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RADIOLOGICAL AND CHEMICAL UPTAKE IN GAME SPECIES AT THE WELDON SPRING SITE

Weldon Spring Site Remedial Action Project
Weldon Spring, Missouri

JULY 1995 **REV. 1**

U.S. Department of Energy
Oak Ridge Operations Office
Weldon Spring Site Remedial Action Project

Prepared by MK-Ferguson Company and Jacobs Engineering Group

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Revision 1

July 1995

Prepared by

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for the

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office
Under Contract DE-AC05-86OR21548

TABLE OF CONTENTS

NUMBER		PAGE
1	INTRODUCTION	1
1.1	Site History	1
1.2	Purpose	3
1.3	Sampling Rationale	5
1.3.1	Study Objectives	5
1.3.2	Sampling Locations and Contaminants of Concern	6
1.3.2.1	Aquatic Habitats	6
1.3.2.2	Terrestrial Habitats	11
1.3.2.3	Exceptions	13
1.3.3	Species	14
1.3.4	Summary of Biouptake Program	15
2	METHODS	17
2.1	Field Methods and Sampling Locations	17
2.1.1	Fish	17
2.1.2	Waterfowl	18
2.1.3	Small Mammals	19
2.1.4	Large Mammals	19
2.2	Analytical Methods	20
2.3	Quality Control	21
3	RESULTS	22

TABLE OF CONTENTS (Continued)

NUMBER **PAGE**

3.1 Fish 22

3.1.1 Radiological Analysis 23

3.1.1.1 Uranium 23
3.1.1.2 Radium and Thorium 29

3.1.2 Polychlorinated Biphenyls 30
3.1.3 Metals 30
3.1.4 Quality Assurance Samples 31

3.2 Waterfowl 34
3.3 Small Mammals 35
3.4 Large Mammals 35

4 DATA INTERPRETATION 39

4.1 Significance and Comparative Review of Data 39

4.1.1 Radionuclides 39
4.1.2 Metals 43

4.2 Bioaccumulation 44
4.3 Dose and Risk Assessment 46

4.3.1 Radiological Compounds 46
4.3.2 Chemical Compounds 50

4.3.2.1 Daily Intake Levels 50

TABLE OF CONTENTS (Continued)

NUMBER	PAGE
5 CONCLUSIONS	53
6 REFERENCES	57

APPENDIX

A Data Results
B Kruskal-Wallis Statistical Results
C Unpublished Documents

LIST OF FIGURES

FIGURE		PAGE
1-1	Weldon Spring Site Area	2
1-2	Surface Water Ponds at the Weldon Spring Chemical Plant Area	7
1-3	Surface Water Habitats at the Weldon Spring Quarry Area	8
1-4	Terrestrial Sampling Areas at the Weldon Spring Site	12

LIST OF TABLES

TABLE		PAGE
1-1	Summary of 1987 - 1993 Surface Water Data for the Weldon Spring Site and Vicinity Areas	9
3-1	Average Uranium Concentrations (pCi/g) in Fish Sampled 1987 - 1993	24
3-2	Metals Results for Mixed Fish Species Composite* Fillet Samples, 1987	32
3-3	Concentration of Metals (μg/g) in Fish	33
3-4	Results of Metals Analysis in Deer Tissue Samples (μg/l) from 1992	36
3-5	Radionuclide Concentrations in White-Tail Deer from the Weldon Spring Chemical Plant	37
4-1	Comparison of Uranium (pCi/g) in Fish 1977 RETA Study vs. 1987 - 1993 Weldon Spring Site Remedial Action Project (WSSRAP)	42
4-2	Comparison of Total Uranium (pCi/g) Concentration in Fish, 1984 MDC and 1987 - 1993 WSSRAP	42
4-3	Comparison of Total Uranium Concentrations, Femme Osage Slough	43
4-4	Comparison of Metals Data from Busch Lake Fish Surveys	45
4-5	Comparison of Bioaccumulation Factors for Uranium	47

ABSTRACT

Biouptake studies have been conducted as part of *Comprehensive Environmental Response, Compensation and Liability Act* and *National Environmental Policy Act* requirements for the Weldon Spring Site Remedial Action Project. Studies were conducted to determine what game biota are exposed to contaminants from the Weldon Spring site and the potential risk to public health associated with human consumption of exposed biota. In addition, environmental monitoring programs under U.S. Department of Energy Order 5400.1 require assessment programs to monitor contaminant levels in biota. Surface water and soils at the chemical plant have shown elevated levels of uranium, thorium, arsenic, lead, polychlorinated biphenyls (PCBs) and nitroaromatics. Lake sediments and surface water in the surrounding conservation areas have shown elevated levels of uranium, lead, mercury, and arsenic. PCBs were detected at 0.2 μg/g in one of three sediment samples from Lake 36, and 2,4-Dinitrotoluene (DNT) was detected at 0.58 μg/l in Lake 35 surface waters in 1988.

Fish samples were collected at surrounding lakes, and several mammal and waterfowl samples were collected from the immediate plant area. Sunfish in August A. Busch Memorial Conservation Area Lakes 35 and 36 were found to have detectable concentrations of radiological contaminants that were statistically higher than background locations. No PCBs were found in fish tissue samples analyzed in 1987 studies. Deer and waterfowl samples were shown to exhibit low levels of radionuclides in organ, bone, and tissue samples. No detectable concentrations of radionuclides or metals were found in small mammal samples collected in 1987.

Historically, mercury, arsenic, and lead levels detected in fish samples from the Busch Lakes were at levels considered to be of potential risk to subsistence fishermen (Mellard, Appendix C). Additional sampling of fish from the Busch lakes was conducted in 1989, 1992, and 1993. The daily consumption rate for subsistence fishermen was recalculated based on new lake-use data provided by the Missouri Department of Conservation. The Agency for Toxic Substances and Disease Registry determined that consumption of fish from the Busch Area does not significantly increase the daily intake of metals. It has been determined that elevated levels of arsenic, mercury, and lead in the Busch area lakes are not attributable to former Weldon Spring Chemical Plant operations (Ref. 1).

Bioaccumulation factors are used to express potential concentrations of contaminants in biota when measured data are not available. Radionuclide bioaccumulation factors were calculated as part of the biouptake studies and were found to be within standards developed by the National Council on Radiation Protection. Dose calculations were also determined for human consumption of fish and were found to be less than 0.1 mrem of uranium per year. Dose to subsistence fisherman, expected to frequent the lakes more often, was 0.40 mrem/year. Doses from waterfowl and deer range from 0.05 mrem to 0.57 mrem per year. The total radiological and chemical risk for increased probability of cancer was calculated at 5×10^{-5} for an avid sportsman assumed to hunt on-site and fish in the August A. Busch Memorial Conservation Area (Ref. 1). This estimate is within the acceptable range of 10^{-4} to 10^{-6}, based upon U.S. Environmental Protection Agency target risk values.

1 INTRODUCTION

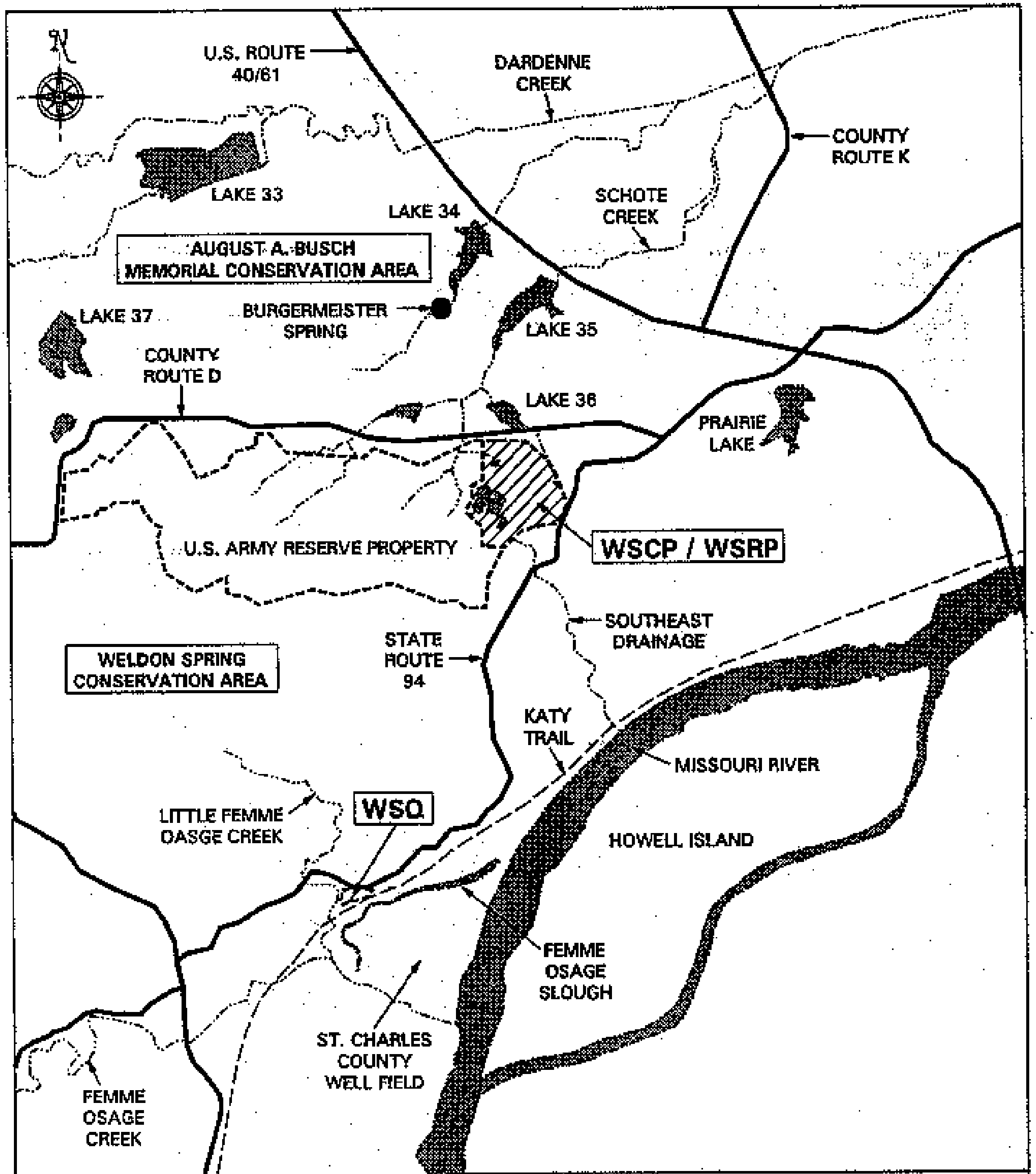
A biouptake study was initiated in 1987 to investigate concentrations and potential exposures of chemical and radiological contaminants to humans by ingestion of fish and game animals exposed to contaminants from the former Weldon Spring Uranium Feed Materials Plant (Ref. 2). The Weldon Spring site is surrounded by 5,805-ha (14,343 acres) of state conservation areas including the August A. Busch Memorial Conservation Area to the north and the Weldon Spring Conservation Area to the south and east. (Figure 1-1). These areas are open to the public for recreational activities including hunting, fishing, and biking. The number of annual visitors to both areas totals 1,200,000 (Ref. 1).

Questions also have been raised during public meetings concerning the potential biouptake of contaminants by biota and the safety of human consumption of animal tissue taken from these wildlife areas (Ref. 3, 4). Game animals such as deer, squirrel, and waterfowl occur within the boundaries of the Weldon Spring site and may migrate on and off site. These animals are exposed to contaminated soils, sediments, and water on site and to contaminated sediments and water leaving the site by natural drainage channels. Fish in the lakes that receive drainage from the Weldon Spring site are also a source of exposure to the public.

This document presents the results of various biological investigations conducted by the U.S. Department of Energy (DOE) since 1987 at the Weldon Spring Site Remedial Action Project (WSSRAP). The document also summarizes the results of other biouptake studies conducted prior to 1987, and the results and conclusions presented by other agencies including the Environmental Protection Agency (EPA), the Agency for Toxic Substances and Disease Registery (ATSDR) and the Missouri Department of Conservation. This comprehensive summary was prepared to inform the public of the safety of human consumption of animal tissue and to define future monitoring activities for the WSSRAP.

1.1 Site History

The Weldon Spring site is a DOE surplus facility located approximately 48.3 km (30 miles) west of St. Louis in St. Charles County, Missouri. From 1941 to 1944, the U.S. Department of the Army (DA) operated the Weldon Spring Ordnance Works for production of trinitrotoluene (TNT) and dinitrotoluene. During this operation, small areas of the



WELDON SPRING SITE AREA

FIGURE 1-1

REPORT NO.:	DOE/OR/21548-426	EXHIBIT NO.:	A/VP/032/0794

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approximately 6,880 ha (17,000-acre) site were contaminated by TNT process materials. In 1954, 89 ha (220 acres) of the Ordnance Works property were transferred to the U.S. Atomic Energy Commission (AEC). From 1957 to 1966, the AEC operated a uranium processing facility on the site. During the operation of the Uranium Feed Materials Plant, the buildings, equipment, and some terrain of the plant site became contaminated with radionuclides in the U-238, U-235, and Th-232 transformation series.

The Weldon Spring Quarry is approximately 6.4 km (4 miles) south-southwest of the Weldon Spring Chemical Plant (Figure 1-1). Radioactive wastes were disposed of in the Weldon Spring Quarry by the AEC from 1958 to 1966 (Ref. 5). The DA also disposed of TNT process wastes in the Weldon Spring Quarry. A large portion of the AEC radioactive wastes were from the Mallinckrodt Chemical Works' Destrehan Street Feed Plant in St. Louis.

After closure of the chemical plant and quarry by the AEC, the Feed Materials Plant was reacquired by the Army in 1967. The Army partially decontaminated the buildings, dismantled some of the equipment, and began to convert the facilities for the production of herbicides. In 1969, prior to the Weldon Spring Chemical Plant becoming operational, the herbicide project was canceled. In 1985, the custody of the Weldon Spring Chemical Plant was transferred from the DA to the DOE. In conjunction with this transfer, the Weldon Spring Site Remedial Action Project was created as DOE Major Project Number 182. In October of 1985, the EPA proposed to include the Weldon Spring Quarry on the National Priorities List and in June 1988, the EPA expanded this designation to include the raffinate pits and chemical plant area. In 1989, both areas were designated as the Weldon Spring site.

1.2 Purpose

This document is a technical summary of various biological investigations conducted since 1987 at the Weldon Spring Site Remedial Action Project. The studies were developed based upon various needs including requirements to support DOE Orders 5400.1, *General Environmental Protection Program* and 5400.5, *Radiation Protection*; to provide data to support human health and ecological risk assessment requirements under the *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA); and to respond to public concerns.

As part of the CERCLA process, an assessment of potential public health risks of contaminants is conducted. As part of the health risk assessment, land-use scenarios were developed to determine actual pathways of exposure to humans. Data from environmental media and modeled assumptions are used in the risk calculations. The type, extent, and levels of contaminants in soils, sediments, surface water, and groundwater at the site were determined by extensive sampling and are presented in the *Remedial Investigation for the Weldon Spring Site Chemical Plant Area* (Ref. 5) and in site environmental reports (Ref. 6, 7, 8). Typically, these data are used to estimate concentrations in biota (bioaccumulation factors) and in turn are used to calculate dose estimates to humans under modeled assumptions.

While standard bioaccumulation factors are developed for some biota, these standards are limited in their use since variability in geographic conditions, species, and habitat are not accounted for. It is preferable to determine contaminant concentrations in biota, if possible, in order to more closely estimate the dose to humans. This method is described as a measured dose estimate as opposed to the modeled dose estimates. Based upon the dose estimates received, a decision is made as to whether consumption of exposed biota is within EPA-designated acceptable risk range.

Biouptake studies are also conducted to monitor environmental conditions as required by DOE Order 5400.1. Sampling is conducted as an environmental surveillance activity so that the Weldon Spring site has the ability to "detect, quantify, and adequately respond to unplanned releases of radioactive materials." In addition, work practices for remedial activities are designed to institute preventative measures. Routine monitoring of environmental media such as surface water and air evaluate the success of these work practices. The periodic sampling of biota ensures that species are safe for human consumption. DOE Order 5400.5 requires that an effective dose be calculated to monitor if radiological exposure is less than 100 mrem per year from all exposure pathways including consumption of biota. Measurements of surface water concentrations are conducted to support health protection at off-site public areas.

No risk assessment is performed as a part of this document; instead the risk assessment is presented in the *Baseline Risk Assessment for the Weldon Spring Chemical Plant Area* (Ref. 1) and excerpts are presented in this document. Other historic biological sampling efforts will be included as part of the discussion of the Weldon Spring site biouptake studies.

1.3 Sampling Rationale

Various limits or criteria were established for DOE biouptake studies. Justifications are provided in the following paragraphs for study objectives, sampling locations, contaminants of concern, and species sampled.

1.3.1 Study Objectives

The various biouptake studies developed for the Weldon Spring site were not designed to serve as a comprehensive evaluation of all levels of the food chain. The 1987 biouptake studies were originally designed to serve as a screening process to identify the ranges of concentrations of some chemical and radiological constituents in the few fish and game species consumed by humans (Ref. 2). Primarily, edible portions of biota were collected and analyzed. Later studies, including waterfowl and deer sampling, were conducted to support data gaps for CERCLA human health assessments. Waterfowl and white-tailed deer frequently use on-site areas, migrate on and off-site, and can potentially be taken by local hunters.

Agricultural lands comprise 17% of the surrounding wildlife areas and include such products as corn, milo, soybeans, and wheat. If a release were to occur, agricultural products could receive airborne radioactive air particulates or radiological compounds from surface water drainage. No surface waters with elevated radionuclides are used for irrigation of agricultural products. Portions of crops are left for wildlife consumption after harvest. The potential exposure to humans via wildlife consumption of agricultural products is a component of the total dose estimate. The sampling of agricultural products is directed by DOE monitoring requirements under Order 5400.5 and was initiated in 1991. The characterization program for agricultural products was conducted in 1991 and 1992 and results were presented in the *Weldon Spring Site Environmental Report for Calendar Year 1992* (Ref. 8). Although the agricultural products grown in the area are not produced for human consumption, a committed effective dose equivalent was calculated at 0.03 mrem/year (Ref. 8). This dose is well below the DOE guideline of 100 mrem per year and therefore, agricultural products are not considered a risk to humans. Further discussion on agricultural products is presented in site environmental reports.

Human consumption of wild plants does not occur at the Weldon Spring site and is considered minimal at the surrounding conservation areas.

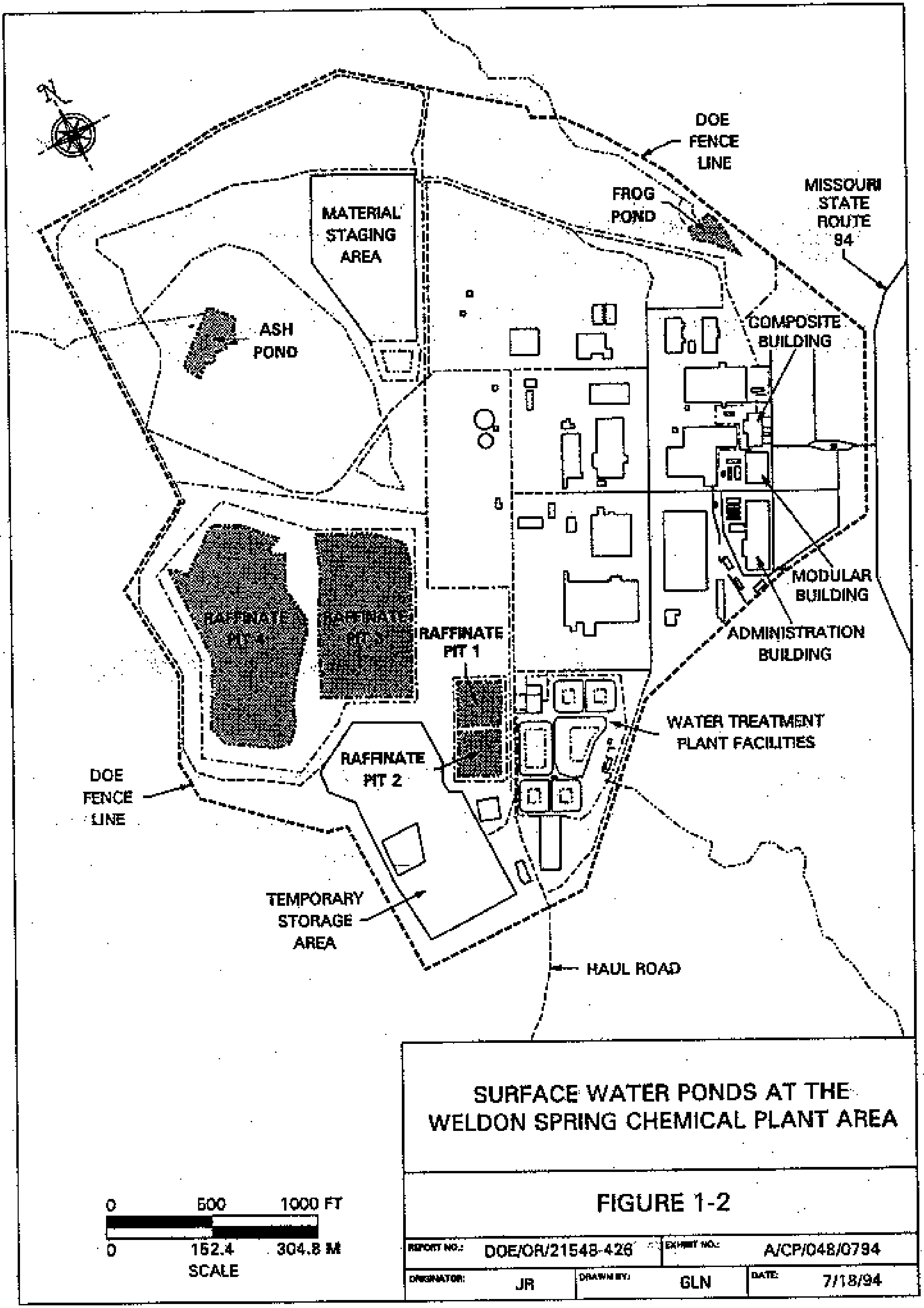
Therefore, the biouptake studies conducted at the Weldon Spring site have been limited to the sampling of fish, small mammals, large mammals, and waterfowl.

1.3.2 Sampling Locations and Contaminants of Concern

Remedial investigation (RI) activities conducted at the Weldon Spring site have provided data to determine the extent and level of contaminants in surface waters, soils, and sediments. The compounds examined under the RI were those historically used or produced on site and that may expose humans to these contaminants. The results of extensive sampling under the RI indicate that uranium, thorium, and radium are the primary contaminants of concern and are found in soil, surface waters, and sediments. In addition, the main chemical contaminants of concern are nitroaromatics, metals, and polychlorinated biphenyls (PCBs) found in soils and metals found in on-site sediments and surface waters. Off-site locations are contaminated with uranium and some metals in surface waters and sediments.

Although some habitats, primarily aquatic, are contaminated from the Weldon Spring site, the biouptake investigation focused on contaminated areas where game species would forage and live and could uptake contaminants, and where these game species might be caught, trapped, or hunted by the public.

1.3.2.1 Aquatic Habitats. Six surface water bodies exist at Weldon Spring Chemical Plant, one at the Weldon Spring Quarry, and five off site that are influenced by contaminant migration from the Weldon Spring site. Located at the Weldon Spring Chemical Plant are Ash Pond, Frog Pond, and four raffinate pits (Figure 1-2). Located at the Weldon Spring Quarry is the quarry pond. Off-site locations are the August A. Busch Memorial Conservation Area Lakes 34, 35, and 36 (Figure 1-1), the Femme Osage Slough, and Missouri River located in the Weldon Spring Conservation Area (Figure 1-3). Table 1-1 summarizes the radiological and chemical data for the aquatic habitats in each of these areas.



SURFACE WATER PONDS AT THE WELDON SPRING CHEMICAL PLANT AREA

FIGURE 1-2

REPORT NO.: DOE/OR/21548-426		EXHIBIT NO.: A/CP/048/0794	
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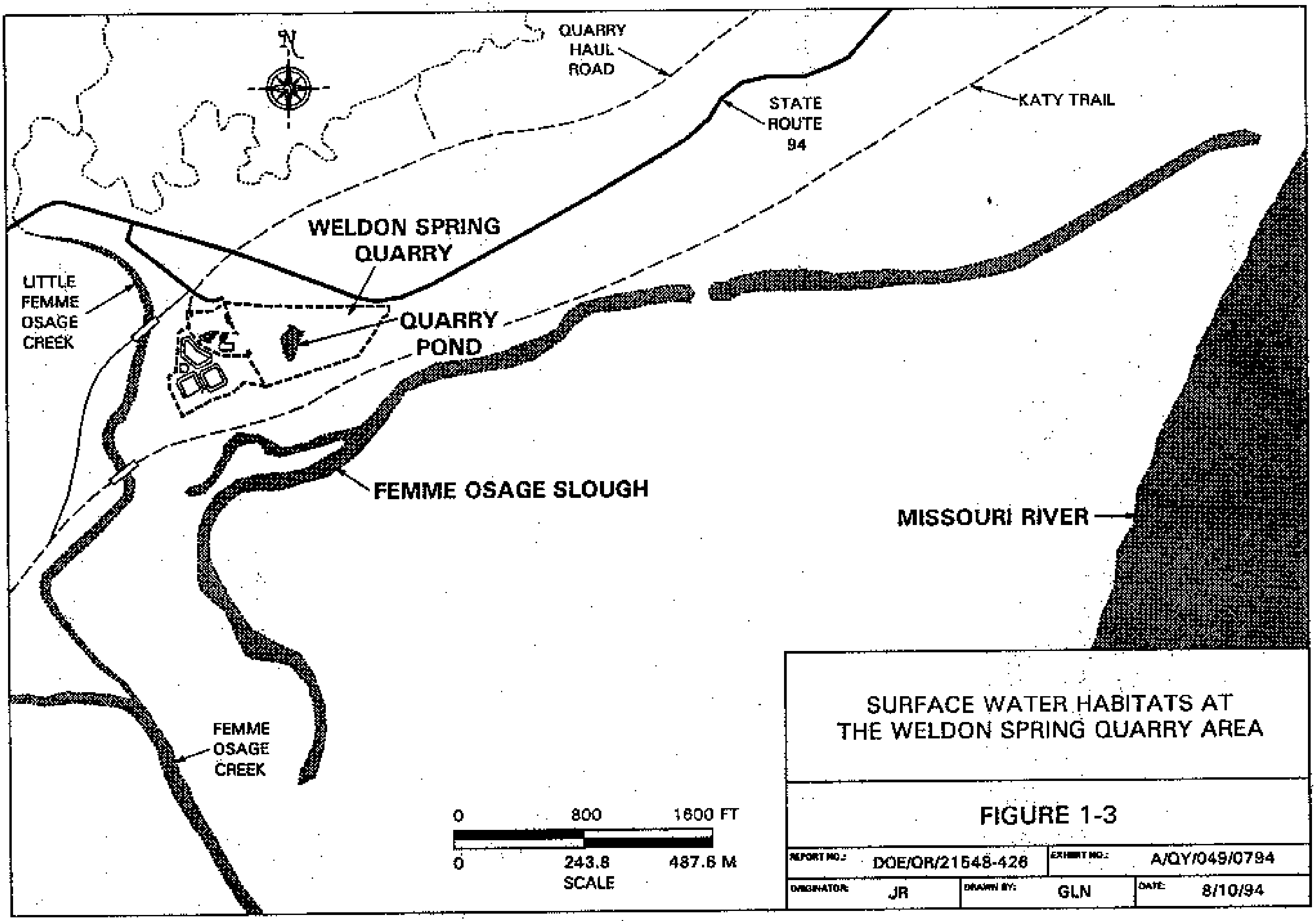

SURFACE WATER HABITATS AT THE WELDON SPRING QUARRY AREA

FIGURE 1-3

REPORT NO.: DOE/OR/21548-426		EXHIBIT NO.: A/QY/049/0794	
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TABLE 1-1 Summary of 1987 - 1993 Surface Water Data for the Weldon Spring Site and Vicinity Areas

Location	Uranium (pCi/l)	Nitrate (mg/l)	Sulfate (mg/l)	Arsenic (μg/l)	Barium (μg/l)	Chromium (μg/l)	Lead (μg/l)	Mercury (μg/l)	Zinc (μg/l)
Ash Pond	1655	3.65	45	< 10.0	< 200	25.5	(2.05)	1.8	26
Frog Pond	231	0.84	53	(2.82)	87	11.2	12.5	< 0.18	< 20
Raffinate Pit 1	184	520	307	15.6	< 200	24.2	7.30	< 0.20	< 20
Raffinate Pit 2	1074	63.6	641	89.3	< 200	23.7	(3.50)	(0.163)	< 20
Raffinate Pit 3	601	1250	462	< 10	< 200	41.9	52.7	< 0.20	20.9
Raffinate Pit 4	1569	360	144	(6.13)	< 200	9.55	91.1	< 0.20	37.0
Busch Lake 33 [bkg]	3.08	1050[a]	750[a]	5.65	87	(4.65)	2.7	< 0.17	< 19.4
Busch Lake 34	16.1	3.33	24.4	(2.93)	91	(5.04)	< 14	0.369	< 16.0
Busch Lake 35	18.8	2.56	16.3	(2.74)	60	(4.13)	(9.63)	(0.14)	53.3
Busch Lake 36	37.5	1.05	37.5	3.75	84.5	(4.93)	(12.9)	(0.181)	58.9
Busch Lake 37 [bkg]	1.00	3.72	NA	1.53	58.1	< 7.0	< 24	< 0.20	67.6
Femme Osage Slough	63.3	0.79	70	(2.73)	135	10.8	8.8	< 0.20	48.8
WS Quarry Pond	1585	75.4	269	(3.71)	114.5	16.5	7.09	< 0.20	< 31.8
Burgermeister Spring	71.3	363	42.9	< 4.70	104	(6.18)	< 3.00	(0.12)	13.9
Southeast Drainage	209	6.93	64.8	< 8.40	(102)	15.8	(3.48)	< 0.18	(16.3)

Average of DOE 5400 monitoring data from 1987 to 12/28/93 (from WIZZARD database) and surface water data from Brugam, 1992.
Averages in parathesis include uncensored data (data detected and reported at below the contract-required detection limits).

bkg background location.
a Data currently being validated.
NA Not analyzed for parameter listed.

Surface water runoff from the north and west sides of the Weldon Spring site flows to Ash Pond. Ash Pond is a natural drainage area impounded during construction of the uranium plant to slurry ash products. As a result, elevated levels of metals, uranium, and nitroaromatics are found in Ash Pond. The water level in Ash Pond fluctuates seasonally. An isolation dike was constructed as part of an Interim Response Action for the site in 1987 to reroute the on-site surface drainage around the Ash Pond slurry area, thereby reducing off-site discharge of contaminants. No sampling of fish from Ash Pond was conducted for the biouptake program since the pond dries up in late summer and it is not expected to support fish.

Surface water runoff from the northeast portion of the Weldon Spring site drains into Frog Pond. Frog Pond was constructed as a settling basin for cinder slurry from the coal-fired steam plant during uranium production. Frog Pond is contaminated with uranium and metals. Limited sampling was conducted in 1987 since there is no public access to Frog Pond.

Four raffinate pits are located within chemical plant boundaries and they cover approximately 10.5 ha (26 ac) (Figure 1-2). These pits were constructed as settling basins for radioactive residues (raffinate) from the uranium processing operations. Radionuclides, including uranium and thorium, are present in the surface waters and sludge sediments of the pits. The principal anions detected in the raffinate pit waters were nitrate, sulfate, and fluoride. Metals present in raffinate pit sludge include arsenic, calcium, lead, magnesium, nickel, and vanadium (Ref. 1). No nitroaromatics were found in the surface waters of the raffinate pits.

Off-site discharge of surface water and sediments is via Ash Pond and Frog Pond drainage. An intermittent creek runs from Frog Pond and flows north to the August A. Busch Memorial Conservation Area Lake 36. The outfall of Lake 36 discharges into Lake 35, to Schote Creek, to Dardenne Creek, and eventually to the Mississippi River. Ash Pond flows to Lake 35 in the August A. Busch Memorial Conservation Area, to Schote Creek, and Dardenne Creek, and eventually to the Mississippi River (Figure 1-1). Surface water and sediments of Busch Lakes 34, 35, and 36 are contaminated with uranium.

Groundwater below the chemical plant area also travels via underground connections to Burgermeister Spring, to Lake 34, to Dardenne Creek, and eventually to the Mississippi River. At present, there is no recreational use of Burgermeister Spring. No public fishing occurs and the drainage is not expected to support game species. Uranium is the major radioactive contaminant in surface water and sediment at Burgermeister Spring, and nitrate and nitroaromatic compounds are detected infrequently in Burgermeister Spring.

Discharge from the southeast portion of the site is toward a natural drainage to the Missouri River. This Southeast Drainage was not sampled, since no recreational fishing is conducted in the drainage and it is frequently dry.

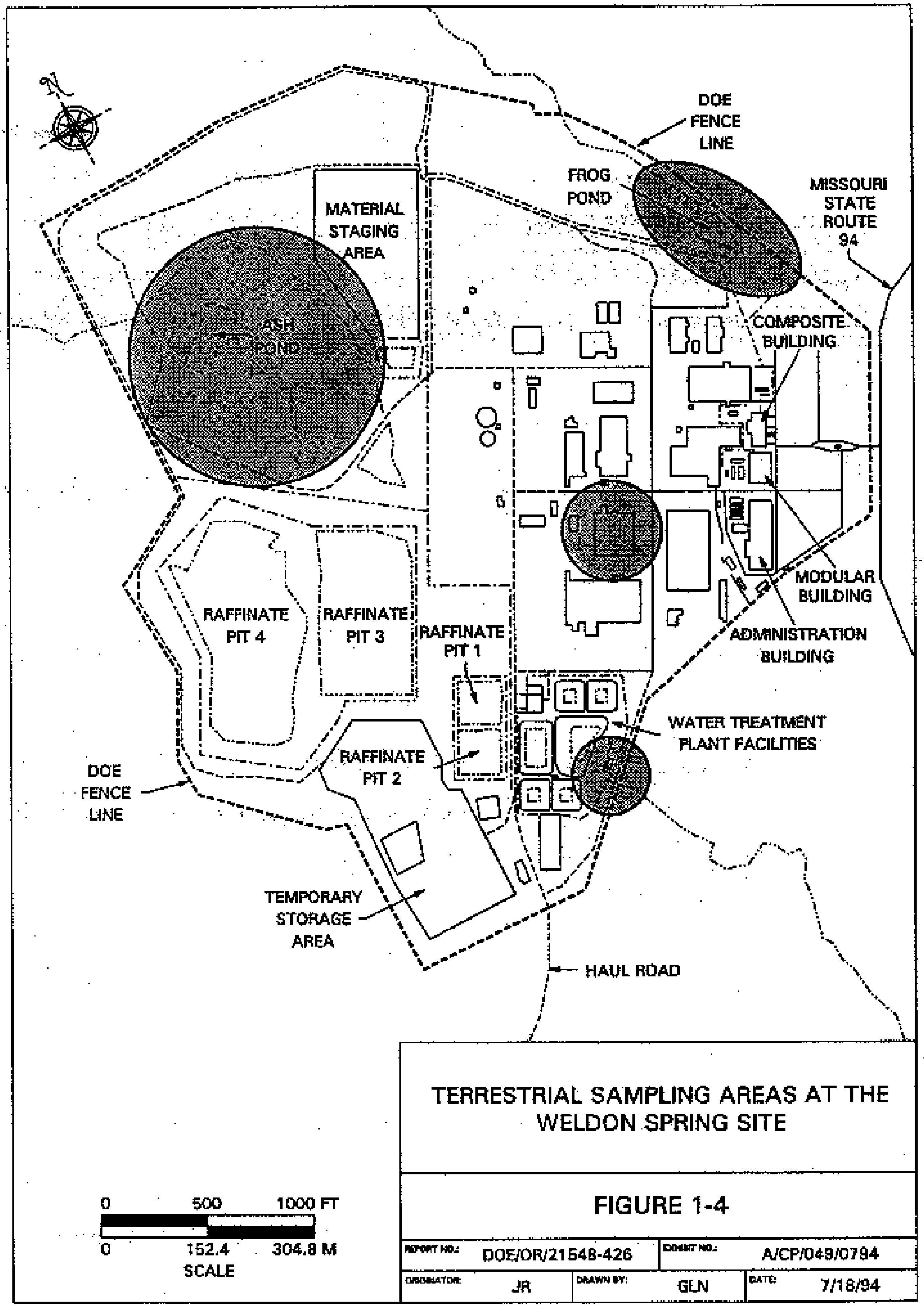
The Weldon Spring Quarry (Figure 1-3) is essentially a closed basin where surface water within the immediate area flows to the quarry floor and pond. The quarry pond covers approximately 0.2 ha (0.5 acres). The main contaminants include radionuclides, metals, semi-volatiles, and nitroaromatics. No public access is allowed at the Weldon Spring Quarry.

The Femme Osage Slough is located in the Weldon Spring Conservation Area, approximately 152.4 m (500 ft) south-southeast of the Weldon Spring Quarry (Figure 1-3). The slough is believed to be hydraulically connected to the quarry pond (Ref. 11). The slough is not used as a source of drinking water or for irrigation, but is frequently used for fishing. Elevated levels of uranium are found in the surface waters and sediments of the slough.

1.3.2.2 **Terrestrial Habitats.** Four terrestrial locations on the Weldon Spring Chemical Plant Area were selected for study in the biouptake program. These include Ash Pond, south dump areas, the buildings area, and the Frog Pond area (Figure 1-4). No off-site locations were studied since locations where contaminants occur are small, localized, and do not predominantly or exclusively support game species for shelter or foraging.

Radiologically contaminated soils at the Weldon Spring Chemical Plant are generally confined to the north and south dump areas, Ash Pond, the Frog Pond drainage, and to areas immediately surrounding the buildings. Uranium concentrations range from background levels of about 1 pCi/g to several thousand pCi/g. Most Ra-226 and Th-232 concentrations are at mean background levels (Ref. 12). Contaminated soils in these areas are also the major source of contamination to surface water via runoff.

PCB contamination at the Weldon Spring site is generally low with some localized hot spots in soils, such as in the area where the plant transformer pads were previously located. All releasable transformers were removed from the site in 1988. Some PCB contamination exists



TERRESTRIAL SAMPLING AREAS AT THE WELDON SPRING SITE

FIGURE 1-4

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within non-process buildings. Polyaromatic hydrocarbons (PAHs) are present in soils in the area previously used for coal storage. A few locations on site have low concentrations of nitroaromatics in soils, primarily in the Ash Pond area where TNT production and wastewater management facilities once existed.

Areas where elevated metal concentrations occur include the north and south dump areas, chemical plant buildings, and the coal pile area. Inorganic anions are found at low levels in some subsurface soils. The small areas where anions are found are not extensively distributed and are a low risk to biota (Ref. 1).

1.3.2.3 Exceptions. Chemical and radiological compounds found at elevated levels are known to affect the reproduction, growth, and development of biota. Some materials, such as PCBs and radionuclides, can accumulate within an organism or may metabolize in the body and form toxins, as is the case with nitroaromatic compounds. All contaminants of concern were studied in the biouptake program, with the exceptions listed below.

Nitroaromatics were initially considered for the 1987 biouptake study since they are present in low concentrations in on-site soils and because of the historic production of nitroaromatic compounds. Nitroaromatics were not analyzed in the 1987 biouptake study since analytical techniques for nitroaromatics were poor in 1987. The 1987 study found that there were no accepted methodologies for the analysis of nitroaromatic compounds in biological tissue. Recovery of target compounds following extraction procedures was estimated by the Subcontractor laboratory to be extremely low, and it was determined that TNT and dinitrotoluene (DNT) degradation products in the samples would probably not be detected. The lower limits of detection would not be low enough to consistently detect the concentrations anticipated (Ref. 2). Nitroaromatics have not been analyzed as part of the latter biouptake studies since areas of surface soil contamination are negligible and nitroaromatics degrade rapidly in surface waters. In addition, during preparation of the ecological risk assessment in 1992, little or no information was found on nitroaromatics and their affect on wildlife, and no determination of potential adverse ecological effects was made (Ref. 1.).

Volatiles and semi-volatiles were considered as part of the sampling, but were discounted because the distribution is limited to the quarry pond and some small soil areas related to coal storage and burn areas (Ref. 5). The quarry pond was and is generally inaccessible to waterfowl and large mammals and there is no public use of the quarry pond. No discharge of these compounds to other surface waters or soils is occurring from the quarry. Semi-volatiles and volatiles were detected in some soil samples, but were found to be common analytical contaminants or of low detection frequency in all samples and the contribution to overall site risk is insignificant (Ref. 1).

Inorganic anions including nitrate, sulfate, and fluoride are found at elevated levels in the raffinate pits. In 1987, little was known about the extent of on-site anions, and therefore, the initial biouptake study did not analyze these compounds in terrestrial or aquatic biota. Since then, remedial investigations have found elevated levels of ions to be primarily of concern to aquatic and semi-aquatic biota that use the raffinate pits. These anions accumulate in blood, bones, teeth, and digestive organs. Since these tissues are not consumed by humans, they are not expected to pose a threat. Therefore, anions were not included in the biouptake program.

No PAHs were found in surface waters or sludges in on-site raffinate pits or in off-site surface waters. Low levels of PAHs were found in on-site soils. PAHs are probable carcinogens by oral, inhalation, or dermal exposure (Ref. 1). While specific biota may be affected by PAHs, humans are not exposed to PAHs via consumption of biota (Ref. 1).

1.3.3 Species

The biota selected for study are important game species within the surrounding wildlife complex and are frequently observed at the chemical plant site or surrounding wildlife area. The biota included mammals (grey squirrels and eastern cottontail), waterfowl, and fish. Deer samples were taken when accidental deaths or hunter donations made deer available. Samples prepared for analyses were chosen considering the affinity of compounds for specific tissues or organs. Organs particularly affected by radionuclides include the liver, gizzards and kidneys. Whole body, fillet, tissue, fishcake, organs, and bone samples were prepared as if for human consumption.

The fish species chosen for study included channel catfish, bluegill, green sunfish, redear sunfish, largemouth bass, and crappie. These species also represent three different patterns of feeding and food preference of fish. Bluegill and green sunfish are omnivorous feeders, feeding on both plants and animals, and they are confined to shallow waters. Largemouth bass are predominantly piscivorous, feeding on other fish and insects, and they live in the deep, open waters of the lake, yet travel to the shallow areas to feed. Catfish are predominantly omnivorous feeders tending to forage and swim in the bottom waters of lakes. Catfish were expected to be the species most likely to exhibit contaminant uptake due to their forage behavior in lake sediments.

Small mammals selected for sampling in the 1987 study were *Sylvilagus floridanus*, the eastern cottontail and *Sciurus carolinensis*, the gray squirrel. Both are common game species and are frequently found on site. Habitat is available on site where these species could subsidize their diet or establish nests for young. Active squirrels nests have been sighted in trees on-site. Larger mammals such as the white-tailed deer, *Odocoileus virginianus*, were not sampled as part of a focused study due to the large sample size required to make conclusions on biouptake. Deer sampling is limited to specimens made available due to accidental death, including roadkills and hunter donations. The white-tailed deer is the largest mammal commonly hunted in Missouri.

Waterfowl selected for study included mallards, wood ducks, and Canada geese. These species were selected for sampling since they are common resident species in Missouri. Waterfowl survey data from 1991 indicate that mallards are most commonly seen as resident species on Raffinate Pit 4 during the summer months (Ref. 8). Mallards and Canada geese are the most common species found during the migratory season and in the winter months (Table A-9).

1.3.4 Summary of Biouptake Program

Fish were sampled and analyzed for radionuclides at on-site and off-site locations including Frog Pond and the Femme Osage Slough in the Weldon Spring Conservation Area, and Lakes 34, 35, and 36 at the August A. Busch Memorial Conservation Area. Metals and PCBs were also analyzed in fish samples from Lakes 34, 35, and 36.

Waterfowl from the Weldon Spring Chemical Plant were sampled where surface water and sediment radiological levels are elevated. Raffinate Pit 4 was also selected as the on-site sampling location since most individuals are known to use Pit 4. Waterfowl were analyzed for radionuclides. White-tail deer were sampled at the chemical plant area and the surrounding conservation areas, when available, and were analyzed for radionuclides and metals. Small game from contaminated soil areas at the chemical plant were sampled and analyzed for radionuclides and metals.

2 METHODS

Methods for collection of specimens are detailed in *Standard Methods for the Examination of Water and Wastewater* (Ref. 12), trapping guidelines by the Missouri Department of Conservation, and sampling protocol developed by the Nuclear Regulatory Comission. Other methods were taken from appropriate scientific research journals or current scientific practices.

2.1 Field Methods and Sampling Locations

2.1.1 Fish

Fish sampling was conducted from 1987 to 1993 at selected study sites. Fish were also sampled from lakes not influenced by site contaminants and these samples were used as background or control samples. Study sites were lakes 34, 35, and 36 in the August A. Busch Memorial Conservation Area and the Femme Osage Slough on the Weldon Spring Conservation Area. Lakes 33 and 37 in the August A. Busch Memorial Conservation Area were sampled as background or control locations. Lake 33 is located at the northwestern edge and Lake 37 is located at the western edge of the August A. Busch Memorial Conservation Area in a small, isolated watershed; neither receive runoff from the Weldon Spring site.

Specimens were collected using an electrofishing technique (Ref. 12). Electrofishing uses a gas-powered generator mounted in a boat to introduce an electric current into the water around the boat. Fish are temporarily stunned by the current, and then netted and placed in holding tanks in the boat. This work was accomplished under the provisions of the Missouri Department of Conservation (MDC). Sampling was conducted in the spring of each year, during the day (except for Lake 34 where lake clarity requires nighttime sampling). In 1992, the MDC conducted gill net sampling and the U.S. Department of Energy obtained catfish fillet samples for analysis.

Fish were collected annually from each location based on the species, size, and number of fish available. Specific species available annually included bass, sunfish, and catfish. Crappie and carp are stocked in some lakes, and if an adaquate number and mass of fish were collected, samples were prepared for analysis. Fillet samples were prepared for analysis as a priority if number or size of fish was limited. During some years, the individual fish were too small to prepare as fillet samples, so whole or fish cake samples were prepared instead. Some species were also composited according to taxonomic family for analysis. Bluegill, redear, and green sunfish were composited and channel catfish and yellow bullhead were composited, if adequate sample size was not collected. Since crappie are abundant in the Femme Osage Slough and in some Busch lakes, these fish were also taken for samples.

In all years except 1987, samples were prepared as whole body, fillet, and fishcake samples. Fishcake samples are cleaned, beheaded, scaled, and eviscerated specimens. In 1987, fillet and fishcake samples were sent to a subcontracted laboratory to be analyzed for total uranium, Ra-226, and isotopic thorium. In 1987, mixed fillet composites were analyzed for polychlorinated biphenyls (PCBs) and U.S. Environmental Protection Agency (EPA) Contract Laboratory Program (CLP) metals. In 1988 to 1993, whole body, fillet, and fishcake samples were analyzed for isotopic uranium and in 1992 and 1993, for mercury, arsenic, and lead. Catfish livers were prepared in 1991 from samples collected from Lake 35.

Fish were cleaned and samples prepared within 1-2 days of sampling. Fishcake, composite (1987), and fillet samples typically consisted of a minimum of three fish with a total sample weight of approximately 800 g. Whole body samples typically consisted of a minimum of one to two fish or a total sample weight of approximately 1,000 g. Samples were placed in plastic bags, weighed, labeled, and frozen prior to shipment to the analytical laboratory.

2.1.2 Waterfowl

Sampling of waterfowl was conducted in October 1990, at the Weldon Spring Chemical Plant area. Raffinate Pit 4 was selected for sampling since usage of Raffinate Pit 4 is significantly higher than any other aquatic habitat on site (Table A-9) (Ref. 6).

Since St. Charles County is along the Mississippi flyway, a major north-south route for migratory North American birds (Ref. 1), up to 295 bird species have been reported from this area. Up to nine waterfowl species are reported as common or abundant during migratory season (Ref. 13). The Canada goose, the mallard and the wood duck were selected for sampling since they are classified as common residents in St. Charles County during at least three seasons of the year and are probable nesting species (Ref. 13). Since no survey was conducted prior to sampling of waterfowl to document the duration of time spent on site, residency of the individuals collected is not known.

Sampling was conducted in the early morning (6:00 am to 9:00 am). Individuals were identified as to species, selected for sampling, and then flushed from the pit interior. Birds were collected using a 12-gauge shotgun. Samples were dressed and separated into tissue and organ (heart, liver, gizzard) samples. All samples were analyzed for isotopic uranium, thorium, and radium.

2.1.3 Small Mammals

Small game mammals (eastern cottontail and gray squirrels) were collected from the Weldon Spring Chemical Plant in 1987 and 1988. Samples were first obtained by trapping using various bait material. Trapping was concentrated in three areas for game animals including the South Dump/Ash Pond area, Frog Pond area and the chemical plant buildings. Trapping was not as effective for some areas and samples were later obtained by hunting on site. Hunting was used to obtain samples from areas around the chemical plant buildings (refer to Figure 1-4).

Small mammal composite samples consisted of three specimens collected from each location. Specimens were cleaned, placed in plastic bags, labeled, frozen, and sent to the laboratory. Small mammal samples were split into tissue and bone subsamples by the laboratory and analyzed for total uranium, Th-230/232, and Ra-226. Small mammal samples were not analyzed for PCBs and metals as planned (Ref. 2), since there was not sufficient sample mass to provide the necessary volume for analysis.

2.1.4 Large Mammals

Large game animals such as deer were not originally planned for sampling in biouptake studies due to the difficulty in obtaining an adequate number of specimens. During construction at the material staging area and retention basin at the chemical plant in 1991, a male white-tailed deer wandered into the basin and was injured. MDC officials destroyed the deer and samples were taken for analysis. In 1992, other deer samples from on-site, off-site, and background locations became available for analysis due to accidental deaths and hunter donations.

Deer samples were prepared within 1 day of death by separating specimens into tissue, bone, select organs (heart, liver, kidneys), and antler samples when available. The samples were frozen and shipped to a subcontractor laboratory for analysis. All samples were analyzed for isotopic uranium, isotopic thorium, Ra-226, and Ra-228. In 1992, additional tissue was available and analyzed for specific metals. The metals selected for analysis were defined as toxicity metals, those particularily toxic to human and biological organisms. These metals were arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, and zinc.

2.2 Analytical Methods

Laboratory analytical methods used for the biouptake study generally followed the same procedures as those used for water samples. The main differences were in the sample preparation procedures. Fish samples analyzed for radionuclides and CLP metals were freeze dried and ashed or digested in concentrated hydrochloric acid and then diluted to one liter before analysis.

Small mammal composite samples and deer samples sent to the laboratory for analysis were separated as bone, soft tissue, or organ portions, and then prepared for analysis according to Eastern Environmental Radiation Facility procedures (Ref. 14). These procedures included ashing the samples at 550°C for 72 hours in a muffle furnace, followed by treatment with various carriers, tracers, and acids prior to the actual analyses.

All samples were analyzed by the following methods: isotopic and total uranium were analyzed according to EPA methods 908.0 and 908.1 and RL-2322 and RL-2323; isotopic thorium by EPA 00/07 907 and RL-2318; and Ra-226 by EPA 903.0 and RL-2313. Variation in numbers is a result of modification in methods over the 5-year sampling period. All analytical methods were reviewed by quality assurance and control audits prior to analysis of samples. Metals were analyzed by SW-846 graphite furnace atomic absorption or by EPA CLP indirectly coupled plasma analysis. PCBs were analyzed using CLP Test Method 608, using fish tissue that was not acid-digested.

2.3 Quality Control

The use of quality control samples is required as part of all sampling programs at the Weldon Spring site. Quality control samples are used to assess sampling performance, laboratory performance, and analytical precision. Quality control samples, including duplicate samples, laboratory duplicables and matrix duplicates, are taken for surface water under a routine environmental monitoring program. Details on quality control sampling are further described in site environmental reports (Ref. 7, 8).

Field replicate samples were taken during each sampling event and were prepared in the same manner as the test samples and were also sent to the laboratory for analysis. Approximately 16% of fish samples were taken as replicates and 18% were taken for small mammals. One replicate was taken for deer samples and one field replicate for waterfowl. All quality control samples were compared to test samples, and relative percent differences were calculated as part of the data review process. Results are presented in Section 3.1.4.

3 RESULTS

3.1 Fish

Over 190 fish samples have been collected and analyzed over the last 7-year period. Of these, approximately 41% were fillet samples, 19% were fishcake samples, and 37% were whole body samples. The remaining 3% were composite and organ samples taken in 1987 and 1991.

Species found and collected at sampling locations were common game species including largemouth bass, *Micropterus salmoides*; channel catfish, *Ictalurus punctatus*; bluegill, *Lepomis macrochirus*; and green sunfish, *Lepomis cyanellus*. Other species taken as samples were common in each lake area as reflected by the electrofishing efforts. These variations are attributable to stocking and management practices, limnological features of the lakes and the slough including water depth, water origin, and shoreline area. White crappie, *Pomoxis annularis* and black crappie, *Pomoxis nigromaculatus* were the predominant sunfish in Lakes 33 and 35, and therefore, were used for analysis instead of bluegill and green sunfish.

Carp, *Cyprinus sp.* was sampled from Lake 33 and bigmouth buffalo, *Ictiobus cyprinellus* and yellow bullhead, *Ameriurus natalis* from the Femme Osage Slough. The fish community in Femme Osage Slough is different than that in the Busch Lakes due to the influence of the Missouri River. The water level in the slough is controlled by a pipe and valve which normally is left open, but is closed when the level reaches the basin rim. Because of this, species of fish routinely found in big river habitats such as the Missouri River, are found in the slough. A list of all species recorded from electrofishing surveys of the study areas is shown in Table A-1 of Appendix A.

In 1987, when Frog Pond was sampled, only small sunfish were collected during electrofishing efforts. Most of the fish from Frog Pond were small in size and a limited number were available. Only cleaned sunfish composite samples (fishcakes) were prepared and analyzed for radionuclides. Electrofishing was conducted at Raffinate Pits 3 and 4 and from the quarry pond. No fish were present or collected as a result of sampling these ponds. Sampling was discontinued for these areas in 1988 due to lack of public access and absence of fish.

In 1992, the MDC collected fish samples from Busch Lakes 35 and 37 using gill net sampling methods. Gill nets were set to specifically select catfish. Since catfish is a bottom-dwelling species and omnivorous feeder, it is more likely that this species will accumulate higher concentrations than other species. The U.S. Department of Energy (DOE) was provided with catfish samples and fillet samples were prepared for analysis of metals and total uranium. The analytical data results from the gill net sampling are presented in Table A-2. Since the analytical data results are not notably different from the concentrations reported using electrofishing collection methods, no additional gill net sampling will be conducted for DOE analysis.

3.1.1 Radiological Analysis

3.1.1.1 Uranium. Annual concentrations of uranium and 5-year average concentration in fish samples collected from 1987 to 1993 are shown in Table 3-1. Data are presented as total uranium concentrations with detection limits ranging from 0.0001 pCi/g to 0.11 pCi/g. Samples were analyzed for Th-230 and Th-232 concentrations and the detection limits ranged from 0.02 pCi/g to 0.7 pCi/g. Samples were also analyzed for Ra-226 with detection limits ranging from 0.003 pCi/g to 0.3 pCi/g. All non-detect data results are presented and used in calculations as half of the detection limit (DL/2) according to EPA guidance (Ref. 15). All results are presented as wet weight concentrations. Summary statistics including total samples, range, and standard deviation are shown in Table A-3 of Appendix A. All standard deviations were shown to be below 1.

In 1987, all samples showed no detectable concentrations of radionuclides at the respective detection limits. Of the samples taken in 1987, 75% were fillet samples and the remaining were fishcake samples. In 1988 - 1993 sampling, the detection limits were lower and whole body samples were added to the sampling program. As a result, radionuclides were detected at low levels in 1988 - 1993 samples. In 1992, all samples were analyzed at 0.3 pCi/g, above the detection limits used in previous years. The 1992 samples were all reanalyzed with lower detection limits. As a result, data from the first analysis in 1992 were not used in any calculations or averages.

The highest average uranium concentrations for 1987 - 1993 samples in all lakes were found in whole catfish samples (0.933 pCi/g) and whole sunfish samples (0.434 pCi/g) from Busch Lake 36. Fillet samples from all sampling locations averaged from 0.002 pCi/g (not

TABLE 3-1 Average Uranium Concentrations (pCi/g) in Fish Sampled 1987 - 1993

Monitoring Locations	Species	1993	1992	1991	1990/1989	1987	5-Year Average	Detects/ Total Samples
Frog Pond	Sunfish Cakes	NS	NS	NS	NS	<0.1	<0.1	0/1
Lake 34	Bass Fillet	0.0005	0.0013	0.010a	<0.003	<0.01	0.0037	3/5
	Bass Whole	NS	0.001	0.003a	0.024a	NS	0.009	3/3
	Catfish Fillet	0.0007	0.0174	<0.003	NS	NS	0.007	2/3
	Catfish Whole	NS	0.002	<0.003	<0.003	NS	0.002	1/3
	Crappie Cakes	0.0023	NS	NS	NS	NS	0.0023	1/1
	Crappie Fillet	NS	NS	NS	NS	<0.01	<0.01	0/1
	Sunfish Cakes	0.019	0.0012	0.010a	0.041a	<0.01	0.015	4/5
	Sunfish Fillet	NS	<0.3	0.004a	<0.003	<0.01	0.04	1/4
	Sunfish Whole	NS	0.0032	0.057a	0.036a	NS	0.032	3/3
Lake 35	Bass Fillet	0.0003	NS	0.072	0.005a	<0.01	0.021	3/4
	Bass Whole	NS	0.002	0.014a	0.027a	NS	0.014	3/3
	Catfish Fillets	0.0044	0.0037	0.030a	<0.003	<0.02	0.010	3/5
	Catfish Livers	NS	NS	0.070a	NS	NS	0.070	1/1
	Catfish Whole	NS	NS	0.009	0.385	NS	0.197	2/2
	Crappie Cakes	0.0077	0.0032	0.003a	0.012a	NS	0.006	4/4
	Crappie Fillet	0.0007	NS	0.006a	0.006a	<0.02	0.005	3/4
	Crappie Whole	0.016	0.007	<0.003	0.035	NS	0.015	3/4

TABLE 3-1 Average Uranium Concentrations (pCi/g) in Fish Sampled 1987 - 1993 (Continued)

Monitoring Locations	Species	1993	1992	1991	1990/1989	1987	5-Year Average	Detects/ Total Samples
Lake 35 (Continued)	Sunfish Cakes	0.047	0.031	0.049a	0.040a	<0.02	0.035	4/5
	Sunfish Fillet	NS	NS	0.016	0.008a	NS	0.012	2/2
	Sunfish Whole	NS	0.085	<0.013	0.282	NS	0.125	2/3
Lake 36	Bass Fillet	0.0004	0.005	0.005a	0.008a	<0.01	0.005	4/5
	Bass Whole	NS	0.035	0.003a	0.303	NS	0.114	3/3
	Catfish Fillet	0.0014	NS	0.016a	0.018a	<0.01	0.010	3/4
	Catfish Whole	NS	NS	0.004a	1.863	NS	0.933	2/2
	Crappie Cakes	0.0193	0.044	0.021a	NS	NS	0.028	3/3
	Crappie Fillet	0.0013	NS	0.014a	0.005a	NS	0.007	3/3
	Crappie Whole	NS	NS	0.009a	0.075a	NS	0.042	2/2
	Sunfish Cakes	0.129	<0.30	0.204	NS	<0.01	0.122	2/4
	Sunfish Fillet	0.0088	0.023	0.029a	0.041	<0.01	0.021	4/5
	Sunfish Whole	NS	0.423	0.351	0.529	NS	0.434	3/3
	Carp Fillet	NS	0.032	NS	NS	NS	0.032	1/1
Femme Osage Slough	Bass Fillet	0.0002	0.005	NS	NS	<0.01	0.003	2/3
	Bass Whole	NS	NS	0.005a	NS	NS	0.005	1/1
	Buffalo Whole	NS	0.002	NS	NS	NS	0.002	1/1

TABLE 3-1 Average Uranium Concentrations (pCi/g) in Fish Sampled 1987 - 1993 (Continued)

Monitoring Locations	Species	1993	1992	1991	1990/1989	1987	5-Year Average	Detects/ Total Samples
Femme Osage Slough (Continued)	Buffalo Fillet	NS	NS	NS	NS	<0.01	<0.01	0/1
	Carp Fillet	0.0017	0.0045	NS	NS	<0.01	0.004	2/3
	Carp Whole	NS	0.21	0.003a	NS	NS	0.106	2/2
	Catfish Fillet	NS	NS	<0.003	NS	NS	<0.003	0/1
	Catfish Whole	NS	0.12	0.005a	NS	NS	0.062	2/2
	Crappie Cakes	0.0046	NS	0.010a	NS	<0.01	0.006	2/3
	Crappie Fillet	NS	NS	0.004a	NS	<0.01	0.004	1/2
	Crappie Whole	NS	NS	0.002a	NS	NS	0.002	1/1
	Sunfish Cakes	NS	NS	0.005a	NS	NS	0.005	1/1
	Sunfish Whole	NS	0.006	0.032	NS	NS	0.019	2/2
BACKGROUND LOCATIONS								
Lake 33	Bass Fillet	0.0001	<0.30	0.003a	NS	NS	0.061	2/3
	Bass Whole	NS	0.0024	0.002a	NS	NS	0.0022	2/2
	Carp Fillet	NS	0.0004	0.002a	NS	NS	0.0012	2/2
	Carp Whole	NS	0.0047	<0.003	NS	NS	0.0031	1/2
	Catfish Fillet	0.0001	0.0014	NS	NS	NS	0.0008	2/2
	Catfish Whole	NS	0.015	NS	NS	NS	0.015	1/1

TABLE 3-1 Average Uranium Concentrations (pCi/g) in Fish Sampled 1987 - 1993 (Continued)

Monitoring Locations	Species	1993	1992	1991	1990/1989	1987	5-Year Average	Detects/ Total Samples
Lake 33 (Continued)	Crappie Whole	NS	0.002	0.007a	NS	NS	0.005	2/2
	Crappie Fillet	0.0001	NS	0.003a	NS	NS	0.0016	2/2
	Crappie Cakes	NS	<0.3	0.002a	NS	NS	0.076	1/2
	Sunfish Cakes	0.0007	0.001	<0.005	NS	NS	0.0014	2/3
	Sunfish Fillet	NS	NS	<0.003	NS	NS	<0.003	0/1
	Sunfish Whole	NS	0.002	0.004a	NS	NS	0.0026	2/2
Lake 37	Bass Fillet	NS	0.001	<0.003	<0.003	<0.02	0.004	1/4
	Bass Whole	NS	0.0024	0.007a	<0.003	NS	0.004	2/3
	Catfish Fillet	NS	0.0001	NS	0.003a	NS	0.002	2/2
	Catfish Whole	NS	NS	0.003a	0.013a	NS	0.008	2/2
	Sunfish Cakes	NS	NS	0.002a	NS	<0.01	0.004	1/2
	Sunfish Fillet	NS	NS	0.003a	<0.003	<0.01	0.003	1/3
	Sunfish Whole	NS	0.001	0.009a	<0.003	NS	0.004	2/3

Values represent U-234,U-235 and U-238 concentrations.
a Includes non-detect concentration
NS No sample

detected) to 0.045 pCi/g. The highest 5-year average uranium concentrations in Busch Lake 35 were whole catfish samples at 0.197 pCi/g and whole sunfish samples at 0.125 pCi/g, which is approximately five times less than the highest concentrations found in Lake 36. The maximum 5-year concentration for uranium in Lake 34 was whole sunfish at 0.032 pCi/g. This is a 15-fold difference in concentrations found in Lake 34 as compared to Lake 36. The highest 5-year average background concentrations found in Lake 33 and Lake 37 were 0.076 pCi/g and 0.008 pCi/g respectively. These concentrations are higher than reported in previous years and can be attributed to higher detection limits (0.1 pCi/g) in 1992. Uranium concentrations found in fish samples from the Femme Osage Slough ranged from 0.003 pCi/g to a high of 0.21 pCi/g in whole carp samples.

Non-detectable concentrations were reported for 42 of the 167 samples (25.1%) taken from 1987 to 1993. Of the total number of samples collected in each lake, the non-detect samples were 42% of all samples collected from Lake 37; 26% from Femme Osage Slough; 36% from Lake 34; 19% from Lake 35; 21% from Lake 33; and 14% from Lake 36.

The most non-detect samples were reported in 1987, when detection limits ranged from 0.01 pCi/g to 0.1 pCi/g. Of all non-detect samples, half (21) were collected in 1987. The remaining non-detect samples were reported in the earlier sampling periods: eight in 1989/1990; nine in 1991; four in 1992; and none in 1993. Detection limits have been drastically reduced since 1987 and were reported at 0.0001 pCi/g in 1993.

Statistical significance of fish data from 1987 - 1993 was tested and a second review using 1989 - 1993 data was done using the Kruskal-Wallis test. Kruskal-Wallis is a one-way, non-parametric analysis of variance test that was selected to test data of small sample size. The tested assumptions included uranium concentrations in all fish, uranium concentrations in specific species, and uranium concentrations in sample types. The assumption, or null hypothesis, is that uranium concentrations in fish (by species, by sample type) from Lakes 34, 35, 36, Femme Osage Slough, and Frog Pond have the same mean concentration of uranium as the background Lakes 33 and 37. If the results of the Kruskal-Wallis test show that the lakes differed, multiple comparisons were conducted to define which lake was signficantly different (Ref. 15).

Results of the multiple comparisons of the significant Kruskal-Wallis analyses are shown in Appendix B. Significant differences in uranium concentrations (95% confidence interval) were shown for Lakes 35 and 36, as compared to background (Table B-1 and B-5). In a species comparison, sunfish were found to have significantly higher uranium concentrations, in Lakes 35 and 36 (Table B-2and B-6). In the comparison of uranium concentrations by sample type, a significant difference was found for each of the sample types; fillet, whole and fishcake, (Table B-3 and B-7) for Lakes 35 and 36. This is attributable to the sunfish species (Table B-4 and B-8). No other species was found to be signficantly different from background by sample type or lake.

Statistical analysis of the fish data using only detectable concentrations resulted in conclusions similiar to those reported for statistical analysis using all data values. The only major exception was statistically significant uranium concentrations in fish from the Femme Osage Slough when compared to background levels. Statistical analysis was also conducted to determine if species or sample types may be different in study lakes and background lakes. These tests compared uranium concentrations in study and background by species, sample type, and sampling year. These tests found significantly higher uranium concentrations in crappie from Lake 36, and the 1989/1990 uranium concentrations in the study lakes were not found to be significantly higher when compared to background lakes. In both of these cases, some of the background lakes datasets were small (1-4 samples), and as a result, affect the strength of the analyses.

Overall, including non-detectable concentrations in the statistical analyses and using one-half detection limits as representative values for non-detect concentrations does not radically affect the outcome of the analysis. In general, non-detect concentrations will become a smaller percentage of the total number of samples due to the availability of lower detection limits. It may be appropriate to eliminate the samples taken in 1987 from future analyses of data due to the high detection limits and high percentage of non-detects (50%) overall. As shown in Tables B-1 through B-8, the exclusion of 1987 does not affect the tests' results.

3.1.1.2 Radium and Thorium. Results of Ra-226, Th-230, and Th-232 analysis for fish samples in 1987 are shown in Table A-4 of Appendix A. All samples analyzed were sunfish fishcake samples, except for Busch Lake 36 where catfish fillet samples were analyzed and for Femme Osage Slough samples where crappie fishcakes were used. In all samples, no radium or thorium concentrations were found above the detection limits ranging from 0.003 pCi/g to 0.7 pCi/g. No further sampling has been conducted since 1987, based on the lack of detectable concentrations of radium and thorium found in off-site surface waters (Ref. 1), the low exposure potential at off-site locations (Ref. 1), and the results of this 1987 fish sampling.

3.1.2 Polychlorinated Biphenyls

Table A-5 in Appendix A presents the results of PCBs analysis from the mixed species composites sampled in 1987. One composite sample was analyzed for each of Lakes 34, 35, 36, and 37. All samples were composite fillet samples of bass, sunfish, and crappie, when available. No PCBs were detected in any of the four composite samples analyzed for these parameters with detection limits of 0.04 to 0.06 $\mu g/g$ (ppm). The detection limits were within acceptable and standard analytical levels for PCBs. No further sampling has been conducted since 1987, based upon no detectable concentrations of PCBs found in off-site surface waters, the low exposure potential at off-site locations, and the results of this 1987 fish sampling.

3.1.3 Metals

Table 3-2 presents the results of the metals analyses from 1987 for mixed species composites from Lakes 34, 35, 36, and background Lake 37. Detection limits for each metal are listed in Table 3-2. Metals detected in fish samples included arsenic, calcium, chromium, iron, lead, manganese, mercury, potassium, sodium, thallium, and zinc. Detectable concentrations of metals (calcium [Ca], potassium [K], and sodium [Na]) were expected because these metals are essential constituents of living tissues. Variations in levels of these elements in tissues are not considered indicative of environmental problems.

Results of the 1987 Weldon Spring site study were reviewed by the Agency for Toxic Substances and Disease Registery and arsenic, lead, and mercury were determined to be a potential human health risk for subsistence fishermen at the levels detected from the Weldon Spring site study (Mellard, Appendix C). Additional review of these levels was conducted by the Missouri Department of Health (MDOH) in 1990. The MDOH stated that subsistence fisherman would concentrate on catfish and fish at "put and take" lakes managed for that purpose (Schmidt, Appendix C). Lakes 34, 35, and 36 at the Busch Conservation Area are not managed as "put and take" lakes. Therefore, based upon the determinations made by the ASTDR and the MDOH, the DOE did not conduct routine sampling for metals.

Additional fish samples were available in 1992 and 1993 and were analyzed for the metals under surveillance monitoring. Table 3-3 shows the results of additional 1992 and 1993 metals analysis. Fish samples for the mercury analysis exceeded analytical holding times, and are therefore considered of limited quality.

The highest arsenic concentration detected in the study lakes was in sunfish fillet samples in Lake 36 at 0.19 μg/g in 1992. Detection limits ranged from 0.046 μg/g to 3.4 μg/g due to variations in the amount of sample for analysis. Lead was found at low levels overall in most fish from both the study and background lakes ranging from <0.023 μg/g to 1.5 μg/g. The highest lead concentration was found in the Femme Osage Slough at 8.9 μg/g, although all other samples from the Femme Osage Slough were detected below 0.35 μg/g.

3.1.4 Quality Assurance Samples

Approximately 32 fish samples were taken as quality assurance samples, representing 16% of all fish collected for biouptake analysis over the past several years. These field duplicate samples are independent samples collected at the same time and point. These duplicates are useful in documenting the precision of the sampling process (Ref. 16). All field duplicate samples were collected at the same time as the routine samples and all were prepared and analyzed under the same methods. The field duplicates collected for the fish sampling were analyzed for radiological and metals parameters.

The relative percent difference is calculated for field duplicate sample set and routine sample set to test the precision of data. Precision is a measure of the agreement among a set of replicate data and is estimated by the means of the dataset (Ref. 16). The relative percent difference (RPD) is calculated as:

TABLE 3-2 Metals Results for Mixed Fish Species Composite* Fillet Samples, 1987

	Concentration (µg/g)																							
Sample Location		Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Hg	Ni	K	Se	Ag	Na	Tl	VZn
Lake 34	ND	ND	ND	ND	ND	ND	1050	2.98	ND	ND	24.2	4.0	ND	ND	ND	0.27	ND	3190	ND	ND	ND	ND	ND	12.3
Lake 35	3.27	ND	13.6	5.0	ND	ND	366.2	ND	ND	0.50	50.7	ND	ND	294.8	2.1	0.24	ND	2666	ND	ND	–	9.4	ND	9.44
Lake 36	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11.7	4.2	ND	ND	ND	0.16	ND	3530	ND	ND	510	ND	ND	9.5
Lake 37	2.76	ND	13.9	5.63	ND	ND	98.7	ND	ND	0.22	4.89	ND	ND	295.4	0.50	0.23	ND	3423	ND	ND	--	9.1	ND	11.3
Det. Limits	20	6	1	20	0.5	0.5	500	1	5	2.5	10	0.5	5	500	1.6	0.1	4	500	0.5	1	500	1	5	2

ND Not Detected

-- Analysis not performed

* Species Composited: Lake 34: 4 bass, 5 sunfish; Lake 35: 2 bass, 2 sunfish, 2 crappie; Lake 36: 2 bass, 4 sunfish, 6 crappie; Lake 37: 1 bass, 2 sunfish, 4 crappie.

TABLE 3-3 Concentration of Metals (µg/g) in Fish

Location	Species	Arsenic		Lead		Mercury
		1992	1993	1992	1993	1993*
Femme Osage Slough	Crappie Cakes	ns	<0.022	ns	0.026	0.033
	Bass Fillet	<0.49	0.085	0.11	0.03	0.14
	Carp Fillet	<0.048	0.048	0.12	0.14	0.09
	Sunfish Whole	<2.0	ns	8.9	ns	ns
	Catfish Whole	<0.048	ns	0.2	ns	ns
	Buffalo Whole	<1.9	ns	0.35	ns	ns
	Carp Whole	<3.4	ns	<2.80	ns	ns
LAKE 34	Crappie Cakes	ns	<0.023	ns	0.15	0.028
	Sunfish Cakes	<1.90	<0.025	1.5	0.099	0.027
	Bass Fillet	<0.49	0.020	<0.049	0.05	0.170
	Catfish Fillet	<0.50	<0.025	0.46	0.11	0.018
	Sunfish Fillet	<3.40	ns	<2.80	ns	ns
	Sunfish Whole	<0.48	ns	0.63	ns	ns
	Catfish Whole	<0.46	ns	0.56	ns	ns
	Bass Whole	<2.00	ns	0.67	ns	ns
LAKE 35	Crappie Cakes	<0.49	<0.021	0.086	0.14	0.032
	Sunfish Cakes	<0.46	<0.020	0.38	0.09	0.033
	Catfish Fillet	<0.020	<0.020	<0.37	0.032	0.040
	Crappie Fillet	ns	<0.019	ns	0.32	0.071
	Bass Fillet	<3.40	<0.020	<2.80	0.084	ns
	Sunfish Whole	<0.5	ns	0.99	ns	ns
	Crappie Whole	<2.00	0.066	0.20	0.53	0.024
	Bass Whole	<0.48	ns	0.29	ns	ns
LAKE 36	Crappie Cakes	ns	0.026	ns	<0.023	0.019
	Sunfish Cakes	<0.46	<0.026	0.44	0.13	0.020
	Catfish Fillet	ns	0.054	ns	0.11	0.029
	Bass Fillet	<0.049	0.098	0.30	0.06	0.180
	Crappie Fillet	ns	0.039	ns	<0.020	0.039
	Carp Fillet	<0.046	ns	<0.046	ns	ns
	Sunfish Fillet	0.19	<0.021	<0.05	<0.021	0.030
	Bass Whole	<0.049	ns	0.084	ns	ns
	Sunfish Whole	<0.095	ns	0.16	ns	ns
LAKE 33#	Sunfish Cakes	<0.49	0.160	0.44	0.041	<0.016
	Crappie Cakes	<0.048	ns	<0.048	ns	ns
	Catfish Fillet	<0.5	<0.023	<0.25	0.110	0.028
	Crappie Fillet	ns	0.083	ns	0.068	0.017
	Carp Fillet	<0.5	ns	1.1	ns	ns
	Bass Fillet	<3.3	0.100	<2.80	0.34	0.06
	Sunfish Whole	<0.5	ns	1.6	ns	ns
	Catfish Whole	<0.46	ns	1.3	ns	ns

TABLE 3-3 Concentration of Metals (μg/g) in Fish (Continued)

Location	Species	Arsenic		Lead		Mercury
		1992	1993	1992	1993	1993*
Lake 33# (Continued)	Carp Whole	<0.46	ns	1.1	ns	ns
	Bass Whole	<0.048	ns	0.079	ns	ns
	Crappie Whole	<0.48	ns	0.21	ns	ns
LAKE 37	Catfish Fillet	<0.048	ns	<0.048	ns	ns
	Bass Fillet	<0.048	ns	<0.048	ns	ns
	Bass Whole	<0.046	ns	0.14	ns	ns
	Sunfish Whole	<1.90	ns	1.4	ns	ns

ns No sample
* Analytical holding times exceeded
\# Background Locations

$$RPD = |DU - RS| / ((DU + RS)/2) * 100$$

where DU = field duplicate and RS = routine sample. Table A-6 in Appendix A shows the comparison and RPD value results.

An RPD value of less than or equal to 35 for metals and 50 for radiological (solids) is considered an acceptable tolerance range for these compounds (Procedure ES&H 4.9.1). As shown in Table A-6, approximately 40% of the sample set RPDs are within the tolerance range for metals, and about 38% are within the tolerance range for radionuclides. This indicates a great deal of variability within the concentrations of contaminants in fish samples at these low detection limits. These RPDs are adequate to support a qualitative assessment of biouptake.

3.2 Waterfowl

Five individuals were collected during waterfowl sampling in October 1990. These included three wood ducks, one mallard, and one Canada goose. Table A-7 in Appendix A lists the results of the radionuclides analysis.

Overall, low levels of specific radionuclides were detected in all samples, although radionuclides were found primarily in organ samples. Ra-226 was found ranging from

0.006 pCi/g to 0.028 pCi/g in organ samples. Ra-226 was detected as 0.001 pCi/g in two tissue samples. Ra-228 was detected in two samples at 0.019 pCi/g (tissue) and 0.030 pCi/g (organ), respectively. Th-230 was found in organ samples at concentrations of 0.017 pCi/g to 0.483 pCi/g. Tissue samples for Th-230 ranged from not detected to 0.014 pCi/g. Uranium was found in concentrations ranging from <0.001 pCi/g to 0.005 pCi/g in tissue samples to 0.334 pCi/g in the organ samples. No significant differences were found between radionuclide concentrations and sample type, or by species.

3.3 Small Mammals

In 1987-1988, eight rabbits and three squirrels were collected from the Ash Pond area, three rabbits from among buildings at the Weldon Spring Chemical Plant, and two rabbits from around the Imhoff Tank drainage in the southeast portion of the chemical plant. Three squirrels were collected from the Frog Pond area. No samples were collected from trapping conducted at the quarry pond area. Table A-8 in Appendix A presents the results of radiological analyses for these samples. In all samples, no radiological contaminants were detected at the lower limits of detection, which ranged from 0.01 pCi/g to 1.00 pCi/g. Detection limits varied due to the amount of sample available for analysis.

3.4 Large Mammals

A total of six deer were analyzed in 1991 and 1992. Three of the deer were from accidental deaths at the chemical plant area and three were from roadkills and hunter donations. Results of the metals analysis are shown in Table 3-4 and the radiological analyses are shown in Table 3-5.

Due to the limited availability of tissue samples, only one muscle sample was analyzed for metals and one replicate tissue sample was taken from the same deer. Overall, most metals were not detected in tissue samples. As shown in Table 3-4, barium, chromium, and zinc were detected in both the tissue and replicate tissue samples.

TABLE 3-4 Results of Metals Analysis in Deer Tissue Samples (μg/l) from 1992

	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver	Zinc
Highway 94 St. Charles	<0.026	0.048	<0.079	0.29	<0.47	<0.007	<0.026	<0.079	17.4
Replicate:	<0.027	0.089	0.12	0.49	<0.47	<0.007	<0.027	<0.078	17.0
Relative % Difference	NA	59.8	NA	Blank* Contam.	NA	NA	NA	NA	2.3

* Analytical laboratory blank quality assurance sample was contaminated and as a result, detected concentrations of chromium in tissue sample was not confirmed.

TABLE 3-5 Radionuclide Concentrations in White-Tail Deer from the Weldon Spring Chemical Plant (pCi/g wet weight)

Location	Sample Type	Ra-226	Ra-228	Th-228	Th-230	Th-232	Total Uranium
Chemical Plant MSA basin	Ribs	0.088	0.123	<0.086	0.707	<0.018	0.016
	Antlers	0.056	0.063	0.360	0.062	<0.024	<0.006
	Kidney	<0.001	0.026	<0.169	<0.045	<0.026	<0.001
	Heart	<0.001	<0.003	<0.006	0.005	<0.001	0.001
	Bone	0.136	<0.104	0.601	2.48	0.374	0.118
	Liver	<0.001	<0.002	0.007	0.003	<0.001	<0.001
	Muscle	<0.001	<0.002	<0.006	0.002	<0.001	<0.001
Chemical Plant Frog Pond Drainage	Bone	2.90	1.28	0.51	<0.0092	<0.011	0.025
Chemical Plant North Dump	Stomach	<0.14	<0.35	0.019	0.007	0.009	0.043
	Bone	0.79	0.94	0.07	<0.003	<0.009	0.026
	Organs	<0.30	<1.04	0.012	0.014	0.013	0.023
Highway 94, St. Charles	Bone	1.20	<1.24	0.123	0.0096	<0.015	0.006
	Muscle	<0.10	<0.29	<0.004	<0.003	<0.004	0.003
Background: Hunter Donation St. Charles County	Organs	<0.23	<0.70	<.0114	0.006	<0.009	0.011
Background: Hunter Donation Macon County	Bone	<0.34	<1.05	0.065	<0.009	<0.024	0.005

The relative percent difference was high for barium at 59.8 and may be indicative of poor laboratory precision, poor field precision, or poor sample homogeneity. The replicate tissue sample was taken from the same deer and tissue portion, so it is more likely to be attributable to poor laboratory precision. The RPD for zinc was acceptable at 2.3. Chromium was also detected in the laboratory blank, and therefore, the samples were rejected for use.

Concentrations of radionuclides were primarily found in bone and organ samples. The highest concentration found in all samples was in bone from the Frog Pond drainage at 2.90 pCi/g for Ra-226, and Ra-228 was 1.28 pCi/g. The highest concentrations of Th-230 were found in bone samples from <0.003 pCi/g to 2.48 pCi/g. Uranium concentrations ranged from the detection limit (<0.001 pCi/g) to 0.118 pCi/g in bone, organ, and intestine samples. Radionuclide concentrations ranged from not detected to 0.002 pCi/g in tissue samples. Ra-226 and Ra-228 concentrations were found in bone, antler, and intestine samples ranging from not detected at 0.001 pCi/g to 0.260 pCi/g. These higher concentrations in bone samples are expected since uranium, thorium, and radium are considered bone-seekers.

4 DATA INTERPRETATION

Elevated levels of contaminants in the environment must be examined to distinguish whether these contaminants are present and accumulating in biota, to determine the significance of these concentrations, and the potential dose to humans from consumption of the biota. In conjunction with sampling conducted by the U.S. Department of Energy (DOE) for the Weldon Spring site, other Federal and State agencies have sampled biota as part of public health studies. This data will be included in the discussion for comparison, and to assist in making conclusions about the safety of human consumption of biota exposed to contaminants from the Weldon Spring site. The risks associated with consumption of biota from the surrounding area are presented in the *Baseline Assessment (BA) for The Weldon Spring Chemical Plant* (Ref. 1). The BA is the decision-making document that guides remedial action decisions for cleanup of contaminant source areas of the Weldon Spring Site Chemical Plant area.

4.1 Significance and Comparative Review of Data

Federal and State agency investigations have examined the extent and level of contamination of environmental media at the Weldon Spring site and at off-site locations. In some cases, the data have shown slight differences in concentrations of contaminants in biotic tissue. In other comparisons, the resulting data has shown a significant conflict in the concentrations of various contaminants. A review of these data as compared to the results of the Weldon Spring site study is presented here.

4.1.1 Radionuclides

In 1977, Ryckman/Edgerley/Tomlinson & Associates (RETA) conducted an extensive study on the presence and concentration of contaminants in a variety of flora and fauna from ponds located at the chemical plant area (Ref. 17). In five different scenarios, RETA compared the concentrations of radionuclides detected in various biota samples from Frog Pond, Ash Pond, and a background location. The Category 3 comparison (Ref. 17) is the most similiar data review to the Weldon Spring site biouptake program. It is a comparison of contaminant levels in similar biota or organs from different sites to determine levels of uptake. No assessment of human risk was made by RETA from consumption of contaminated biota.

RETA found low, but detectable concentrations of uranium in invertebrates, the roots of aquatic plants, frogs, and the intestines of raccoons. No waterfowl were sampled for the RETA study. One detectable uranium concentration was found in a frog skeleton at two times the concentration found in water. No detectable uranium or significant difference in concentrations was found for mammal bone samples. Uranium and thorium were found to be concentrated in organ samples. Th-232 was found in invertebrate samples and in one muskrat skeleton sample from the Weldon Spring site. Ra-226 was detected in chemical plant samples taken by RETA, but no significant difference was observed for radium in mammal bone and organ samples taken from the Weldon Spring site as compared to background samples (Ref. 17). Low levels of uranium and Ra-226 were found in whole fish samples taken by RETA. In comparison, no detectable concentrations were found in the 1987 fish sampling conducted by the DOE (refer to Table 3-1).

In 1984, the Missouri Department of Conservation (MDC) conducted a radiological survey of fish from background lakes and Busch Lakes with elevated levels of radionuclides. The MDC study found low levels of radiological contaminants in fish from the Busch lakes and from the Femme Osage Slough (deRoos, Appendix C). MDC detected uranium concentrations in fish from 0.002 pCi/g to 0.06 pCi/g.

The variations in reported results from the three studies prompted independent review by the DOE to address the inconsistencies in the reported results. The findings of this review are summarized in the document by Schlenker entitled *Comparative Review of Studies on the Uptake of Radioactive Contaminants by Biota at the Weldon Spring Site, Weldon Spring, Missouri* (Ref. 18). The report indicates that disparities that seemed evident in direct comparison of the data results reported from each study, were actually insufficient to prove disagreement between the studies. In some cases, once the data were "adjusted for the differences in methods, the data between the RETA study and Weldon Spring site study were comparable" (Ref. 18).

The differences found between results of each study were attributed to differences in sample preparation, detection limits, and reporting units (ash vs. wet weight). Some modifications in the Weldon Spring site fish biouptake program were made since the comparative review. These modifications include sampling of whole fish as well as fillet and analysis of specific uranium isotopes in addition to total uranium.

Listed in Table 4-1 is a data comparison between the uranium concentration reported from the RETA 1977 study and the study results from the Weldon Spring site since 1987 under the more recent site sampling methods. Total uranium concentrations in fish from 1987-1993 were averaged and compared to the RETA results of U-235, the only radionuclide available for comparison. In addition, a second comparison for U-235 was made using the 1989-1992 data where specific uranium isotopes were analyzed. In both comparisons, the results indicate that while no detectable concentrations were reported from RETA and detectable concentrations were found for the Weldon Spring site data, the Weldon Spring site values for most data were below the detection limits set by the RETA study. As concluded by Schlenker in the comparative study (Ref. 18) and supported by this second review, the Weldon Spring site data as compared to the RETA study only further indicate that the RETA data is of little use today for analysis of presence or trends in radionuclides accumulation since detection limits are too high. Schlenker (Ref. 18) concludes that "apparent errors in the RETA data, are serious enough to question the accuracy of the entire study."

A review of the MDC 1984 study and Weldon Spring site results from 1987 was also conducted by Schlenker. Previously, the 1987 Weldon Spring site results contradicted the MDC results. MDC reported detectable concentrations, and the Weldon Spring site reported no detectable concentrations of radionuclides. Schenkler (Ref. 18) attributed the differences to sampling methodologies and of those samples that could be compared, (similar species and sample type), the concentrations were found to be comparable.

The 1984 MDC data is shown in Table 4-2 compared to data collected by the Weldon Spring site under the new sampling methods as a part of this report. Total uranium concentrations in fish from 1987-1993 were averaged and compared to the total uranium results modified and presented by Schenkler (Ref. 18). The comparison of data indicates that both studies find detectable concentrations of uranium in fish and the concentrations found are similar.

A biouptake study of fish in the Femme Osage Slough was conducted in 1980 by National Lead of Ohio, Inc. (NLO) under the DOE Monitoring Program for 1979 and 1980 (Ref. 19). This study was conducted prior to the opening of the area as the Weldon Spring Conservation Area (WSCA) in June of 1980. MDC personnel assisted NLO with collection of fish from the slough. All samples were analyzed for total uranium.

TABLE 4-1 Comparison of Uranium (pCi/g) in Fish 1977 RETA Study vs. 1987 - 1993 Weldon Spring Site Remedial Action Project (WSSRAP)

Location/Species*	WSSRAP		RETA
	Total Uranium	Uranium 235**	Uranium 235
Frog Pond Sunfish	<0.1	----	<0.35 - <0.70
Lake 35 Sunfish	0.119	0.09	<1.1 - < 2.1
Lake 36 Bass	0.002	0.02	<3.3 - < 6.5
Lake 36 Sunfish	0.423	0.022	<0.48 - <0.95
Lake 35 Bass	0.035	0.021	<0.055 - <0.11

* WSSRAP and RETA data for whole fish samples.
** U-235 concentrations may be higher due to fewer number of samples analyzed for isotopic uranium.

TABLE 4-2 Comparison of Total Uranium (pCi/g) Concentration in Fish, 1984 MDC and 1987 - 1993 WSSRAP

Location/Species	WSSRAP Study	MDC Study
Lake 35 Catfish Fillet	0.010	0.002
Lake 35 Bass Fillet	0.021	0.005
Lake 36 Catfish Fillet	0.010	0.007
Lake 36 Bass Fillet	0.005	0.004
Femme Osage Slough Carp Fillet	0.004	0.007
Femme Osage Slough Crappie Fishcakes	0.005	0.009

Note: For comparison propose these uranium values for WSSRAP do not include isotopic uranium.

Results of the 1980 NLO study are shown in Table 4-3. The NLO study found low, detectable concentrations of uranium in whole body fish samples (0.057 - 0.073 pCi/g) and NLO found no detectable concentrations of radionuclides in fillet samples for buffalo and carp. The current Weldon Spring site data set (samples collected from 1987 to 1993) from the Femme Osage Slough concur with the NLO results.

TABLE 4-3 Comparison of Total Uranium Concentrations, Femme Osage Slough pCi/g wet weight

Species	NLO, 1982	WSSRAP 1987-1993
Buffalo Fillet	<.0014	<0.01
Buffalo Whole	0.067	0.002
Carp Fillet	<0.0007	0.004
Carp Whole	0.073	0.109

4.1.2 Metals

In 1987, fish were analyzed for metals by the Weldon Spring Site Remedial Action Project (WSSRAP) and arsenic, chromium, lead, mercury, thallium, and zinc were detected. In 1989, the MDC sampled fish from Busch Lakes 35, 36, and 37 for lead, cadmium, mercury, and arsenic in response to potential human health concerns expressed by the Agency for Toxic Substance and Disease Registry (ATSDR) based on the DOE findings. No justification has been provided for not including Lake 34 in the sampling program, although the levels found in Lake 34 in the 1987 Weldon Spring site study were below the levels found in the other study lakes. Cadmium was analyzed in fish as a result of findings presented in the Remedial Investigation (RI) of the Weldon Spring Training Area as part of the cleanup process for the U.S. Department of the Army (Lutz, Appendix C). Cadmium was not detected in the 1987 Weldon Spring site study.

The MDC results from 1989 are presented in Table A-10. Lead concentrations in fish from Lake 35, Lake 36, and Lake 37 were found ranging from <0.01 μg/g to 0.119 μg/g. These concentrations were significantly lower than those originally reported for the 1987 Weldon Spring site study. The MDC also performed mercury analysis on fish in the 1989 study. The results indicated a detectable level of mercury in fish ranging from 0.006 μg/g to 0.07 μg/g, which is approximately a twenty-fold reduction in the measured concentration in fish from the 1987 Weldon Spring study. Arsenic levels were also significantly less.

In 1991, sediment sampling of Lake 36 was conducted by the Department of the Army as part of their RI for the Weldon Spring Ordnance Works. Elevated levels of arsenic, barium, chromium, and lead were detected in the sediments. As a result, the U.S. Environmental Protection Agency (EPA) sampled fish in June of 1992 for these metals (Reitinger, Appendix C). These results are shown in Table A-11 of Appendix A. When detection limits from the June 1992 sampling were not low enough, the EPA was required to resample fish in the Busch Lakes in October 1992, and to analyze them for lead, arsenic, and mercury (Mellard, Appendix C). Analysis was not performed for chromium and barium. Results from the resampling are also shown in Table A-11 of Appendix A.

Analytical results of the studies by the EPA, the MDC and the Weldon Spring site for metals in fish at the August A. Busch Memorial Conservation Area were tabulated and are compared by both species and lake in Table 4-4. Mercury results are presented and compared, although holding times were exceeded by Weldon Spring site analytical laboratories and are of limited quality.

The results for all studies are comparable. The only significant difference in the data in the Weldon Spring site study as compared to the MDC study is a higher lead concentration in whole sunfish samples from Lake 37 (1.4 μg/g vs. 0.063 μg/g). In general, the MDC study had lower detection limits than either the EPA or the Weldon Spring site study.

4.2 Bioaccumulation

A bioaccumulation factor (BF) is an expression of the potential concentration of radionuclides in biota caused by contaminated soil, sediment, or water. BFs are the ratio of the concentration of uranium in the biota to the concentration of uranium in the surface water. Average surface water and fish concentrations data were used to calculate BFs, which are presented in Table 4-5. Factors taken from the literature are typically used in human dose calculations (modeled) to characterize levels of radionuclides in biota, when actual concentrations (measured) are not available. Gilbert (Ref. 20) lists the bioaccumulation factor for uranium for freshwater fish as 2.0. The National Council on Radiation Protection (NCRP) (Ref. 21) has published values ranging from 0.5 to 38 for BFs for specific species. No NCRP standard was reported for catfish. The Gilbert and NCRP values are used to calculate the internal radiation dose to humans from consumption of fish when actual data are not available.

TABLE 4-4 Comparison of Metals Data from Busch Lake Fish Surveys

Lake/Species	Arsenic (µg/g)			LEAD (µg/g)			Mercury (µg/g)		
	MDC 1989	EPA 1992	WSS 1993	MDC 1989	EPA 1992	WSS 1993	MDC 1989	EPA 1992	WSS 1993
Lake 35: Catfish Fillet	ns	ns	< 0.02	< 0.01	ns	0.032	0.006	ns	0.04
Lake 36: Sunfish Whole	0.078	< 0.1	< 0.095[a]	0.119	< 0.1	0.16[a]	0.065	0.027	ns
Lake 36: Catfish Fillet	0.035	< 0.1	0.064	0.064	< 0.1	0.11	0.07	0.031	0.029
Lake 36: Bass Whole	ns	< 0.1	< 0.049[a]	ns	< 0.1	0.084[a]	ns	0.10	ns
Lake 36: Bass Fillet	ns	< 0.1	0.098	ns	< 0.1	0.06	ns	0.212	0.18
Lake 36: Sunfish Fillet	ns	< 0.1	< 0.021	ns	< 0.1	< 0.021	ns	0.028	0.03
Lake 37: Sunfish Whole	0.161	ns	< 1.90[a]	0.063	ns	1.4[a]	0.046	ns	ns
Lake 37: Catfish Fillet	0.048	ns	< 0.048[a]	0.024	ns	< 0.048[a]	0.059	ns	ns

[a] Weldon Spring Site, 1992
ns no comparable sample taken

BFs are also a method by which to assess the validity of published bioaccumulation data under specific environmental conditions unique to each site. Variations in bioaccumulationfactors are common since the species of fish and the chemistry of the water body can differ widely from area to area. BFs were calculated for fish sampled by the Weldon Spring site and were also compared to the Gilbert and NCRP standards (Table 4-5).

The bioaccumulation factors calculated for the Weldon Spring site study indicate that all fillet samples fall below 2.0, the factor standard published by Gilbert (Ref. 20). The fillet bass sample from Lake 35 was calculated to be 1.12 which was above the NCRP standard of 0.5 - 0.7. The BFs calculated for six whole body and fishcake samples from Lakes 35 and 36 were above the Gilbert standards. These included whole sunfish and whole catfish samples from Lake 35 and whole sunfish, sunfish fishcakes, whole catfish, and whole bass samples from Lake 36. BFs calculated for sunfish were below the range of 0.5 to 38 set by NCRP for sunfish. The highest BF calculated was 24.9 for whole catfish samples from Lake 36. This is likely since catfish forage in the sediments of the lake and are more likely to ingest a greater amount of contaminated sediment.

4.3 Dose and Risk Assessment

The main objective of a biouptake program is to estimate dietary intake level or to calculate dose to the public from consumption of biota. Concentrations from samples are taken, appropriate consumption scenarios are developed, and a dose or level is determined. Regulatory agencies standardize the annual effective dose per year for radionuclides. Other nonradiological contaminant limits are set by the EPA in the Federal Water Quality Criteria (Ref. 22) for maximum contaminant levels for ingestion of aquatic organisms and by the U.S. Public Health Service Food and Drug Administration (FDA) which provides typical dietary intake levels.

4.3.1 Radiological Compounds

Annual dose estimates are calculated as part of DOE 5400 monitoring requirements to determine exposure levels to the general population from consuming fish from contaminated lakes. The exposure scenario created to calculate dose was an individual who was maximally exposed to contaminated water and fish from Lake 36 and to sediments from Lake 34. These

TABLE 4-5 Comparison of Bioaccumulation Factors for Uranium

Area	Species[a]	Gilbert Bioaccumulation Factor	NCRP Bioaccumulation Factor	WSSRAP[b] Bioaccumulation Factor
Lake 34	Catfish (f)	2.0	----	0.44
	Catfish (w)	2.0	------	0.12
	Crappie (f)	2.0	0.5-0.7	0.31
	Crappie (c)	2.0	0.5-0.7	0.14
	LM Bass (f)	2.0	0.5-0.7	0.23
	LM Bass (w)	2.0	0.5-0.7	0.56
	Sunfish (f)	2.0	0.7-38	0.18
	Sunfish (c)	2.0	0.7-38	0.93
	Sunfish (w)	2.0	0.7-38	1.98
Lake 35	Sunfish (f)	2.0	0.7-38	0.64
	Sunfish (w)	2.0	0.7-38	6.65
	Crappie (f)	2.0	0.5-0.7	0.27
	LM Bass (w)	2.0	0.5-0.7	0.75
	Catfish (w)	2.0	-----	10.5
	Catfish (f)	2.0	----	0.59
	LM Bass (f)	2.0	0.5-0.7	1.12
	Sunfish (c)	2.0	0.7-38	1.86
	Crappie (w)	2.0	0.5-0.7	0.80
	Crappie (c)	2.0	0.5-0.7	0.32
Lake 36	LM Bass (f)	2.0	0.5-0.7	0.13
	Sunfish (f)	2.0	0.7-38	0.56
	Catfish (f)	2.0	-----	0.27
	Sunfish (c)	2.0	0.7-38	2.93
	Sunfish (w)	2.0	0.7-38	11.6
	Catfish (w)	2.0	-----	24.8
	LM Bass (w)	2.0	0.5-0.7	3.04
	Crappie (c)	2.0	0.5-0.7	0.76
	Crappie (f)	2.0	0.5-0.7	0.19
	Crappie (w)	2.0	0.5-0.7	1.12
	Carp (f)	2.0	------	0.85
Frog Pond	Sunfish (f)	2.0	0.7-38	0.22
Femme Osage Slough	LM Bass (f)	2.0	0.5-0.7	0.08
	Crappie (c)	2.0	0.5-0.7	0.16
	LM Buffalo (f)	2.0	0.7-38	0.13
	Crappie (f)	2.0	0.5-0.7	0.11
	Carp (f)	2.0	------	0.11
	LM Bass (w)	2.0	0.5-0.7	0.13
	Sunfish (w)	2.0	0.7-38	0.51
	Catfish (f)	2.0	-----	0.40
	Catfish (w)	2.0	-----	1.65
	LM Buffalo (w)	2.0	0.7-38	0.53
	Sunfish (c)	2.0	0.7-38	0.13
	Carp (w)	2.0	------	0.40
	Crappie (w)	2.0	0.5-0.7	0.40

[a] Letter in () indicates fillets, whole, or fishcake (c) samples.
[b] Bioaccumulation factor based on average fish and surface water data.
Adapted from (Ref. 20) and (Ref. 21)

locations were selected since the highest uranium concentration for each media was reported from these locations. The dose calculation assumes that the annual consumption rate of fish is 6.5 g/day and annual average catch is 12.3 fish. The calculation assumes 14.3 hours swimming in the lakes and a 0.05 liter/hour ingestion rate for a total annual consumption of 0.72 liters. The calculations also assumes a 200 mg/day sediment ingestion rate for the 14.3 hour of swimming for a total of 120 mg of sediment. This scenario is further presented in the *Weldon Spring Site Environmental Report for Calendar Year 1992* (Ref. 8).

The exposure scenario resulted in a total estimated committed effective dose of 0.07 mrem/year in 1991, 0.01 mrem/year in 1992, and 0.03 mrem/year in 1993 (Refs. 7, 8, and 23). The annual allowable effective committed dose equivalent for a member of the general population is 100 mrem/year. These limits are set by the National Council on Radiation Protection. This recommendation is designed to limit the exposure of members of the public to reasonable levels of risk comparable with risks from other common sources (Ref. 10). The 0.01 mrem/year and 0.07 mrem/year exposure from consumption of fish is less than 1% of the allowable annual limits.

A second scenario considers exposure to a smaller group of individuals with higher consumption rates such as subsistence fisherman. Based upon the assumptions set in the first scenario and usage of the Busch area at once a week, the total swimming time would be 74.1 hours with a total annual ingestion rate of sediment of 618 mg/year and 3.7 liters of water per year. A fish consumption rate of 39.8 g/day was used. The total estimated committed effective dose was calculated at 0.40 mrem/year in 1992 (Ref. 8).

The human health risk associated with ingesting fish from Lakes 34, 35, and 36 with elevated levels of uranium was calculated under scenarios similar to the previous dose calculation. The risk was calculated to be 4×10^{-7} and is below the EPAs target range for unacceptable human risk levels (Ref. 1). As a result of this assessment, no limits were placed on human consumption of fish from the August A. Busch Memorial Conservation Area.

As part of the *Baseline Assessment for the Weldon Spring Chemical Plant*, an estimated dose was calculated (Ref. 1) for consumption of waterfowl from the Weldon Spring Chemical Plant. One method used was defined as measured dose and used the concentrations of radionuclides found in the waterfowl flesh samples. The second method was a modeled tissue concentration in which components of dose calculations included concentrations of contaminants in plant tissues, soil, and surface water, which were expressed as bioaccumulation factors. The period of exposure for waterfowl was assumed to be 365 days. This is the maximum period for use and is based on survey data that indicates that waterfowl do use the pits on a year-round basis (Ref. 1).

The committed effective dose equivalent calculated for waterfowl tissue under the measured method was 0.19 mrem/year for mallards and wood ducks and 0.049 mrem/year for Canada geese. The modeled tissue concentrations were 0.69 mrem/year for mallards and wood ducks and 0.47 mrem/year for Canada geese (Ref. 1).

The estimated human health risk for consumption of waterfowl from the chemical plant area of the Weldon Spring site was calculated as 5×10^{-9} for U-238 in ducks. This value is only one portion of the total risk calculated for human ingestion of game animals. In the *Baseline Assessment for the Weldon Spring Chemical Plant Area*, game ingestion exposures were calculated for a sportsman obtaining the maximum take for deer, turkey, duck, and geese in the area (Ref. 1). The game ingestion radiological and chemical risk is calculated as 8×10^{-7} and 4×10^{-8}, respectively, which is below the EPA's target risk range. Deer and turkey ingestion account for about 70% of this risk reflected by the higher ingestion rates assumed for these animals (Ref. 1). No limits were placed on human consumption of waterfowl from the Weldon Spring site area as a result of this assessment.

In order to assess the dose to humans from consumption of deer tissue, a dose estimate was calculated (Ref. 1). The main exposure points for deer on-site are ingestion of surface water and soils, but there is also potential for radionuclide accumulation in vegetation which is consumed by the deer. Dermal absorption of surface soil from bedding in contaminated areas is a low exposure potential, but inhalation of soils may be a larger exposure pathway due to foraging behavior (Ref. 1). The modeled estimate again used soil and surface water concentrations to establish a bioaccumulation factor for deer. The ingestion rate used was 1.5 kg/day of plant material, and usage of area was estimated at 33% (Ref. 1). The measured dose was calculated using the concentrations of radionuclides detected in the deer sample from the material storage area basin as noted in Table 3-4.

- The committed effective dose equivalent for the measured deer tissue was 0.57 mrem/year. The modeled estimate was 1.4 mrem/year (Ref. 1). Both values are significantly low as compared to the annual allowable dose of 100 mrem/year.

Human health risk calculations for radionuclides are presented in Section 5 as a combined total health risk estimate. Risk estimates from deer concentrations from the Weldon Spring site result in a 3 x 10^{-7} risk (Ref. 1), which is below the EPA target range. As a result, no limits are placed on human consumption of deer in the Weldon Spring site area.

4.3.2 Chemical Compounds

The FDA has developed daily intake limits and the EPA has developed the Reference Dose (RfD) values to set guidelines for the protection of human health from contaminants in the environment. In 1992, the baseline risk assessment for the chemical plant area determined that concentrations of metals in surface waters and sediments at the Busch Lakes were not attributable to chemical plant operation activities, based on the fact that similar concentrations were also found at background lakes (Ref. 1). Prior to the baseline risk assessment, the Agency for Toxic Substances and Disease Registry concluded from 1987 DOE sampling that arsenic, mercury, and lead were metals of concern at the Busch Lakes. The following review is a summary of human health intake reviews and activities conducted by the ATSDR, the EPA, the MDC, and the DOE since the 1987 sampling.

4.3.2.1 Daily Intake Levels. As a result of the 1987 Weldon Spring site fish sampling of the August A. Busch Memorial Conservation Area Lakes 34, 35, 36, and 37, the EPA, as Superfund regulators, requested that the ATSDR evaluate the fish data for human health concerns (Mellard, Appendix C). Using data results from the 1987 Weldon Spring site sampling, the ATSDR calculated daily intake levels for mercury, lead, and arsenic. These levels were compared to the FDA estimated typical daily intake levels, which were based on an average consumption rate of commercial fish for the typical American of 19 g/day (Mellard, Appendix C). The FDA calculated the dietary intake of mercury in the typical American diet to be 3.2 μg/day, of arsenic to be 46 μg/day and of lead to be 57 μg/day (Mellard, Appendix C). Sports fishermen and subsistence fishermen are two subpopulations that may be at increased risk since they are more likely to consume greater quantities of fish. The EPA 50th percentile rate for fish consumption is 39.8 g/day (Mellard, Appendix C). The ATSDR used sports fishermen consumption rates to calculate weekly intake rates.

The ATSDR calculated the intake rate from Lakes 34, 35, 36, and 37, and found that the concentrations of mercury would be 6 μg/day to 11 μg/day. This intake was determined to be greater than the EPA's maximum contaminant limit (MCL) of 2μg/l but is similar to the EPA's Rfd for mercury is 0.158 μg/kg/day, which is equivalent to an intake of 11 μg/day (Mellard, Appendix C). The ATSDR concluded that for sports fishermen (individuals consuming one fish meal per week), intake levels are below the EPA's RFD for mercury and would appear to be below levels that cause health effects (Mellard, Appendix C).

The intake rate of lead from consumption of fish from Lakes 34 and 36 (the only lakes with detected lead levels in fish) was calculated by the ATSDR at 160 μg/day for sports fishermen. The ATSDR stated that this intake exceeded the EPA's MCL of 50 μg/l for lead at an intake of 100 μg/day using a 2 to 1 water consumption rate (Mellard, Appendix C).

The intake rate of arsenic from consumption of fish from Lakes 35 and 37 was calculated at 550 μg/day. The ATSDR stated that this intake exceeded the EPA's MCL of 50 μg/l, which is equivalent to 100 μg/day (Mellard, Appendix C).

The ATSDR concluded from the review of the 1987 data, that there was no public health threat to the general population that occassionally consumed fish from Busch Lakes. The ATSDR did recommend that additional sampling be conducted to confirm the findings of the 1987 Weldon Spring site study and to protect sports fishermen and subsistence fishermen who may be at increased risk (Mellard, Appendix C).

In 1989, the MDC resampled the Busch Conservation Lakes to obtain additional data and requested that ATSDR review the 1989 data results for human health concerns (Dickneite Appendix C). The MDC provided area use data which were used to calculate daily take limits for the Busch Area. From the use data, the ATSDR assumed that a subsistence fishermen would fish 7 days per year, would specifically select catfish, and would consume 14 lb/year (6,356 g/year) which equals a consumption rate of 17.4 g/day (Schmidt, Appendix C). This value is less than half of the consumption rate (39.8 gm/day) previously used by ATSDR in reviewing the 1987 Weldon Spring site data for determining intake rates.

The ATSDR calculated the intake rate for subsistence fishermen as 1.0 μg/day for lead, 0.5 μg/day for arsenic and 1.2 μg/day for mercury from fish taken at the Busch Lakes (Schmidt, Appendix C). These levels, combined with the FDA's daily intake limits (57 μg/day, 46 μg/day, 3.2 μg/day), were below the EPA's MCL of 100 μg/day for lead and arsenic and the EPA's Rfd of 11 μg/day for mercury.

The ATSDR concluded from this additional review, that there was not a significantly increased risk of adverse health effects to subsistence fishermen due to consumption of fish from Busch Lakes 35, 36, and 37. The ATSDR did recommend that the MDC continue to conduct routine sampling of fish for analysis and further characterization of subsistence fishing populations (Schmidt, Appendix C).

Data results from the EPA sampling of Busch Lake 36 in 1992 (Section 4.1.2) found few detectable concentrations of lead and mercury in fish samples. The EPA reported that these samples were below harmful levels and subsistence fisherman are not expected to be affected (Morby, Appendix C). ATSDR is reported to have concurred with the EPAs position on the sample results (Reitinger, Appendix C).

5 CONCLUSIONS

Potential risks for chemical and radiological exposures are assessed in terms of the increased probability that an individual will develop cancer over the course of a lifetime (Ref. 1). The U.S. Environmental Protection Agency (EPA) has identified a range of 1×10^{-6} to 1×10^{-4} for the incremental cancer risk to individuals from exposures at National Priorities List (NPL) sites. This range is referred to as the target risk range (Ref. 1). The current guidelines under *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA) for assessment of potential carcinogenic risk to humans by consumption of biota is typically calculated using models. Risk calculations are prepared using measured soils, surface waters, and sediment concentrations; estimated use of habitat and foraging behavior are determined; and bioaccumulation factors are used to approximate risk to humans from consumption of biota. If the modeled risk is above established target rates, sampling of biota should then be conducted to measure actual risk.

The availability of biotic data with which to prepare measured estimates of dose is not typically available in the CERCLA process. In response to public concern about the surrounding wildlife areas, samples were collected to determine concentrations of radionuclides in selected game species. The modeled dose estimates were found to be greater by factors from 3 to 10 as compared to measured dose estimates. An explanation for this difference may be the highly conservative assumptions made in the modeled dose calculations as compared to the unknowns still evident in the measured calculations. Except for the fish studies, there is no confirmed record of the duration of use of the habitats at Weldon Spring site by other game species. The modeled data assumes year-round use, and the dose to humans is based upon this assumption. Results show levels that are below those that would cause an unacceptable risk to humans.

A total carcinogenic risk was calculated from the modeled dose estimates. The risk calculated for an avid sportsman assumed to hunt on site and fish in the August A. Busch Memorial Conservation Area at Lakes 34, 35, and 36 is 5×10^{-5} (Ref. 1). The total radiological and chemical risks estimated for off-site locations for a recreational visitor such as a sportsmen at Busch Conservation Areas are within or below the EPA target range. In the *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site* (Ref. 5), no evidence was found to attribute elevated metal concentrations found in Busch Lake surface waters at the Weldon Spring site to previous uranium processing activities, and therefore, risk calculation for metals was not performed for ingestion of fish in the *Baseline Assessment for the Chemical Plant Area of the Weldon Spring Site* (Ref.1).

No additional monitoring of biota will be conducted at the Weldon Spring site as part of the routine environmental monitoring program, except for surveillance monitoring of fish at Busch Lakes 34, 35, and 36 and at the Femme Osage Slough in the Weldon Spring Conservation Area. Monitoring of fish for radiological compounds will continue on a surveillance basis to ensure that fish from these public recreational areas will continue to be safe for human consumption. At a minimum, sampling of fish will occur once every other year.

In addition to routine surveillance sampling, the annual surface water monitoring program will be used to determine supplemental fish monitoring activities. The nature and extent of the supplemental fish monitoring activities will be based on radiological results from the surface water monitoring conducted on a quarterly basis as part of the environmental monitoring program at the Weldon Spring site. Annual average concentrations of total uranium in surface waters will be calculated and compared to the previous year's average. If statistically higher concentrations of uranium are found in surface waters in a year, biological monitoring of fish at the respective lake will be conducted during the same fishing season. Fish sampling will consist of specific game species, and only fishcake and fillet samples will be prepared. Results of all future biological surveillance activities will be presented in site environmental reports.

In summary, the conclusions and monitoring recommendations from the biouptake program are:

- No significant biological uptake of radiological contaminants have been detected in small mammals collected from the Weldon Spring site.

- No PCBs have been detected in off-site fish samples collected.

- Bioaccumulation factors calculated using data from this study are within published ranges by Gilbert and the National Council on Radiation Protection (NCRP) except for whole bass samples (10.5) from Lake 35 and whole catfish (24.9) and whole bass (3.04) from Lake 36. Since uranium tends to accumulate in bones and organs these bioaccumulation factors are expected. Only the bass fillet samples from Lake 35 were above the NCRP published ranges of (0.5-0.7). All other fillet samples were below published values.

- Significant differences have been found in concentrations of uranium in sunfish from Lake 35 and 36 samples, and therefore, surveillance monitoring will continue. Currently, no significant radiological dose has been received from consumption of these fish. Surveillance monitoring will be conducted every other year or additionally in years when the average radiological concentrations are statistically higher in surface waters of the lake.

- No significant radiological dose to humans is received from consumption of waterfowl, deer, rabbit, and squirrel. Doses calculated from measured and modeled estimates range from 0.049 mrem/year to 0.47 mrem/year, far below the DOE guidelines of 100 mrem/year.

- Historically, mercury, arsenic, and lead levels detected in DOE fish samples from the Busch Lakes were at levels considered to be of potential risk to subsistence fishermen. Additional sampling of fish from the Busch Lakes was conducted in 1989, 1992, and 1993 by the Missouri Department of Conservation (MDC), the EPA and the U.S. Department of Energy (DOE). Site specific daily consumption rates for subsistence fishermen were recalculated based on new lake-use data provided by the MDC. The Agency for Toxic Substance and Disease Registry (ATSDR) and EPA have determined that consumption of fish by substance fishermen from the Busch area does not significantly increase the daily intake of contaminants (Appendix C, Schmidt).

- Annual radiological doses for subsistence fishermen should be calculated as part of the site environmental report and should use area-use data provided by MDC; specifically, the annual consumption rate of 17.5 g/day (Schmidt, Appendix C) instead of the 39.8 g/day used in the site environmental reports (Ref. 7, 8).

- It has been determined that elevated levels of arsenic, mercury, and lead in the Busch Area Lakes are not attributable to former Weldon Spring Chemical Plant operations. No further sampling of metals concentrations in fish or surface waters from the

August A. Busch Conservation Area will be conducted for biouptake studies by the site.

- Carcinogenic risk levels calculated for fish, waterfowl, deer, rabbit, or squirrel as part of the *Baseline Assessment for the Weldon Spring Chemical Plant* (Ref. 1) were found to be within the EPA target risk range of 10^{-4} to 10^{-6}. Therefore, no remedial action (such as game limits, etc.) is specifically required as a result of biouptake.

6 REFERENCES

1. U. S. Department of Energy. *Baseline Assessment for the Chemical Plant Areas of the Weldon Spring Site*. DOE/OR/21548-091. Prepared with technical assistance from Environmental Assessment and Information Sciences Division, Argonne National Laboratory. November 1992.

2. MK-Ferguson Company and Jacobs Engineering Group, Inc. *Plan for Determination of Biological Uptake of Radionuclides in Species in the Food Pathways at the WSS*. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. June 22, 1987.

3. MK-Ferguson Company. *Transcript of: The December 6, 1988 Public Meeting Lindenwood College St. Charles, Missouri*. DOE/OR/21548-072. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. June 1989.

4. MK-Ferguson Company. *Transcript of: February 13, 1989 MoDNR NPDES Hearing on Proposed DOE Discharge Permit*. DOE/OR/21548-076. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. June 1989.

5. MK-Ferguson Company and Jacobs Engineering Group. *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site*, Rev. 0; 2 Vols. DOE/OR/21548-074. Prepared for the U.S. Department of Energy, Oak Ridge Field Office, Weldon Spring Site Remedial Action Project. November 1992.

6. MK-Ferguson Company and Jacobs Engineering Group. *Annual Site Environmental Report for Calendar Year 1990*, Rev. 1. DOE/OR/21548-193. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. September 1991.

7. MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 1991*, Rev. 1. DOE/OR/21548-283. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project. July 1992.

8. MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 1992*, Rev. 0. DOE/OR/21548-372. Prepared for the U.S. Department of Energy, Oak Ridge Field Office. St. Charles, MO. June 1993.

9. Boerner, A.J. *Radiological Survey of the August A. Busch and Weldon Spring Wildlife Areas Weldon Spring Site, St. Charles County, Missouri*, Final Report. Prepared by Oak Ridge Associated Universities, for U.S. Department of Energy, Division of Remedial Action Projects. April 1986.

10. National Council on Radiation Protection and Measurements. *Recommendations on Limits for Exposure to Ionizing Radiation*, NCRP Report No. 91. Bethesda, MD. June 1, 1987.

11. MK-Ferguson Company. *Water Quality Phase I Assessment Report*, Rev. 0. DOE/OR/21548-003. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. December 1987.

12. American Public Health Association, American Water Works Association, Water Environment Federation. *Standard Methods for the Examination of Water and Wastewater*, Eighteenth Edition. Washington, D.C. 1992.

13. Missouri Department of Conservation. *A Checklist of Birds of the August A. Busch Memorial Wildlife Area, St. Charles, Missouri*. Published in cooperation with The Webster Groves Nature Study Society. 1990.

14. U.S. Environmental Protection Agency. *Eastern Environmental Radiation Facility Radiochemistry Procedures Manual*, EPA 520/5-84-006. Agency of Office of Radiation Programs. Montgomery, AL. August 1984.

15. U.S. Environmental Protection Agency. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities Interim Final Guidance*, EPA/530-SW-89-026. Office of Solid Waste, Waste Management Division. Washington, D.C. April 1989.

16. U.S. Environmental Protection Agency. *Test Methods for Evaluating Solid Waste, Volume II: Physical/Chemical Methods*, Third Edition. Prepared for U.S. Department of Commerce. Washington, D.C. 1986.

17. Ryckman/Edgerley/Tomlinson & Associates. *Phase III Report: Assessment of Disposition Alternatives*. Prepared for the Department of the Army, Aberdeen Proving Ground, Maryland. No date.

18. Schlenker, R. and L. Haroun. *Review of the WSSRAP and RETA Studies*.

19. Weidner, R.B. and M.W. Boback. *Weldon Spring Storage Site Environmental Monitoring Report for 1979 and 1980*. Prepared for the U.S. Department of Energy, Weapons Division of Oak Ridge Operations, by Feed Materials Production Center, NLO, Inc. Cincinnati, Ohio. April 19, 1982.

20. Gilbert, T.L., C. Yu, Y.C. Yuan, A.J. Zielen, M.J. Jusko, and A. Wallo III. *A Manual for Implementing Residual Radioactive Material Guidelines*, DOE/CH/8901. Prepared for U.S. Department of Energy, by Argonne National Laboratory, Energy and Environmental Systems Division. June 1989.

21. National Council on Radiation Protection and Measurements. *Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment*, NCRP Report No. 76. Bethesda, MD. March 15, 1984.

22. U.S. Environmental Protection Agency. *Quality Criteria for Water 1986*, EPA 440/5-86-001. Office of Water Regulations and Standards. Washington, D.C. May 1, 1986.

23. MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 1993*, Rev. 0. DOE/OR/21548-436. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. May 1994.

REGULATIONS

10 CSR 80-3.010, Design and Operation

FR87-1716, Radiation Protection Guidance to Federal Agencies for Occupational Exposure

PROCEDURES

ES&H 4.9.1a/3, *Environmental Monitoring Data Verification*

APPENDIX A
Data Results

TABLE A-1 Fish Species Found in Electrofishing Surveys for the Weldon Spring site, 1987-1993

Location	Species
Busch Lake 34	Largemouth Bass Channel Catfish Hybrid Sunfish Warmouth Black Crappie Green Sunfish Grass Carp Bluegill German Carp White Crappie Brook Silverside Redear Sunfish Gizzard Shad Muskellunge
Busch Lake 35	Largemouth Bass Bluegill Black Crappie Channel Catfish Black Bullhead Redear Sunfish Gizzard Shad Yellow Bullhead Golden Shiner Green Sunfish Brook Silverside Hybrid Sunfish White Crappie
Busch Lake 36	Largemouth Bass Black Crappie Redear Sunfish Gizzard Shad Green Sunfish Grass Carp Channel Catfish Bluegill

TABLE A-1 Fish Species Found in Electrofishing Surveys for the Weldon Spring site, 1987-1993 (Continued)

Location	Species
Femme Osage Slough	Largemouth Bass Bluegill Gizzard Shad Warmouth Black Crappie German Carp Rock Bass White Crappie Yellow Bullhead Green Sunfish Plains Top Minnow Redtail Shiner Golden Shiner Shortnose Gar Spotted Bass Bigmouth Buffalo Smallmouth Buffalo Channel Catfish Longear Sunfish Brook Silverside Black Bullhead Sauger Longnose Gar Hybrid Sunfish
Busch Lake 33	Redear Sunfish Yellow Bullhead Gizzard Shad Green Sunfish Bluegill Black Crappie White Crappie Largemouth Bass Carp Black Bullhead Brook Silverside Channel Catfish
Busch Lake 37	Largemouth Bass Brook Silverside Green Sunfish Redear Sunfish Bluegill Channel Catfish Hybrid Sunfish Grass Carp Gizzard Shad

TABLE A-1 Fish Species Found in Electrofishing Surveys for the Weldon Spring site, 1987-1993 (Continued)

Location	Species
Busch Lake 26	Largemouth Bass Bluegill Green Sunfish Black Crappie Redear Sunfish Golden Shiner

TABLE A-2 Analytical Results for Catfish Fillets from Gill Net Sampling, 1992.

Location	Uranium, Total pCi/g	Arsenic μg/g	Barium μg/g	Cadmium μg/g	Chromium μg/g	Lead μg/g	Mercury μg/g	Selenium μg/g	Silver μg/g	Zinc μg/g
Lake 35	0.0037	<0.020	0.20	<0.061	0.22	<0.37	0.05	<0.020	<0.061	5.1
Lake 37[bkg]	0.0009	<0.018	0.034	<0.053	0.32	<0.32	0.073	0.036	≤0.053	4.7

bkg = background location

TABLE A-3 Summary Statistics[a] for Total Uranium Concentration in Fish, 1987-1993

Location	Sample	Total Samples	Range of Values	Average Value	Standard Deviation
Lake 33	Sunfish Fillet	1	0.0015 - 0.0015	0.0015	0.00000
	Sunfish Fishcake	3	0.0007 - 0.0025	0.0014	0.00079
	Bass Fillet	3	0.0001 - 0.15	0.0510	0.08572
	Catfish Fillet	2	0.0001 - 0.0014	0.0008	0.00065
	Crappie Fillet	2	0.0001 - 0.0025	0.0016	0.00120
	Carp Fillet	2	0.0004 - 0.0020	0.0012	0.00080
	Crappie Fishcake	2	0.0020 - 0.150	0.076	0.00000
	Carp Whole	2	0.0015 - 0.0047	0.0031	0.00160
	Sunfish Whole	2	0.0017 - 0.0035	0.0026	0.00090
	Bass Whole	2	0.0020 - 0.0024	0.0022	0.00020
	Catfish Whole	1	0.0150 - 0.0150	0.0150	0.00000
	Crappie Whole	2	0.0022 - 0.0070	0.0046	0.00240
Lake 34	Sunfish Fillet	4	0.0016 - 0.0050	0.04	0.07326
	Sunfish Fishcake	5	0.0012 - 0.0405	0.0149	0.01402
	Bass Fillet	5	0.0005 - 0.0100	0.0037	0.00353
	Catfish Fillet	3	0.0007 - 0.0174	0.0065	0.00769
	Crappie Fillet	1	0.0050 - 0.0050	0.0050	0.00000
	Crappie Fishcake	1	0.0023 - 0.0023	0.0023	0.00000
	Sunfish Whole	3	0.0032 - 0.0565	0.0317	0.02192
	Bass Whole	3	0.0010 - 0.0235	0.0090	0.01027
	Catfish Whole	3	0.0015 - 0.0018	0.0016	0.00014
Lake 35	Sunfish Fillet	2	0.0075 - 0.0160	0.0118	0.00425
	Sunfish Fishcake	5	0.0100 - 0.0485	0.0352	0.01404
	Bass Fillet	4	0.0003 - 0.0720	0.0205	0.02982
	Catfish Fillet	5	0.0015 - 0.0295	0.0098	0.01165
	Crappie Fillet	4	0.0007 - 0.0100	0.0054	0.00329
	Crappie Fishcake	4	0.0026 - 0.0115	0.0062	0.00364

TABLE A-3 Summary Statistics[a] for Total Uranium Concentration in Fish, 1987-1993 (Continued)

Location	Sample	Total Samples	Range of Values	Average Value	Standard Deviation
Lake 35 (cont)	Sunfish Whole	3	0.0066 - 0.2820	0.1246	0.11584
	Bass Whole	3	0.0016 - 0.0265	0.0139	0.01017
	Catfish Whole	2	0.0085 - 0.3850	0.1968	0.18825
	Crappie Whole	4	0.0015 - 0.0345	0.0147	0.01257
	Catfish Livers	1	0.0695 - 0.0695	0.0695	0.00000
Lake 36	Sunfish Fillet	5	0.0050 - 0.0410	0.0213	0.01315
	Sunfish Fishcake	4	0.0050 - 0.2040	0.122	0.48800
	Bass Fillet	5	0.0004 - 0.0075	0.0047	0.00229
	Catfish Fillet	4	0.0014 - 0.0175	0.0099	0.00681
	Crappie Fillet	3	0.0013 - 0.0135	0.0066	0.00511
	Carp Fillet	1	0.0315 - 0.0315	0.0315	0.00000
	Crappie Fishcake	3	0.0193 - 0.0439	0.0279	0.01132
	Sunfish Whole	3	0.3510 - 0.5290	0.4343	0.07311
	Bass Whole	3	0.0025 - 0.3030	0.1136	0.13457
	Catfish Whole	2	0.0035 - 1.8630	0.9333	0.92975
	Crappie Whole	2	0.0085 - 0.0745	0.0415	0.03300
Lake 37	Sunfish Fillet	3	0.0015 - 0.0050	0.0030	0.00147
	Sunfish Fishcake	2	0.0020 - 0.0050	0.0035	0.00150
	Bass Fillet	4	0.0010 - 0.0100	0.0035	0.00376
	Catfish Fillet	2	0.0001 - 0.0030	0.0016	0.00140
	Sunfish Whole	3	0.0010 - 0.0085	0.0037	0.00342
	Bass Whole	3	0.0015 - 0.0065	0.0035	0.00216
	Catfish Whole	2	0.0025 - 0.0125	0.0075	0.00500
Frog Pond	Sunfish Fishcake	1	0.0500 - 0.0500	0.0500	0.00000
Femme Osage Slough	Sunfish Fishcake	1	0.0045 - 0.0045	0.0045	0.00000
	Bass Fillet	3	0.0002 - 0.0051	0.0034	0.00229
	Catfish Fillet	1	0.0015 - 0.0015	0.0015	0.00000
	Crappie Fillet	2	0.0035 - 0.0050	0.0043	0.00075

TABLE A-3 Summary Statistics[a] for Total Uranium Concentration in Fish, 1987-1993 (Continued)

Location	Sample	Total Samples	Range of Values	Average Value	Standard Deviation
Femme Osage Slough (cont)	Carp Fillet	3	0.0017 - 0.0050	0.0037	0.00145
	Buffalo Fillet	1	0.0050 - 0.0050	0.0050	0.00000
	Crappie Fishcake	3	0.0046 - 0.0095	0.0064	0.00222
	Buffalo Whole	1	0.0021 - 0.0021	0.0021	0.00000
	Carp Whole	2	0.003 - 0.2100	0.1063	0.01463
	Sunfish Whole	2	0.0057 - 0.0320	0.0189	0.01315
	Bass Whole	1	0.0045 - 0.0045	0.0045	0.00000
	Catfish Whole	2	0.0045 - 0.1200	0.0623	0.05776
	Crappie Whole	1	0.0020 - 0.0020	0.0020	0.00000

(a) All summaries include use of half of the detection limit for concentrations reported as less than the detection limit (non-detects).

TABLE A-4 Concentrations of Thorium and Radium in Fish (pCi/g), Weldon Spring Site Study Area, 1987

Location	Ra-226	Th-230	Th-232
Busch Lake 34	<0.01	<0.20	<0.05
Busch Lake 35	<0.30	<0.30	<0.10
Busch Lake 36	<0.003	<0.06	<0.02
Busch Lake 37	<0.20	<0.20	<0.30
Frog Pond	<0.10	<0.20	<0.07
Femme Osage Slough	<0.20	<0.70	<0.30

All samples are sunfish fishcake samples except Busch Lake 36, which is a catfish fillet sample and Femme Osage Slough which is a crappie fishcake sample.

TABLE A-5 PCB Concentrations (ppm) in Mixed Fish Composite Samples, 1987

Location	Composited Species	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260
Busch Lake 34	1 Bass, 2 Sunfish, 4 Crappie	<0.04	<0.06	<0.04	<0.05	<0.04	<0.04	<0.04
Busch Lake 35	2 Bass, 4 Sunfish, 6 Crappie	<0.04	<0.06	<0.04	<0.05	<0.04	<0.04	<0.04
Busch Lake 36	2 Bass, 2 Sunfish, 2 Crappie	<0.04	<0.06	<0.04	<0.05	<0.04	<0.04	<0.04
Busch Lake 37	4 Bass, 5 Sunfish	<0.04	<0.06	<0.04	<0.05	<0.04	<0.04	<0.04

TABLE A-6 Field Duplicate Results and Calculation of Relative Percent Differences (RPD) for Fish Biouptake Samples, 1989-1993, for Metals (μg/g) and Total Uranium (pCi/g)

Location	Species Sampled	Date Sampled	Parameter	Sample Conc.	Field Duplicate Conc.	RPD
Lake 33	Sunfish Cakes	1993	Arsenic	0.16	0.11	37
			Lead	0.041	0.041	0
			Mercury[a]	<0.016	<0.016	na
			Total Uranium	0.0007	0.0006	15
	Carp Fillet	1992	Arsenic	<0.46	<0.46	na
			Lead	1.1	0.68	47
			Total Uranium	0.0004	0.0107	186
	Crappie Cakes	1992	Total Uranium	0.1	0.00131	195
	Carp Whole	1991	Total Uranium	<0.003	<0.003	na
	Sunfish Whole	1992	Arsenic	<0.49	<0.49	na
			Lead	1.6	1.1	37
			Total Uranium	0.002	0.0006	108
		1992 rep 2	Total Uranium	0.002	0.0008	86
	Catfish Whole	1992	Arsenic	<0.46	<0.046	na
			Lead	1.3	1.5	14
			Total Uranium	0.015	<0.005	na
		1992 rep 2	Arsenic	<0.46	<0.50	na
			Lead	1.3	1.2	8
	Crappie Whole	1991	Total Uranium	0.007	<0.007	na
Lake 34	Sunfish Cakes	1992	Arsenic	< 1.90	2	na
			Lead	1.5	0.34	126
			Total Uranium	0.0012	0.0006	67
	Catfish Fillet	1992	Arsenic	< 0.5	< 3.4	na
			Lead	0.46	< 2.8	na

TABLE A-6 Field Duplicate Results and Calculation of Relative Percent Differences (RPD) for Fish Biouptake Samples, 1989-1993, for Metals (µg/g) and Total Urnaium (pCi/g) (Continued)

Location	Species Sampled	Date Sampled	Parameter	Sample Conc.	Field Duplicate Conc.	RPD
Lake 34 (cont)	Sunfish Whole	1992	Arsenic	< 0.48	< 2.0	na
			Lead	0.63	0.81	25
			Total Uranium	0.0032	0.00275	15
	Bass Whole	1992	Arsenic	< 2.0	<0.46	na
			Lead	0.57	0.43	28
			Total Uranium	0.001	0.000486	69
Lake 35	Sunfish Fillet	1990	Total Uranium	0.008	0.003	91
	Sunfish Cakes	1992	Lead	0.38	0.46	19
			Total Uranium	0.031	0.0637	69
	Bass Fillet	1990	Total Uranium	0.005	0.004	22
	Crappie Fillet	1990	Total Uranium	0.006	0.005	18
	Crappie Cakes	1992	Arsenic	<0.049	<0.049	na
			Lead	0.086	0.074	15
			Total Uranium	0.0032	0.0085	91
	Sunfish Whole	1992	Arsenic	<0.5	<0.5	na
			Lead	0.99	1.3	27
			Total Uranium	0.085	0.139	48
		1992 rep 2	Arsenic	<0.5	<0.49	na
			Lead	0.99	0.9	10
			Total Uranium	0.085	0.194	78
	Bass Whole	1990	Total Uranium	0.027	0.025	8
	Catfish Whole	1990	Total Uranium	0.385	0.703	58

TABLE A-6 Field Duplicate Results and Calculation of Relative Percent Differences (RPD) for Fish Biouptake Samples, 1989-1993, for Metals (μg/g) and Total Urnaium (pCi/g) (Continued)

Location	Species Sampled	Date Sampled	Parameter	Sample Conc.	Field Duplicate Conc.	RPD
Lake 36	Bass Fillet	1993	Arsenic	0.098	0.08	20
			Lead	0.06	0.021	96
			Mercury[a]	0.18	0.21	15
			Total Uranium	0.0004	0.000692	53
	Bass Fillet	1989	Total Uranium	0.008	0.004	67
	Sunfish Whole	1991	Total Uranium	0.351	0.307	13
		1992	Arsenic	<0.095	<0.047	na
			Lead	0.16	0.26	48
			Total Uranium	0.423	0.305	32
		1992 rep 2	Arsenic	<0.095	<0.050	na
			Lead	0.16	2.1	172
			Total Uranium	0.423	0.473	11
		1992 rep 3	Arsenic	<0.095	<0.046	na
			Lead	0.16	0.14	13
			Total Uranium	0.423	0.394	7
Lake 37	Bass Whole	1992	Arsenic	<0.049	<0.048	na
			Lead	0.084	0.42	133
			Total Uranium	0.0024	0.0029	19
Femme Osage Slough	Carp Fillet	1993	Arsenic	0.048	0.065	30
			Lead	0.14	0.14	0
			Mercury[a]	0.09	0.094	4
			Total Uranium	0.0017	0.00197	15
	Carp Whole	1991	Total Uranium	< 0.003	0.001	na

(a) Samples analyzed for mercury exceeded analytical holding times and are considered of limited use; both the routine sample and replicate sample exceeded holding times.

na not applicable/calculable for non-detect results.

TABLE A-7 Radionuclide Concentrations in Waterfowl from Raffinate Pit 4, 1990

	Ra-226	Ra-228	Th-227	Th-228	Th-230	Th-232	U-232, -234	U-235	U-238
Wood Duck - tissue (3)	0.001	0.019	0.426	<0.045	0.014	<0.003	0.004	<0.001	0.004
Goose - tissue	<0.001	<0.004	0.014	<0.002	0.010	<0.001	0.002	<0.001	0.002
Mallard - tissue	0.001	<0.002	0.081	<0.011	<0.001	<0.001	0.005	<0.001	0.005
Wood Duck - organs	0.028	<0.007	0.086	<0.018	0.170	<0.002	0.315	0.020	0.334
Goose - organs	0.006	<0.003	0.037	0.008	0.483	0.008	0.054	<0.001	0.056
Mallard - organs	0.026	0.030	0.061	0.022	0.040	<0.001	0.053	0.005	0.057

-pCi/g wet weight

TABLE A-8 Radionuclide Concentrations in Small Mammals, on the Weldon Spring Site

		CONCENTRATIONS (pCi/g)			
Sample No.	Matrix	Total Uranium	Thorium 230	Thorium 232	Radium 226
ASH POND AREA					
BG-AP20-1287	Rabbit Tissue	<0.02	<0.03	<0.01	<0.01
	Rabbit Bone	<0.03	<0.1	<0.4	<0.1
WSCP AREA					
BG-IT20-021188	Rabbit Tissue	<0.04	<1	<1	ns
	Rabbit Bone	<0.08	<1	<1	ns
BG-CP20-021188	Rabbit Tissue	<0.04	<1	<1	ns
	Rabbit Bone	<0.05	<1	<1	ns
FROG POND AREA					
BG-FP21-1287	Squirrel Tissue	<0.09	<0.05	<0.01	<0.01
	Squirrel Bone	<0.03	<0.07	<0.06	<0.07

ns not sampled

TABLE A-9 Occurrence of Common Species of Waterfowl, Weldon Spring Site

	7/91	8/91	9/91	10/91	11/91	12/91	1/92	2/92	3/92	4/92	5/92	6/92	7/92	8/92	9/92	10/92	11/92	12/92
Mallard	11	13	51	45	33	14	33	10	9	11	12	23	0	0	12	6	0	0
Wood Duck	6	0	1	40	0	0	0	2	3	23	30	38	0	0	26	0	0	0
Canada Goose	4	13	41	18	137	20	2	20	13	65	19	50	0	0	30	17	0	0
Total count	21	26	93	103	170	34	35	32	25	99	61	111	0	0	0	0	0	0
Total survey days	5	5	7	6	6	4	3	2	3	7	3	5	4	4	4	5	2	2
Individuals/day	4.2	5.2	13.2	17.2	28.3	8.5	11.7	16.0	8.4	14.1	20.3	22.2	0	0	17.0	1.0	0	0

TABLE A-10 Metals Concentrations in Fish ($\mu g/g$) MDC Survey, 1989

Lake	Species	Lead	Cadmium	Mercury	Arsenic
Lake 35	Catfish Fillet	<0.01	<0.001	0.006	-----
Lake 36	Sunfish Whole	0.119	0.026	0.065	0.078
	Catfish Fillet	0.064	0.001	0.070	0.035
Lake 37	Sunfish Whole	0.063	0.015	0.046	0.161
	Catfish Fillet	0.024	0.009	0.059	0.048

(Ref. 19)

TABLE A-11 Metals Concentrations in Fish-Busch Lake 36 EPA Survey, 1992 ($\mu g/g$)

Species	Lead		Chromium		Arsenic		Barium		Mercury	
	June	Oct	June	Oct	June	Oct	June	Oct	June	Oct
Largemouth Bass Whole	<0.5	<0.1	0.335	NS	<0.5	<0.1	1.91	NS	NS	0.10
Sunfish Whole	<0.5	<0.1	0.437	NS	<0.5	<0.1	4.91	NS	NS	0.027
Crappie Whole	<0.5	<0.1	0.398	NS	<0.5	<0.1	4.34	NS	NS	0.081
Catfish Whole	<0.5	0.109	0.258	NS	<0.5	<0.1	2.19	NS	NS	0.08
Largemouth Bass Fillet	<0.5	<0.1	0.102	NS	<0.5	<0.1	0.078	NS	NS	0.212
Sunfish Fillet	<0.5	<0.1	0.131	NS	<0.5	<0.1	0.284	NS	NS	0.028
Crappie Fillet	<0.5	NS	0.101	NS	<0.5	NS	0.383	NS	NS	NS
Catfish Fillet	<0.5	<0.1	0.201	NS	<0.5	<0.1	0.086	NS	NS	0.031

(Ref. 21)
NS Not Sampled

APPENDIX B

Kruskal-Wallis Statistical Results

The Kruskal-Wallis statistical test is a one-way, non-parametric analysis of variance tests used to assess significant relationships in fish data collected from 1987 to 1993. Statistical results from the 1987 - 1993 tests are presented in Tables B-1 through B-4. Results from tests conducted with data from 1989 - 1993 are presented in Tables B-5 through B-8. The assumptions tested included uranium concentration in all fish, uranium concentrations in specific species, and uranium concentrations in sample types. The assumption or null hypothesis is that uranium concentrations in fish (by species, by sample type) from Lakes 34, 35, 36, Femme Osage Slough, and Frog Pond have the same mean concentration of uranium as the background lakes, Lakes 33 and 37. If the results of the Kruskal-Wallis test show that the lakes differ, multiple comparisons are conducted to define which lake is signficantly different (Ref. 14).

For each assumption, the calculated value H was compared to a tabulated chi-square value with (k-1) degrees of freedom, where k was the number of groups (lakes). If the calculated H value exceeded the chi-square table value, the hypothesis of equal means was rejected. If the H value was not exceeded, results indicated no significant difference between the concentrations at the lakes (i.e., no significant biouptake). If the H was found to be significant, the multiple comparisons test was conducted by comparing the concentration differences between background and study lakes (Ref. 14). If the critical value calculated from the multiple comparisons test was higher than the difference in numeric rank between the study lake and background lakes, then the difference was considered signficant.

TABLE B-1 Results of Kruskal-Wallis (One-Way, Non-parametric) Test on Uranium Concentrations (pCi/g) in Fish, 1987-1993

	Background Lakes 33 & 37	Study Lakes				
		Lake 34	Lake 35	Lake 36	Femme Osage Slough	Frog Pond
Number of samples (n):	41	27	35	34	22	1
Average rank:	48.3	66.4	101.5	110.1	75.6	146.0
H = 46.67 df = 5 χ^2 = 11.07						
Difference from background (D):	0	18.1	53.2	61.8	27.3	97.7
Critical value (C):	23.7	26.6	24.7	24.9	28.4	106.9
Significant (C <= D?)	NO	NO	YES	YES	NO	NO[a]

[a] small sample size (1 sample)

TABLE B-2 Results of Kruskal-Wallis (One-Way, Non-parametric) Test on Uranium Concentrations (pCi/g) in Sunfish, 1987-1993

	Background Lakes 33 & 37	Study Lakes				
		Lake 34	Lake 35	Lake 36	Femme Osage Slough	Frog Pond
Number of samples (n):	14	11	10	11	3	1
Average rank:	11.4	21.7	35.1	37.2	25.0	42.0
H = 26.6 df = 5 Y^2 = 11.07						
Difference from background (D):	0	10.3	23.7	25.8	13.6	30.6
Critical value (C):	12.7	13.6	14.0	13.6	21.5	35.0
Significant (C < = D?)	NO	NO	YES	YES	NO	NO

* small sample size (1 sample)

TABLE B-3 Results of Kruskal-Wallis (One-Way, Non-parametric) Test on Uranium Concentrations (pCi/g) in All Fish by Sample Type, 1987-1993

Sample Type		Background Lakes 33 & 37	Study Lakes			
			Lake 34	Lake 35	Lake 36	Femme Osage Slough
Fillet	Number of samples (n):	18	12	14	18	10
	Average rank:	21.7	30.0	46.0	48.7	35.8
	H = 19.12 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	8.3	24.3	27.0	14.1
	Critical value (C):	15.6	17.4	16.7	15.6	18.4
	Significant? (C < D)	NO	NO	YES	YES	NO
Whole	Number of samples (n):	17	9	12	10	8
	Average rank:	19.3	21.8	35.0	43.6	27
	H = 17.43 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	2.5	15.7	24.3	7.7
	Critical value (C):	12.5	15.0	13.7	14.5	15.6
	Significant ? (C < D)	NO	NO	YES	YES	NO
Fishcake[a]	Number of samples (n):	6	6	9	6	4
	Average rank:	5.5	14.6	19.7	24.7	13
	H = 15.85 df = 5 χ^2 = 11.07					
	Difference from background (D):	0	9.0	14.2	19.2	7.5
	Critical value (D):	12.5	12.5	11.4	12.5	14.0
	Significant (C <= D?)	NO	NO	YES	YES	NO

a Frog Pond fishcake samples: samples-1, rank-30, difference-24.5, critical value-23.5, signficant-YES (small sample size).

TABLE B-4 Results of Kruskal-Wallis (One-Way Nonparametric) Test on Uranium Concentrations (pCi/g) in Sunfish by Sample Type, 1987-1993

Sample Type		Background Lakes 33 & 37	Study Lakes			
			Lake 34	Lake 35	Lake 36	Femme Osage Slough
Fillet	Number of samples (n):	4	3	2	5	ns
	Average rank:	4.6	3.3	10.0	11.3	
	H = 9.71 df = 3 χ^2 = 7.815					
	Difference from background (D):	0	-1.3	5.4	6.7	
	Critical value (C):	6.3	6.9	7.7	5.9	
	Significant? (C < D)	NO	NO	NO	YES	
Whole	Number of samples (n):	6	3	3	3	2
	Average rank:	3.8	8.3	10.7	15.0	7.5
	H = 11.18 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	4.5	6.9	11.2	3.7
	Critical value (C):	6.74	7.78	7.78	7.78	8.9
	Significant ? (C < D)	NO	NO	NO	YES	NO
Fishcake[a]	Number of samples (n):	5	5	5	3	1
	Average rank:	4.0	9.6	14.2	15.7	6
	H = 12.58 df = 5 χ^2 = 11.07					
	Difference from background (D):	0	5.6	10.2	11.7	2.0
	Critical value (D):	8.68	8.68	8.68	10.0	15.0
	Significant (C <= D?)	NO	NO	YES	YES	NO

[a] Frog Pond fishcake samples: samples-1, rank-18, difference-14, critical value-15.0, signficant-NO (small sample size).

TABLE B-5 Results of Kruskal-Wallis (One-Way, Non-parametric) Test on Uranium Concentrations (pCi/g) in Fish, 1989-1993

	Background Lakes 33 & 37	Study Lakes			
		Lake 34	Lake 35	Lake 36	Femme Osage Slough
Number of samples (n):	38	23	31	29	17
Average rank:	41.5	58.7	86.5	98.5	66.3
H = 41.3 df = 4 χ^2 = 9.488					
Difference from background (D):	0	17.2	45	57	24.8
Critical value (C):	20.5	23.6	21.6	22.0	26.1
Significant (C <= D?)	NO	NO	YES	YES	NO

[a] small sample size (1 sample)

TABLE B-6 Results of Kruskal-Wallis (One-Way, Non-parametric) Test on Uranium Concentrations (pCi/g) in Sunfish, 1989-1993

	Background Lakes 33 & 37	Study Lakes			
		Lake 34	Lake 35	Lake 36	Femme Osage Slough
Number of samples (n):	12	9	9	9	3
Average rank:	8.5	19.9	28.8	33.6	20.3
H = 25.5 df = 4 Y^2 = 9.488					
Difference from background (D):	0	11.4	20.3	25.1	11.8
Critical value (C):	11.2	12.1	12.1	12.1	17.7
Significant (C <= D?)	NO	NO	YES	YES	NO

[a] small sample size (1 sample)

TABLE B-7 Results of Kruskal-Wallis (One-Way, Non-parametric) Test on Uranium Concentrations (pCi/g) in All Fish by Sample Type, 1989-1993

Sample Type		Background Lakes 33 & 37	Study Lakes			
			Lake 34	Lake 35	Lake 36	Femme Osage Slough
Fillet	Number of samples (n):	16	9	11	14	6
	Average rank:	17.2	24.7	35.2	39.5	26.4
	H = 16.5 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	7.5	18	22.3	9.2
	Critical value (C):	12.9	15.2	14.3	13.3	17.4
	Significant? (C < D)	NO	NO	YES	YES	NO
Whole	Number of samples (n):	17	9	12	10	8
	Average rank:	19.3	21.8	35.0	43.6	27
	H = 17.49 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	2.5	15.7	24.3	7.7
	Critical value (C):	12.5	15.0	13.7	14.5	15.6
	Significant ? (C < D)	NO	NO	YES	YES	NO
Fishcake[a]	Number of samples (n):	5	5	8	5	3
	Average rank:	3.9	11.9	16.2	21.6	11.5
	H = 14.9 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	8.0	12.3	17.7	7.6
	Critical value (D):	10.8	10.8	9.76	10.8	12.6
	Significant (C <= D?)	NO	NO	YES	YES	NO

[a] Frog Pond fishcake samples: samples-1, rank-30, difference-24.5, critical value-23.5, signficant-YES (small sample size).

TABLE B-8 Results of Kruskal-Wallis (One-Way Nonparametric) Test on Uranium Concentrations (pCi/g) in Sunfish by Sample type, 1989 - 1993

Sample Type		Background Lakes 33 & 37	Study Lakes			
			Lake 34	Lake 35	Lake 36	Femme Osage Slough
Fillet	Number of samples (n):	3	2	2	4	ns
	Average rank:	2.7	3.5	7.0	9.2	
	H = 8.19 df = 3 χ^2 = 7.815					
	Difference from background (D):	0	0.8	4.3	6.5	
	Critical value (C):	5.7	6.44	6.44	5.39	
	Significant? (C < D)	NO	NO	NO	YES	
Whole	Number of samples (n):	5	3	3	3	2
	Average rank:	3.8	8.3	10.7	15.0	7.5
	H = 11.18 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	4.5	6.9	11.2	3.7
	Critical value (C):	6.74	7.78	7.78	7.78	8.9
	Significant ? (C < D)	NO	NO	NO	YES	NO
Fishcake[a]	Number of samples (n):	4	4	4	2	1
	Average rank:	3.0	7.2	11.0	14.5	6
	H = 11.34 df = 4 χ^2 = 9.488					
	Difference from background (D):	0	4.2	8.0	11.5	3.0
	Critical value (D):	7.08	7.08	7.08	8.67	11.2
	Significant (C < = D?)	NO	NO	YES	YES	NO

[a] Frog Pond fishcake samples: samples-1, rank-18, difference-14, critical value-15.0, signficant-NO (small sample size).

APPENDIX C
Unpublished Documents

MORRISON KNUDSEN CORPORATION

MK-FERGUSON GROUP

INTER-OFFICE CORRESPONDENCE

DATE: April 8, 1993

TO: File

FROM: Melissa Lutz

SUBJECT: TELECON: EPA'S SAMPLING RATIONALE FOR FISH AT LAKE 36

Date of Call: April 6, 1993

Call to: Cecilia Tapia, EPA-KC

Caller: Melissa Lutz

SUBJECT: EPA'S SAMPLING RATIONALE FOR FISH AT LAKE 36

During 1991, the Department of Defense sampled sediments from Busch lakes in order to support the RI for the WSOW. The results showed Lake 36 with some of the highest metal concentrations (Ar, Ba, Cr, Hg, and Pb) in the sediments. In order to address these high sediment concentrations, and the biouptake of these metals in fish in a timely manner, the EPA took lead responsibility for Lake 36. The Department of Defense is responsible for sampling other Busch lakes if determined to be necessary.

The WSS also wanted to clarify the sampling rationale behind the resampling effort of Lake 36 (October, 1992). Cecilia explained that the resampling was done to obtain lower detection limits necessary to determine if any harmful effects were expected to substanance fishermen. Mercury was also added based upon the 1987 PMC sampling results.

ML/jn

cc: Ken Meyer
Jim Meier
Julie Reitinger
Lou Gonzales

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Form 222-A 06/92

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VII
726 MINNESOTA AVENUE
KANSAS CITY, KANSAS 66101

FEB 2 4 1993

COPY

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Mr. Bill Dieffenbach
Assistant Environmental Administrator
Missouri Department of Conservation
P.O. Box 180
Jefferson City, Missouri 65102

Dear Mr. Dieffenbach:

Enclosed are copies of the analytical data, Data Qualification Codes sheet, and field sheets for the fish and sediment samples collected from Lake 36 at the August A. Busch Wildlife Area. The samples were collected on October 21, 1992 by Ecology and Environment, a contractor for the U.S. Environmental Protection Agency (EPA).

The whole fish and fish fillet (edible portion) samples were analyzed for lead, arsenic, and mercury at a detection limit of 0.100 milligrams per kilograms (mg/kg). Sample analysis results are summarized below.

All whole fish and fish fillet samples were below the quantitative detection limit of 0.100 mg/kg for lead except for the samples listed in the table below. At the levels detected, harmful effects from subsistence fishing and consumption are not expected.

CHEMICAL	CONCENTRATION (mg/kg)	TISSUE ANALYSIS	SAMPLE NUMBER
Lead	0.109	whole fish	CS6BC009
Lead	0.176	whole fish	CS6BC010

All whole fish and fish fillet samples were below the quantitative detection limit of 0.100 mg/kg for arsenic. A value of 0.28 mg/kg was calculated as a level which is not expected to cause harmful effects for subsistence fishing.

01[illegible]94
3/11/93

Mercury was detected in samples listed in the table below:

CHEMICAL	CONCENTRATION (mg/kg)	TISSUE ANALYSIS	SAMPLE NUMBER
Mercury	0.028	edible portion	CS6BC001
Mercury	0.212	edible portion	CS6BC002
Mercury	0.031 0.018	edible portion	CS6BC005 CS6BC005D (duplicate)
Mercury	0.027	whole fish	CS6BC006
Mercury	0.1	whole fish	CS6BC007
Mercury	0.081	whole fish	CS6BC008
Mercury	0.079	whole fish	CS6BC009
Mercury	0.02	whole fish	CS6BC101

A value of 0.28 mg/kg was calculated as a level which is not expected to cause harmful effects for subsistence fishing. All of the concentrations detected were below this level.

Ten sediment samples and one duplicate were taken along the southeastern end of Lake 36 and analyzed for total metals. Listed below is a summary of the samples with concentrations above maximum background. The enclosed table contains the background concentrations. See Figure 1 for sample locations.

Aluminum was detected above the maximum background concentration of 4570 mg/kg in sample # CS6BC101-108, and CS6BC110-111. The highest concentration was detected in sample # CS6BC111 (duplicate of CS6BC102) at 11,200 mg/kg.

Barium was detected above the maximum background concentration of 50 mg/kg in sample # CS6BC101-103, CS6BC105-106 and CS6BC110-111. The highest concentration was detected in sample # CS6BC105 at 137 mg/kg.

Beryllium was detected above the maximum background concentration of 0.6 mg/kg in sample # CS6BC105 and CS6BC111. The highest concentration was detected in sample # CS6BC105 at 0.892 mg/kg.

Cadmium was detected above the maximum background concentration of 0.181 mg/kg in sample # CS6BC101-111. The highest concentration was detected in sample # CS6BC105 at 1.66 mg/kg.

Cobalt was detected above the maximum background concentration of 7 mg/kg in sample # CS6BC102, CS6BC105, and CS6BC110-111. The highest concentration was detected in sample # CS6BC105 at 22.4 mg/kg.

Chromium was detected above the maximum background concentration of 10.7 mg/kg in sample # CS6BC102, CS6BC105-106, and CS6BC110-111. The highest concentration was detected in sample # CS6BC105 at 26.3 mg/kg.

Copper was detected above the maximum background concentration of 6.95 mg/kg in sample # CS6BC101-102, CS6BC104-108, and CS6BC110-111. The highest concentration was detected in sample # CS6BC102 at 13 mg/kg.

Iron was detected above the maximum background concentration of 16,200 mg/kg in sample # CS6BC105 at 24,300 mg/kg.

Manganese was detected above the maximum background concentration of 238 mg/kg in sample # CS6BC101 and CS6BC105. The highest concentration was detected in sample # CS6BC105 at 1150 mg/kg.

Nickel was detected above the maximum background concentration of 7.25 mg/kg in sample # CS6BC102, CS6BC105 and CS6BC110-111. The highest concentration was detected in sample # CS6BC111 at 10.3 mg/kg.

Lead was detected above the maximum background concentration of 20 mg/kg in sample # CS6BC105 at 25.3 mg/kg.

Vanadium was detected above the maximum background concentration of 27.5 mg/kg in sample # CS6BC102, CS6BC105 and CS6BC110-111. The highest concentration was detected in sample # CS6BC105 at 52.1 mg/kg.

Magnesium was detected above the maximum background concentration of 498 mg/kg in sample # CS6BC101-111. The highest concentration was detected in sample # CS6BC102 at 1260 mg/kg.

Sodium was detected above the maximum background concentration of 29.3 mg/kg in sample # CS6BC101-111. The highest concentration was detected in sample # CS6BC111 at 248 mg/kg.

Potassium was detected above the maximum background concentration of 297 mg/kg in sample # CS6BC101-111. The highest concentration was detected in sample # CS6BC111 at 849 mg/kg.

This information is forwarded to you in accordance with the provisions of Section 3007(a) of the Resource Conservation and Recovery Act of 1976 (RCRA), and Section 104(e)(4)(B) of the

Comprehensive, Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by The Superfund Amendments and Reauthorization Act of 1986. If you have any questions regarding this analytical data, please contact Cecilia Tapia of my staff at

Sincerely yours,

Robert L. Morby
Chief, Superfund Branch
Waste Management Division

Enclosure

cc: Ray Strebler, MDNR (w/ encl.)
Steve Iverson, USACE (w/ encl.)

MISSOURI DEPARTMENT OF HEALTH

RECEIVED
JUL 16 1990
PLANNING

John Ashcroft
Governor
John R. Bagby, Ph.D.
Director

P.O. Box 570, Jefferson City, MO 65102 • 314-751-6400 • FAX 314-751-6010

July 16, 1990

Dan F. Dicknelte
Environmental Administrator
Missouri Department of Conservation
P.O. Box 180
Jefferson City, Mo 65102-0180

Dear Mr. Dicknelte:

I am writing in response to your April 9, 1990 letter, and would like to apologize for the delay. Per your request, Stephen Meek, Toxicologist for the Bureau of Environmental Epidemiology, reviewed the available data on consumption of contaminated fish taken from Lakes 35, 36, and 37 of the August A. Busch Wildlife Area and offers the following assessment:

Background

The Missouri Department of Conservation (DOC) sampled fish taken from lakes in the August A. Busch Wildlife Area to determine current contamination levels. Previous analyses and reviews indicated a potential health problem might exist from consumption of the fish.

The wildlife area is adjacent to the Weldon Spring Site (WSS) and surface water run-off from the WSS has apparently resulted in the contamination of the lakes with heavy metals and other pollutants. The lakes are used for recreational and some subsistence fishing.

Documents Reviewed

DOC letter dated April 9, 1990. (copy attached)

Unpublished data from DOC on fishing practices and likely consumption associated with the wildlife area lakes.

Toxicological profiles published by Agency for Toxic Substances and Disease Registry, U.S. Public Health Service.

Discussion

The average U.S. consumption rate of commercial fish has been estimated at 19 grams per day and the 95th percentile rate at 27 grams per day. Subsistence and sport fisherpersons may exceed these rates and, therefore, may have increased exposure to contaminants. The DOC has calculated from area use data that the average fisherperson spends 3.5 days annually fishing at wildlife area lakes and that he/she fishes for bass 40 per cent of the time, catfish 39 per cent of the time, and whatever he/she can catch 11 per cent of the time. Subsistence fisherpersons concentrate on catfish and tend to fish in the "put and take" lakes managed for that purpose. These lakes are not known to be contaminated. The creel limit is 4 channel catfish per day; the average live weight is one pound. Assuming a subsistence fisherperson fishes Lake 36*, which has the highest contamination levels in catfish, at twice the average rate (in addition to more frequent fishing at the put and take lakes), catches and consumes his/her limit daily, the annual and daily ingestion of contaminants can be calculated.

ANNUAL CATFISH CONSUMPTION (Subsistence Fisherperson)

Fishing Days	#Catfish/Day	#Pounds(Fillet)/Catfish	Pounds (Grams)Consumed
7	4	.5	14(6356)

LAKE 36 MEAN CATFISH FILLET CONTAMINATION (ug/g)

Chlordane	Lead	Cadmium	Mercury	Arsenic
<.002	0.06	0.01	0.07	0.03

ANNUAL CONTAMINANT INGESTION (ug)(Subsistence Fisherperson)

Chlordane	Lead	Cadmium	Mercury	Arsenic
Unk	381	64	445	191

DAILY CONTAMINANT INGESTION (ug)(Subsistence Fisherperson)

Chlordane	Lead	Cadmium	Mercury	Arsenic
Unk	1.0	.2	1.2	0.5

TYPICAL U.S. DAILY INTAKE (ug)(All Sources)

Chlordane	Lead	Cadmium	Mercury	Arsenic
0.28	57	20	3.2	46

TOTAL DAILY INTAKE (ug)(Subsistence Fisherperson)

Chlordane	Lead	Cadmium	Mercury	Arsenic
Unk	58.0	20.2	4.2	46.5

DAILY INTAKE GUIDELINES (ug)

Chlordane	Lead	Cadmium	Mercury	Arsenic
4	100	20	4	100

The subsistence fisherperson's total daily intake above is calculated from annual fish consumption with the indicated contaminant levels. The daily contaminant ingestion from the fish is added to typical U.S. daily intake values to arrive at total daily intake. These totals can then be compared to published guidelines for daily ingestion. From this calculation, it is apparent that the fish from the wildlife area do not significantly increase the daily intake of the contaminants.

A more likely exposure scenario is the sport fisherperson spending 3.5 days annually fishing at one or more of the lakes and catching and consuming a relatively small mixed catch of bass, catfish, and panfish. While predator species are likely to have higher levels of contaminants in their flesh than catfish, this scenario would result in probable ingestion levels significantly lower than the subsistence fisherperson.

CONCLUSION

Using the subsistence fisherperson and associated assumptions for worst-case analysis, it is evident that consumption of fish from Lakes 35, 36, and 37 at the August A. Busch Wildlife Area does not present a significant increased risk of adverse health effects from the contaminants in question.

RECOMMENDATIONS

1. Continue routine sampling of fish for analysis. Provide separate analyses for catfish, bass, and panfish.

2. Further characterize subsistence fishing population, i.e. number, daily catch, lakes used, etc.

Sincerely,

William R. Schmidt, M.P.H., PA-C
Director
Division of Environmental Health
and Epidemiology

WRS:SLM:pw

/02 13:50

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service
Agency for Toxic Substances
and Disease Registry

RECEIVED
APR 27 1989
PREP SECTION

Memorandum

Date - April 24, 1989

From Toxicologist
Emergency Response Branch, Office of Health Assessment, ATSDR

Subject Health Consultation: Fish Data, Weldon Spring Site, St. Charles County, Missouri.

To Mr. David Parker
Public Health Advisor
EPA Region VII
Kansas City, Missouri
Through: Chief, Emergency Response Branch, OHA, ATSDR

BACKGROUND

The United States Department of Energy (DOE) has completed a fish survey of lakes and ponds at the Weldon Spring Site (WSS) in St. Charles County, Missouri. The WSS is a DOE surplus facility which was previously operated as an ordinance facility by the Department of the Army and as a uranium processing facility by the Atomic Energy Commission. Several ponds are suspected of having elevated heavy metal contamination resulting from surface water run-off from previous site activity. The Environmental Protection Agency (EPA) has requested the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the fish data for human health concerns.

DOCUMENTS REVIEWED

Radiological and Chemical Uptake by Selected Biota at the Weldon Spring Site, Draft, November 1988, Department of Energy, DOE/OR/21548-044,

DISCUSSION

The Food and Drug Administration has estimated the average consumption rate of commercial fish for the typical American is around 19 grams per day. The consumption rate for the upper 95th percentile is estimated to be 27 grams of fish per day. While the typical American will consume commercial fish from a variety of sources, sports fishermen and subsistence fishermen are more likely to consume greater quantities of fish than the average American and to consume fish from a restricted geographic area. Therefore, these two subpopulations may be at increased risk when consuming contaminated fish from a particular area. Studies on sports fishermen in the Great Lakes area have shown that, on average, 32 lbs. of sport caught fish are consumed each year with certain individuals consuming as much as 3 to 5 times this average amount. This average fish consumption rate is equivalent to 1 fish meal per week which approximates 280 grams of fish per week or 39.8 grams per day.

Proportionate, composite, fillet samples of sunfish, bass, and crappie were collected from WSS lakes. Catfish were not included in composite samples. Using 39.8 grams fish per day to approximate the fish intake for sport fishermen, one can calculate daily and weekly intake for mercury (Table 1), lead (Table 2) and arsenic (Table 3).

Sport and subsistence fishermen may have a favorite lake or fishing spot from which they obtain the majority of their fish; therefore, the most conservative approach in this case is to assume that the fish consumed are from the lakes with detectable levels of the metal of concern. A great deal of variation can exist in calculated intakes levels. Because these are average values from composite samples, levels are higher in half the fish sampled. Also, variation in heavy metal content in fish fillets certainly exists both within species (depending upon age) and between species (depending upon feeding habits and pharmacokinetics). The manner in which the fillet is prepared for analysis also affects the quantitative results. Therefore, it would be prudent not to rely strictly upon the quantitative results.

The FDA has calculated the dietary intake of mercury in the typical American diet to be 3.2 ug/day. For the adult who consumes one contaminated fish meal per week, the weekly intake for mercury from lakes 34, 35, 36, and 37 would range from 44 - 75 ug/week or 6 - 11 ug/day (see Table 1). This intake is greater than the acceptable intake from water based upon EPA's Maximum Contaminant Level (MCL) of 2 ug/l and is similar to EPA's RfD for mercury of 0.158 ug/kg/day which is equivalent to an intake of 11 ug/day for a 70 kg adult male. The World Health Organization has established a maximum tolerable intake of 0.3 ug organic mercury/kg/day for adults. This corresponds to 15 to 21 ug of organic mercury per day for adult females and males. The WHO maximum tolerable level was based upon the observation that the long-term daily ingestion of approximately 250 ug per day of mercury as methyl mercury has been observed to cause the onset of neurological impairment. For individuals consuming 1 fish meal per week from fish caught at the WSS, intake levels appear to be below levels that may cause adverse health effects. This conclusion may not be valid for individuals who are consuming fish from WSS on a more frequent basis.

Table 1. Daily and weekly intake values for mercury are depicted for fish consumption where 39.8 g/day of contaminated fish are consumed. This intake level approximates 1 fish meal per week for sport and subsistence fishermen.

lake	composite concentration (ug/g)	daily intake (ug/day)	weekly intake (ug/week)
34	0.27	10.7	75.2
35	0.24	9.5	66.9
36	0.16	6.4	44.6
37	0.23	9.2	64.1

The FDA has estimated an intake of 57 ug/day of lead for the typical American diet. From lead in fish from lakes 34 and 36, the estimated intake from 1 contaminated fish meal per week is approximately 1100 ug/week or 160 ug/day. This intake exceeds the intake of 100 ug/day using EPA's MCL for lead of 50 ug/l and assuming a 2 l/day water consumption rate for the average adult. Populations at increased risk to lead exposure include children and pregnant women, since lead is capable of crossing the placental barrier. For each 100 ug per liter of oral lead intake, an increase of 4-5 ug of lead per 100 ml of blood is expected. WHO has estimated that this intake level may cause a significant number of children to exceed the recommended blood lead level of 25 ug per 100 ml blood. Lead from fish taken from lakes 34 and 36 has the potential for increasing lead exposure to children and pregnant women who consume the contaminated fish.

Table 2. Daily and weekly intake values for lead are depicted for fish consumption where 39.8 g/day of contaminated fish are consumed. This intake level approximates 1 fish meal per week for sport and subsistence fishermen.

lake	composite concentration (ug/g)	daily intake (ug/day)	weekly intake (ug/week)
34	4.0	159	1,114
36	4.2	167	1,170

The FDA has calculated that the average American dietary intake for arsenic (As) is 46 ug/day. The predominant food source is seafood which ranges from 2 to 10 ug As/g. It is very unusual for freshwater fish to have higher levels than those found in seafood.

For the adult who consumes 1 contaminated fish meal per week from fish taken from lakes 35 and 37, the weekly intake of arsenic is about 3,890 ug/week or 550 ug/day. This intake is much greater than the intake established by EPA's drinking water MCL of 50 ug/1, which is equivalent to 100 ug/day based upon a 2 l/day water consumption rate. An intake of 550 ug/day would be quite unacceptable were the exposure occurring through drinking water. For subsistence fisherman and sport fishermen who have more than 1 fish meal per week from fish taken from lakes 35 and 37, the intake of arsenic obviously would be greater.

Table 3. Daily and weekly intake values for arsenic are depicted for fish consumption where 39.8 g/day of contaminated fish are consumed. This intake level approximates 1 fish meal per week for sport and subsistence fishermen.

lake	composite concentration (ug/g)	daily intake (ug/day)	weekly intake (ug/week)
35	13.9	553	3,872
37	13.6	541	3,788

Daily intake from contaminated fish at the USS site has been calculated from the mean fish consumption rate for sport fishermen. Some sport fishermen will have higher intake than those used in these calculations. Also, it is very likely that subsistence fishermen in the area will consume more locally caught fish when compared to sport fishermen. Therefore, their intake of these metals will be increased thus increasing their risk to adverse health outcome.

A problem does exist in the manner in which the fish were collected. The logic was used that fish are eaten according their proportional population within each lake. This logic does not seem reasonable to me for estimating fish consumption patterns since some residents may have a preference for certain species in their diet. In addition, catfish were not sampled in the survey for heavy metal content. It is very likely that catfish comprise a major portion of fish in the diet of subsistence fishermen. Catfish are also likely to have increased levels of heavy metal because of their close association with sediment feeding, which is the sink for heavy metals in ponds and lakes.

CONCLUSION

All individuals receive some quantity of mercury, arsenic, and lead from both dietary and environmental exposure routes. Quantitation of the environmental exposure route (i.e., air and soil ingestion) is not precise and depends largely upon local conditions.

Quantitation of dietary intake has been made by FDA from food baskets surveys. The intake of heavy metals found in fish at the WSS is in addition to this background exposure.

The occurrence of heavy metals in composite fish samples from the WSS does not present a public health threat to area residents who have occasional fish meals from locally caught fish. However, sport fishermen and subsistence fishermen may be at increased risk to adverse health effects if a major portion of the fish in their diet comes from the lakes with heavy metal contaminated fish. A great deal of variation exists in the fishing and eating habits of these two populations; therefore, it is difficult to quantitate their metal intake with certainty. By using the average consumption rate for sport fisherman from the Great Lakes area, one can obtain some quantitative idea of the potential intake levels. However, because of uncertainty in estimating dietary fish intake, one should not rely strictly upon the quantitative results which tends to indicate a potential problem. The major concern involves those individuals and their families who rely heavily on fish from the WSS. This population has the potential for exceeding the safety factor used in establishing acceptable heavy metal intakes.

RECOMMENDATIONS

1. Collect composite samples of species specific fish from lakes in the WSS. Include catfish as a separate species to be evaluated.

2. Identify subpopulations, like sport fishermen and subsistence fishermen who might use the lakes at the WSS and educate them to the potential hazard.

3. Fish from the WSS should not be consumed more than once per month.

David N. Mellard

David N. Mellard, Ph.D.

MISSOURI DEPARTMENT OF CONSERVATION

MAILING ADDRESS:
P.O. Box 180
Jefferson City, Missouri 65102-0180

STREET LOCATION:
2901 North Ten Mile Drive
Jefferson City, Missouri

Telephone 314/751-4115
LARRY R. GALE, Director

April 20, 1984

Ms. Gale P. Turi
FUSRAP/Surplus Facilities Group
Division of Remedial Action Projects
Department of Energy
Washington, D.C. 20545

Dear Ms. Turi:

Enclosed you will find two sets of data that we received concerning water samples and fish samples taken from our Weldon Spring and Busch Wildlife Areas. I was not sure where you wanted this information sent so I have mailed it directly to you for distribution.

Based on the results of these studies we have opened our areas to fishing in the usual manner. However, we have taken the precaution of posting signs which indicate that the public should drink only from approved sources since both Burgermeister Spring and Lake 36 had elevated concentrations of radionucleotides, as indicated by the results of our sampling analysis. In addition, we have not opened the wildlife trail that runs south from the Army property along the former drainage easement. We understand that there may be spots of radioactivity in that area so we have delayed a formal opening of this trail. Your comments and advice regarding any potential hazard to the public along this area would be appreciated.

As you are aware, our primary concern is for the safety of the people visiting our wildlife areas. We sincerely hope that your agency will find a method to contain the radioactive materials on your property in addition to removing any dangerous levels which are discovered on either the Busch or the Weldon Spring Area.

Thank you very much for the reports of the aerial radiological surveys of the Weldon Spring Chemical Plant. I have sent them to our Fisheries Division so if you want these returned, please let me know. Our Fisheries Division is also interested in any additional information that you might have outside of that shown on your maps, regarding properties now belonging to the Department of Conservation (formerly property of the University of Missouri).

deRoos, 1984

I have one final request concerning the Weldon Spring area. When we acquired this property from the University of Missouri there were several easements attached to the deed. Some of these easements dated back more than twenty years and should have terminated automatically. In addition, there were other areas that were to be marked, or were to be kept from public use. We are somewhat confused as to the current status of these easements under current federal guidelines. Would you have your real estate division update us on what they conclude are the viable easements that remain attached to this property now known as the Weldon Spring Wildlife Area?

Thank you very much for your cooperation. I do hope that the scoping plan will be worked out so that you will be able to contain and to find a solution to this problem in the near future.

Sincerely,

Carolyn deRoos

CAROLYN deROOS
ASSISTANT GENERAL COUNSEL

CdeR:ca
Enclosures