001	0.00000	0.00003	0.00001	0.00194
	Hg(p)	0.00003	<0.00001	0.00007	0.00056	0.00109	0.08976
2003							
	Hg(0)	0.00329	0.00003	0.00032	0.00156	<0.00001	0.00016
	Hg(+2)	0.00005	<0.00001	<0.00001	0.00002	0.00001	0.00122
	Hg(p)	0.00003	<0.00001	0.00008	0.00046	0.00181	0.06168

the Industrial Source Complex (ISC3) Model Appendix B. Washington, D.C.: GPO, 2002. ANL/ER/TR-01/003.

[17] 70 FR 68232, November 9, 2005.

Table 4-3
AERMOD Air Dispersion Model Results

		Highest Air Concentration (ug/m³)		Highest Deposition Rate (ug/m²/yr)			
2004							
	Hg(0)	0.00335	0.00003	0.00035	0.00172	<0.00001	0.00019
	Hg(+2)	0.00005	<0.00001	<0.00001	0.00003	0.00001	0.00136
	Hg(p)	0.00003	<0.00001	0.00009	0.00059	0.00135	0.04439
2005							
	Hg(0)	0.00260	0.00003	0.00039	0.00200	<0.00001	0.00036
	Hg(+2)	0.00004	<0.00001	<0.00001	0.00003	0.00001	0.00150
	Hg(p)	0.00003	<0.00001	0.00010	0.00065	0.00083	0.04881

5.1 Drainage Areas

Watershed drainage areas were delineated using USGS 7.5 minute and 1 minute by 2 minute quadrangles. Working from the Missouri River, URS identified major tributaries that drain the area within 50km of the proposed power plant site. In the case of larger tributaries, their tributaries leading from the area of concern were also 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**. Areas delineated in a red outline are sub-areas of the Lamine River Watershed.

5.2 Deposition Isopleths

The model provides maximum individual receptor wet and dry deposition rates for each of the three mercury phases in $\mu g/m^2$/year. 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 2002 data in the risk assessment as it had the highest maximum total deposition rate for mercury as shown in **Table 5-1**.

Table 5-1
Air Dispersion Results for Highest Deposition Rates

Year	Mercury Phase	Annual Deposition (ug/m²/yr)		
		Wet	Dry	Total
2001				
	Hg(0)	0.00178	0.00020	0.00180
	Hg(+2)	0.00002	0.00115	0.00115
	Hg(p)	0.00052	0.03257	0.03265
	Total Hg	0.00232	0.03388	0.03417
2002				
	Hg(0)	0.00151	0.00028	0.00153
	Hg(+2)	0.00003	0.00194	0.00194
	Hg(p)	0.00056	0.08976	0.08983

Table 5-1
Air Dispersion Results for Highest Deposition Rates

Year	Mercury Phase	Annual Deposition (ug/m²/yr)		
		Wet	Dry	Total
	Total Hg	0.00210	0.09191	0.09220
2003				
	Hg(0)	0.00156	0.00016	0.00312
	Hg(+2)	0.00002	0.00122	0.00122
	Hg(p)	0.00046	0.06168	0.06174
	Total Hg	0.00204	0.06302	0.06320
2004				
	Hg(0)	0.00172	0.00019	0.00174
	Hg(+2)	0.00003	0.00136	0.00137
	Hg(p)	0.00059	0.04439	0.04451
	Total Hg	0.00234	0.04593	0.04644
2005				
	Hg(0)	0.00200	0.00036	0.00205
	Hg(+2)	0.00003	0.00150	0.00150
	Hg(p)	0.00065	0.04881	0.04892
	Total Hg	0.00267	0.05067	0.05110

For each receptor, the maximum wet deposition rate was added to the maximum dry deposition rate to determine the total deposition rate for each mercury phase. The maximum wet and dry deposition rates for any receptor usually does not occur on the same date; therefore, by using the maximum wet and dry deposition rates for each receptor, URS was being conservative. The total deposition rates for each mercury phase were then added to determine the total mercury deposition rate at each receptor.

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 total 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 2002 annual isopleth is shown in **Figure 5-2**.

These deposition isopleths are then used with the watershed boundaries to determine total mercury deposition 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, Moss Creek, Lamine River, and Cooley Lake 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 to obtain the total deposition (grams/year) for the watershed.

5.3 Surface water concentrations of methylmercury

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

Local ponds near the proposed facility have much smaller drainage areas than either Moss or Wakenda Creek and therefore would have several orders of magnitude less mercury available for uptake to the fish population than the creeks. Because there are no fish mercury concentration data available for any of the nearby waterbodies, the larger more conservative waterbodies (Moss Creek and Wakenda Creek) were used for this evaluation.

5.3.1 Total Mercury Load Calculation

URS calculated the load of total mercury (LT_m) to Moss Creek, Wakenda Creek, Lamine River, and Cooley Lake. The following equation from USEPA (2005) can be used to calculate mercury loading, 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 2002 (annual data that would result in the highest predicted mercury deposition), were used to predict LT_m values.

LT_m Wakenda Creek watershed = 10.606 grams/year total mercury
LT_m Moss Creek watershed = 3.203 grams/year total mercury
LT_m Lamine River watershed = 55.748 grams/year total mercury
LT_m Cooley Lake watershed = 0.056 grams/year total mercury

5.3.2 Methylmercury Load Calculation

URS then converted the load of total mercury in surface water (LT_m) to the load of methylmercury 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 = 10.606 gm/yr total mercury * 0.15
= 1.591 gm/yr methylmercury

LT_{mm} Moss Creek watershed = 3.203 gm/yr total mercury * 0.15
= 0.480 gm/yr methylmercury

LT_{mm} Lamine River watershed = 55.748 gm/yr total mercury *
0.15 = 8.362 gm/yr methylmercury

LT_{mm} Cooley Lake watershed = 0.056 gm/yr total mercury * 0.15
= 0.008 gm/yr methylmercury

5.3.3 Methylmercury Concentration

URS calculated the water body methylmercury 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 methylmercury 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 methylmercury 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 methylmercury 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 Creek, Wakenda Creek, Lamine River, and Cooley Lake near the confluence of the creek, river, or lake with the next largest tributary (i.e., portions of the creeks, river, or lake that are assumed to be large enough to support a harvestable fishery). 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); 24.77 in/year (0.63 m/year) for the year of maximum predicted mercury deposition (2002)[18]

A_{ws} = Area of watershed (m^2); 951,796,993 m^2 Wakenda Creek; 235,904,819 m^2 Moss Creek; 6,793,636,918 m^2 Lamine River; 21,372,086 m^2 Cooley Lake

Calculated V_{fx} values are as follows:

V_{fx} Wakenda Creek = 951,796,993 m^2 * 0.63 m/year = 598,224,093 m^3/year

V_{fx} Moss Creek = 235,904,819 m^2 * 0.63 m/year = 148,271,057 m^3/year

V_{fx} Lamine River = 6,793,636,918 m^2 * 0.63 m/year = 4,269,941,296 m^3/year

[18] High Plains Regional Climate Centre for Kansas City WSMO AP, MO Monthly Total Precipitation Listing http://hprcc1.unl.edu/cgi-bin/cli_perl_lib/cliMAIN.pl?mo4358

V_{fx} Cooley Lake = 21,372,086 m^2 * 0.63 m/year = 13,432,798 m^3/year

Resulting surface water methylmercury concentrations are:

C_{wtot} Wakenda Creek = 1.591 gm/yr methylmercury / 598,224,093 m^3/yr = 2.7E-9 gm/m^3 = 2.7E-3 ug/m^3

C_{wtot} Moss Creek = 0.481 gm/yr methylmercury / 148,271,057 m^3/yr = 3.2E-9 gm/m^3 = 3.2E-3 ug/m^3

C_{wtot} Lamine River = 8.362 gm/yr methylmercury / 4,269,941,296 m^3/yr = 2.0E-9 gm/m^3 = 2.0E-3 ug/m^3

C_{wtot} Cooley Lake = 0.008 gm/yr methylmercury / 13,432,798 m^3/yr = 0.63E-9 gm/m^3 = 0.63E-3 ug/m^3

Converting to ug/L:

C_{wtot} Wakenda Creek = 2.7E-3 ug/m^3 * 0.001 m^3/L = 2.7E-6 ug/L

C_{wtot} Moss Creek = 3.2E-3 ug/m^3 * 0.001 m^3/L = 3.2E-6 ug/L

C_{wtot} Lamine River = 2.0E-3 ug/m^3 * 0.001 m^3/L = 2.0E-6 ug/L

C_{wtot} Cooley Lake = 0.63E-3 ug/m^3 * 0.001 m^3/L = 0.63E-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 methylmercury 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 methylmercury 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 50^{th} 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 methylmercury (USEPA, 2001), anglers typically consume a mixture of fish species from these three trophic levels.

Recommended BAF_{fish} for Methylmercury (USEPA, 2006)

Trophic Level 2	Trophic Level 3	Trophic Level 4
117,000	680,000	2,670,000

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

C_{fish} Wakenda Creek = 2.7E-6 ug/L * 2.67E+6 L/kg = 7.1 ug/kg
C_{fish} Moss Creek = 3.2E-6 ug/L * 2.67E+6 L/kg = 8.7 ug/kg

C_{fish} Lamine River = 2.0E-6 ug/L * 2.67E+6 L/kg = 5.2 ug/kg

C_{fish} Cooley Lake = 0.63E-6 ug/L * 2.67E+6 L/kg = 1.7 ug/kg

As a point of comparison, these fish tissue concentrations are considerably below the USEPA (2001) Water Quality Criterion comparison fish tissue value (300 ug/kg), the concentration USEPA considers safe for human consumption. However existing fish tissue samples collected by Federal and State agencies (See **Appendix B**) already exceed this Water Quality Criterion, which is the reason MHSS has issued fish advisories for the entire State of Missouri. The cumulative impact of the proposed facility's impact and existing conditions with regard to the Missouri Fish Advisory is addressed in **Section 5.6**.

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 methylmercury 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 = (7.1*0.087*0.001*365*30) / (70*10,950*0.0001) = 0.09

HI_{child} Wakenda Creek = (7.1*0.013*0.001*365*6) / (15*2,190*0.0001) = 0.06

HI_{adult} Moss Creek = (8.7*0.087*0.001*365*30) / (70*10,950*0.0001) = 0.11

HI_{child} Moss Creek = (8.7*0.013*0.001*365*6) / (15*2,190*0.0001) = 0.08

HI_{adult} Lamine River = (5.2*0.087*0.001*365*30) / (70*10,950*0.0001) = 0.07

HI_{child} Lamine River = (5.2*0.013*0.001*365*6) / (15*2,190*0.0001) = 0.05

HI_{adult} Cooley Lake = (1.7*0.087*0.001*365*30) / (70*10,950*0.0001) = 0.02

HI_{child} Cooley Lake = (1.7*0.013*0.001*365*6) / (15*2,190*0.0001) = 0.01

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.

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

5.6 Impacts on Missouri Fish Advisory

As identified previously, the risk assessment evaluated risks associated with the incremental increase in overall mercury levels that could be released from the Norborne power plant. In an attempt to address cumulative effects from all regional sources of mercury, including the proposed Norborne facility, URS evaluated the impact the increased mercury deposition in local waterbodies would have on historic fish mercury levels as analyzed by MDNR, MDC, and USEPA. As discussed in **Section Two**, these agencies have been collecting fish and analyzing the amount of mercury found in these collected fish. 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). But URS did calculate incremental mercury fish tissue concentrations for Lamine River and Cooley Lake using the methodology in **Section 5.1** through **5.4**. These two locations are the nearest two sampling points that have significant portions of their drainage areas within the area modeled. This incremental increase of mercury in fish tissue for the Lamine River near the Blackwater River was calculated to be 0.0052 ppm. The incremental increase of mercury in fish tissue for Cooley Lake was calculated to be 0.0017 ppm. The measured mercury in fish was 0.023 and 0.130 ppm for whole fish (carp) samples taken in the Lamine River and 0.620 for ppm for a fillet sample (large mouth bass) taken in Cooley Lake. Based upon the current DHSS fish advisory[20] and USEPA's guidance[21] the number of recommended fish meals per month will not change.

[20] Found at www.dhss.mo.gov/NewsAndPublicNotices/07FishAdvisory.pdf

[21] United States Environmental Protection Agency (USEPA). “Origin of 1 Meal/Week Noncommercial Fish Consumption Rate in National Advisory for Mercury.” Technical Memorandum. 11 March 2004.

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 were used throughout the evaluation process. These assumptions are likely to overestimate the potential impacts. 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., 2002 data, which produced the highest predicted mercury deposition rates).
- 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 portions (4 ounces each) per week, and that all of that fish originates from the impacted watershed (i.e., that 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 portions (4 ounces each) 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 methylmercury 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

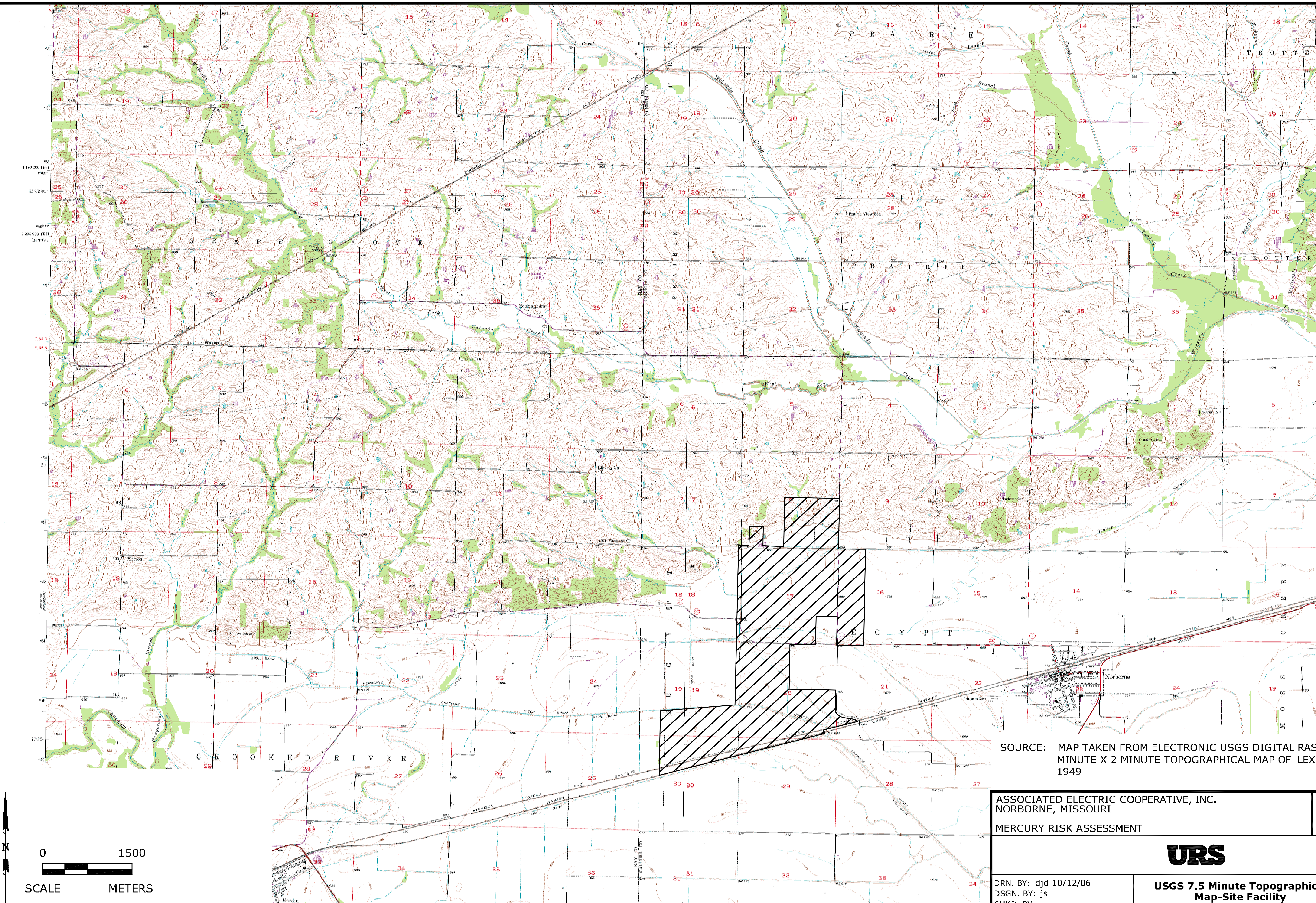
most anglers would be expected to eat a variety of fish from different trophic levels, with a lower overall methylmercury concentration.

- 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 resulted in an 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 kilometers of the proposed plant and the incremental effect the mercury released by the proposed plant would have on mercury levels in those fish. Based on this evaluation, there would be no change in the current MHSS Fish Advisory due to the incremental increase of mercury in the fish, due to the construction of the facility.

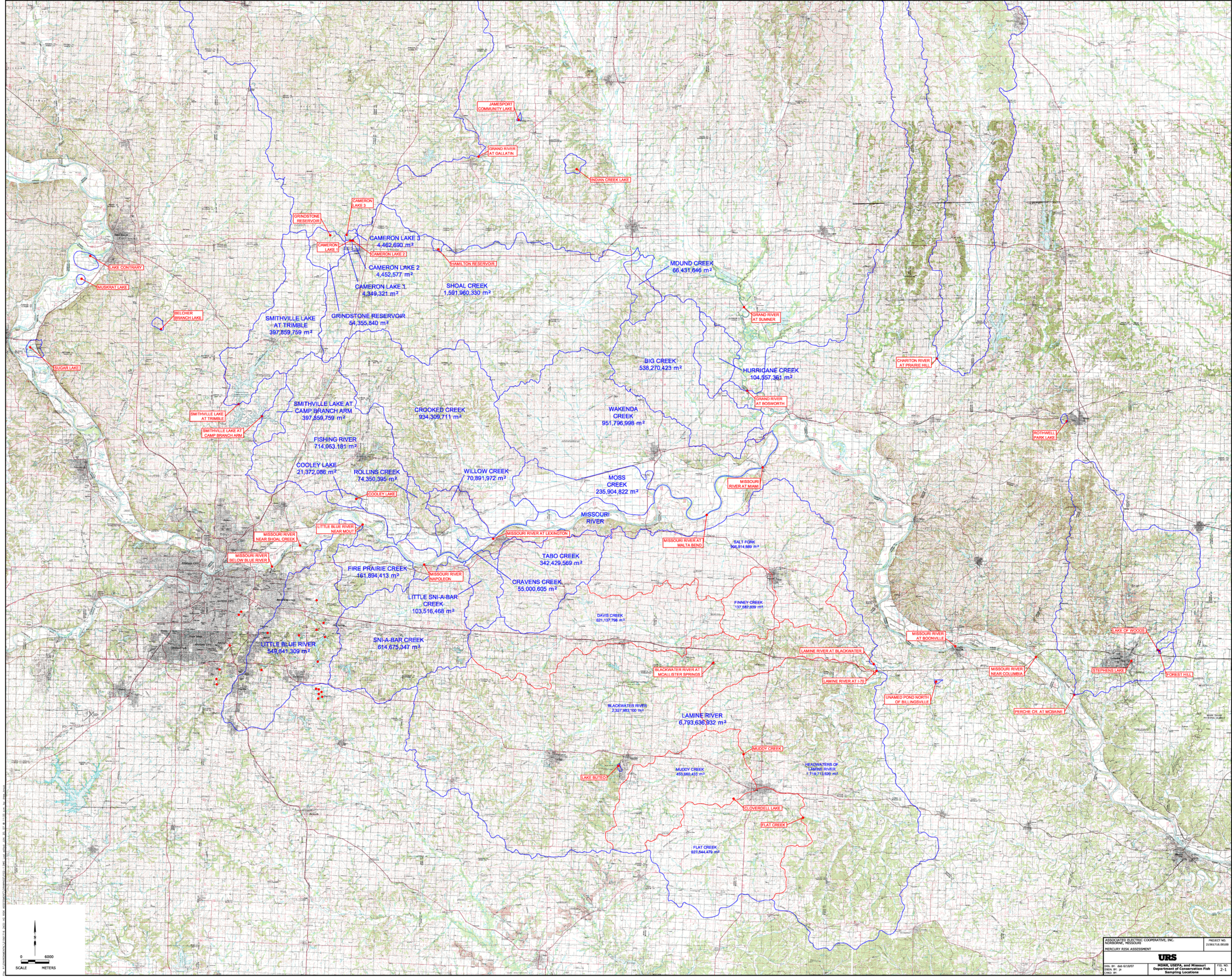
Figures



SOURCE: MAP TAKEN FROM ELECTRONIC USGS DIGITAL RASTER GRAPHIC 1 MINUTE X 2 MINUTE TOPOGRAPHICAL MAP OF LEXINGTON MO 1949

ASSOCIATED ELECTRIC COOPERATIVE, INC. NORBORNE, MISSOURI MERCURY RISK ASSESSMENT	PROJECT NO. 21561716.00100
URS	
DRN. BY: djd 10/12/06 DSGN. BY: js CHKD. BY:	**USGS 7.5 Minute Topographical Map-Site Facility** — FIG. NO. 1-1

File: P:\ENVIRONMENTAL\21561716 (AECI HG RISK ASSESSMENT)\DRAWINGS\FIG1-1 POTENTIAL WETLAND PLOTS EXAMINED.DWG Last edited: OCT. 16, 06 @ 09:06 a.m. by: dobrouk0



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DRN. BY: dab 6/18/07
DSGN. BY: js
CHKD. BY:

MDNR, USEPA, and Missouri Department of Conservation Fish Sampling Locations

FIG. NO. 2-1