Reading

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December 7, 1988

Mr. Dave Parker
ATSDR, Superfund Branch
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Dear Mr. Parker:

RADIOLOGICAL AND CHEMICAL UPTAKE BY SELECTED BIOTA AT THE WELDON SPRING SITE

Enclosed is a draft copy of the above report. Please provide any comments by December 23, 1988.

If you have any questions call Ken Lawver at 314-441-8978.

Sincerely,

R. R. Nelson

R. R. Nelson
Project Manager
Weldon Spring Site
Remedial Action Project

Enclosure:
As stated

DOE/OR/21548-044

United States Department Of Energy

RADIOLOGICAL AND CHEMICAL UPTAKE BY EDIBLE PORTIONS OF SELECTED BIOTA AT THE WELDON SPRING SITE

NOVEMBER, 1988

WELDON SPRING SITE REMEDIAL ACTION PROJECT

RADIOLOGICAL AND CHEMICAL UPTAKE

BY EDIBLE PORTIONS OF SELECTED BIOTA

AT THE WELDON SPRING SITE

PREPARED BY:

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PREPARED FOR:

U.S. DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS

WELDON SPRING SITE

REMEDIAL ACTION PROJECT OFFICE

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1.0 INTRODUCTION

This study was initiated to investigate the possible exposure pathways of chemical and radiologic contamination to humans by ingestion of potentially contaminated fish and game from the presence of the former Weldon Spring Uranium Feed Materials Plant. Since the Weldon Spring Site (WSS) is surrounded by prime hunting and fishing habitat, (i.e. August A. Busch and Weldon Spring Wildlife areas), questions concerning the consumption of potentially contaminated animal tissue have been raised. Game animals that migrate on and off site are exposed to contaminated soils and water on site and to contaminated water leaving the site by natural drainage channels. Fish in the lakes and streams which receive this water are also a potential source of exposure to the public.

The interest in a bio-uptake study was generated in response to concerns expressed at the Draft Environmental Impact Statement (DEIS) public hearings. As a result, a draft bio-uptake sampling plan was submitted by the Department of Energy (DOE) to the Environmental Protection Agency (EPA Region VII) and the Missouri Department of Natural Resources for review (DOE, 1987d). Suggested changes and additions to the proposed scope of work were incorporated into the sampling plan where feasible, and field work began in November 1987.

This document is a report of the data and a discussion of the results obtained. A discussion of other biological sampling efforts and bio-uptake studies which have been performed by others prior to the current effort is included also. This study is not a comprehensive evaluation of all levels of the food chain. It is a screening process to identify the ranges of the concentrations of some chemical and radiological constituents within the few fish and mammal species that are eaten by humans. The purpose of this study was limited to evaluating only those tissues that are routinely consumed for food. Human

exposure through ingestion pathways is being determined as part of a risk assessment for EPA Remedial Investigation/Feasibility Study (RI/FS) documentation for the WSS.

1.1 SITE HISTORY AND ENVIRONMENTAL SETTING

The Weldon Spring Site is a DOE surplus facility located approximately 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 (DNT). During this operation, small areas of the 17,000-acre site were contaminated by TNT process materials. In 1954, 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 uranium transformation series.

After closure 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 (WSCP) becoming operational, the herbicide project was cancelled. In 1985, the custody of the WSCP was transferred from the DA to the Department of Energy (DOE). In conjunction with this transfer, the Weldon Spring Site Remedial Action Project (WSSRAP) was created as DOE Major Project Number 182.

1.2 SOURCES OF CONTAMINATION

Radiologically contaminated soils at the WSCP are generally confined to the north and south dump areas, 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. The majority of radium-226 and thorium-232 concentrations are at mean background levels (UNC, 1988). Therefore, sampling of small mammals on site was focused on those areas where the potential for radionuclide uptake was greatest. Contaminated soils in these areas are also the major source areas contributing to surface water runoff contamination.

Surface water runoff from the north and west sides of the WSS flows to Ash Pond (Figure 1-1). A significant portion of this runoff flows through the south dump area and enters Ash Pond. Water from Ash Pond flows to Lake 35 in the August Busch Wildlife Area, to Schote Creek and Dardenne Creek, and eventually to the Mississippi River (Figure 1-2). Since plant operations ceased in 1967, the discharge from Ash Pond has become an intermittent stream.

Lake 35 is the closest lake to Ash Pond that receives effluent from Ash Pond. Lake 35 is commonly used by the public for recreational activities such as fishing and limited boating.

Water from Ash Pond also discharges via underground connections to Burgermeister Spring, to Lake 34, to Dardenne Creek, and eventually to the Mississippi River (Dean, 1985). At present, there is no recreational use of Burgermeister Spring, but Lake 34 is used for recreational purposes similar to those of Lake 35. Lakes 34 and 35 are not used as drinking water or as irrigation sources (Figure 1-2).

Surface water runoff from the northeast portion of the WSS drains into Frog Pond. An intermittent stream running out of Frog Pond flows north to Lake 36. The outfall of Lake 36 discharges into Lake 35, to Schote Creek, to Dardenne Creek, and eventually to the Mississippi River. Lake 36, located in the Busch Wildlife Area, is the closest lake in an unrestricted area receiving effluent from Frog Pond. Lake 36 is also used for

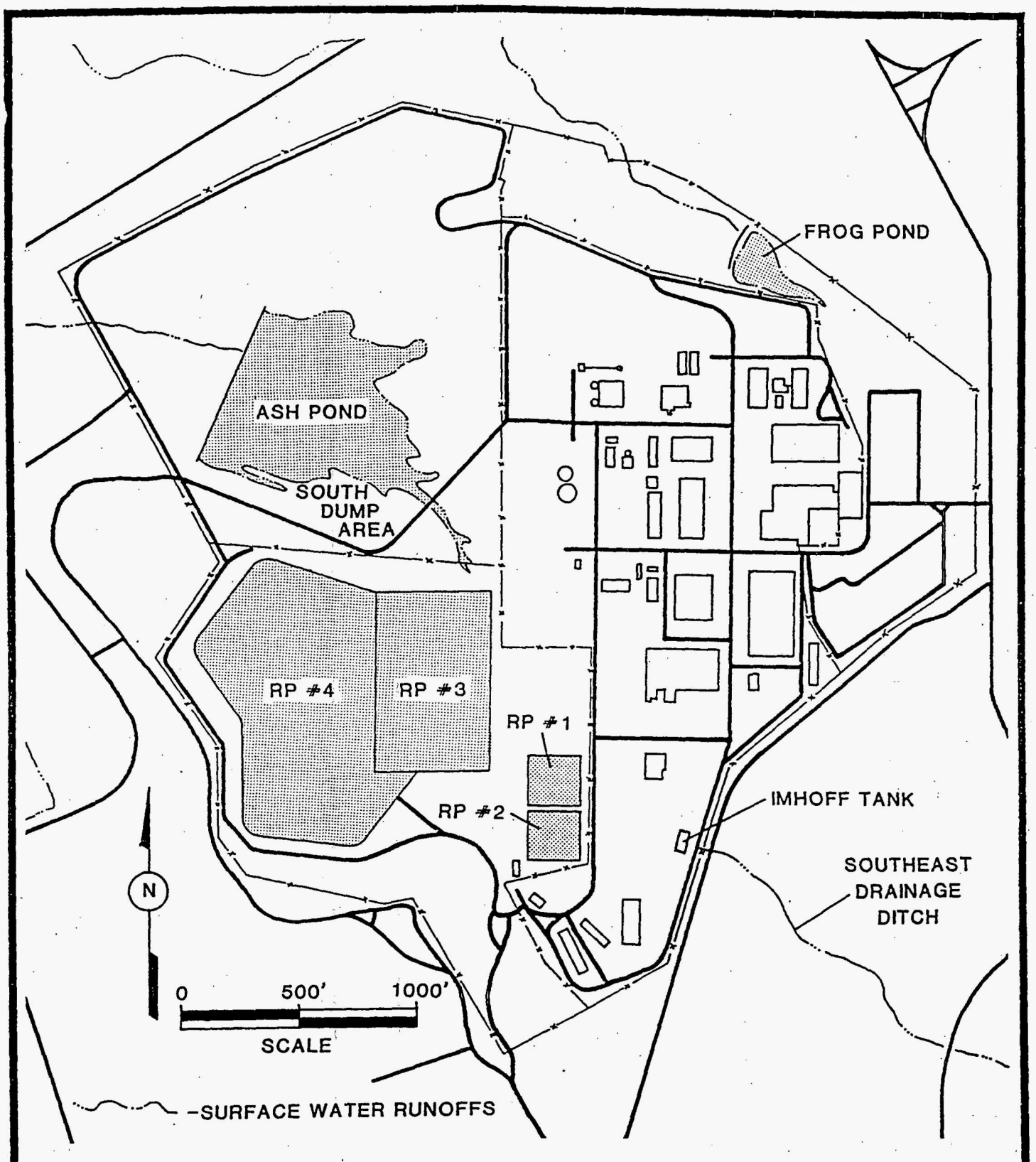


FIGURE 1-1

SITE MAP WITH ASH POND AND FROG POND DRAINAGES

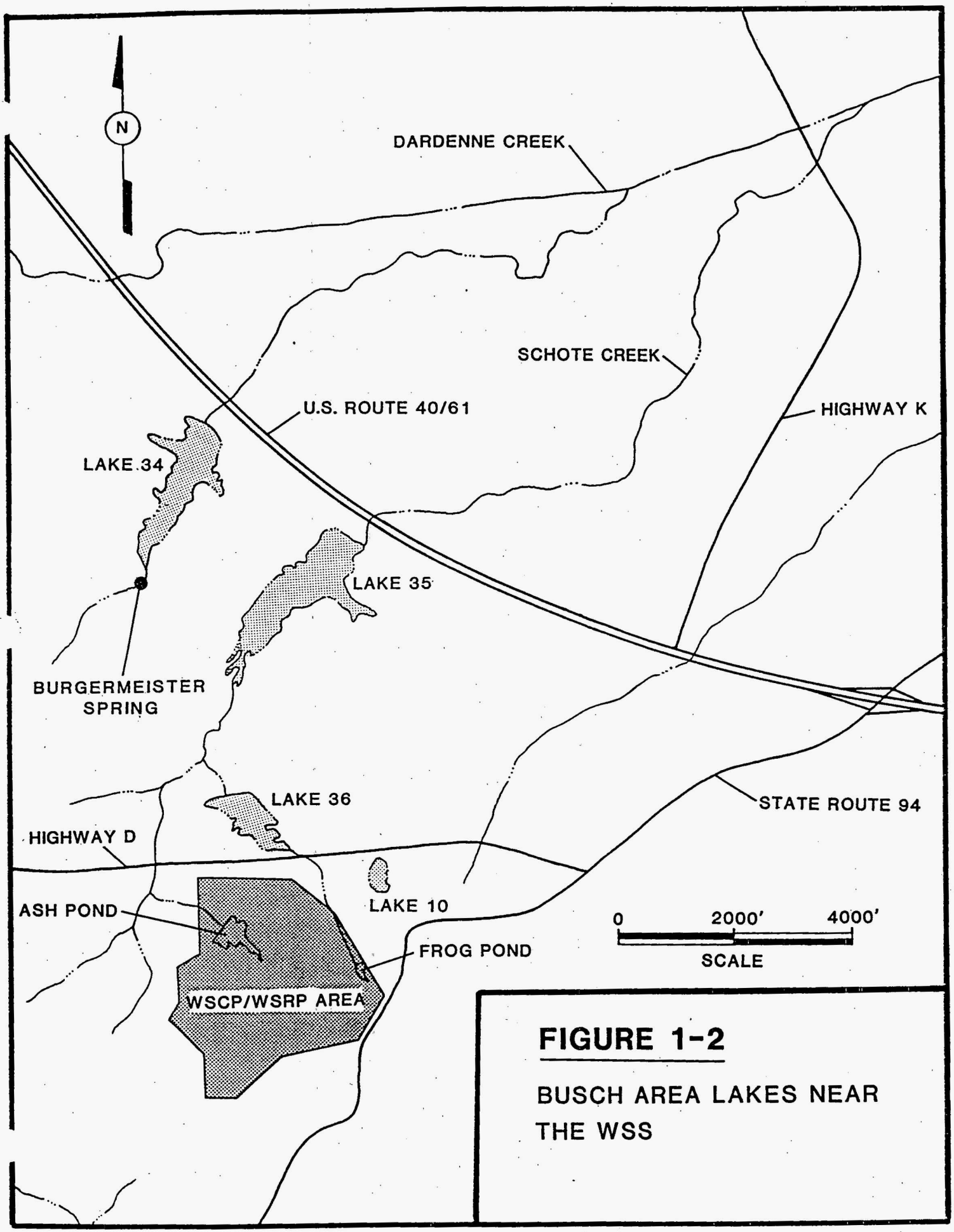


FIGURE 1-2

BUSCH AREA LAKES NEAR THE WSS

fishing and boating but not as a source of drinking water or as a source for irrigation.

On the southeast corner of the WSCP, the outfall from the Imhoff tank (the former WSCP sanitary sewage system) flows down a drainage ditch to the Missouri River. This drainage system contains areas of elevated radionuclide concentration. Currently, flow through the Imhoff tank results from the infiltration of storm water flowing into the sewer system. Sanitary wastes no longer enter the sewer system.

The Weldon Spring Quarry (WSQ) is approximately 4 miles south-southwest of the WSCP. Radioactive wastes were disposed of in the WSQ by the AEC from 1957 to 1966 (Figure 1-3) (U.S. DOE, 1987a). The DA also disposed of TNT process wastes into the WSQ. A large portion of the AEC radioactive wastes were from the Mallinckrodt Chemical Works' Destrehan Street Feed Plant in St. Louis. Materials from this plant were contaminated with radionuclides in the uranium transformation series.

The Femme Osage Slough is located in the Weldon Spring Wildlife Area, approximately 500 feet south-southeast of the WSQ (Figure 1-3). The slough is believed to be hydraulically connected to the quarry sump (U.S. DOE, 1987b). This slough is not used as a source of drinking water or for irrigation, but is used frequently for fishing.

Average radioactivity levels in surface water and runoff samples taken from in and around the WSS during 1987 are presented in Tables 1-1, 1-2 and 1-3. Figures 1-4, 1-5 and 1-6 illustrate the locations of these samples. Tables 1-1 and 1-2 present data from samples that were collected from surface water locations at quarterly intervals and averaged over the entire year. Table 1-3 presents data from surface water runoff samples collected monthly and averaged for the year. These runoff samples are collected monthly, following significant rainfall events, to

monitor contaminant concentrations leaving the WSSRAP as a result of surface runoff. These averaged values are also presented in the 1987 Environmental Monitoring Report (U.S. DOE, 1987c). The radiologic activity levels in surface water generally decrease with increased distance from the site, mainly due to dilution by lake and runoff water.

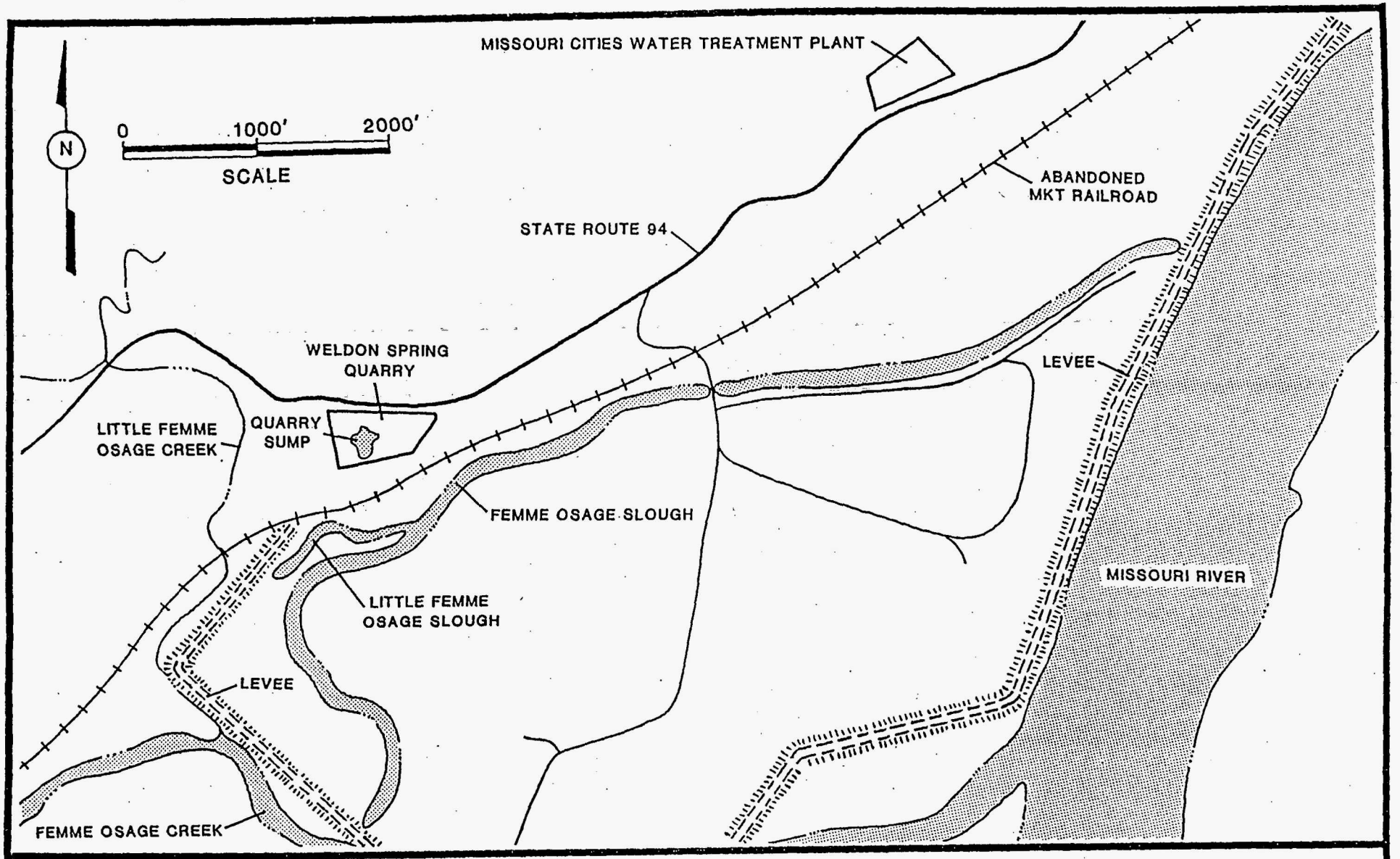


FIGURE 1-3

WSQ AND SLOUGH AREA

TABLE 1-1
ANNUAL AVERAGE RESULTS FROM SURFACE WATER SAMPLES COLLECTED FROM WSQ AREA*

LOCATION		GROSS ALPHA (pCi/L)	GROSS BETA (pCi/L)	NATURAL URANIUM (pCi/L)	Ra-226 (pCi/L)	TH-230 (pCi/L)	TH-232 (pCi/L)	NITRATE (ppm)	SULFATE (ppm)
WSQ AREA									
L. Femme Osage Ck.	SW-1001	<8	12	3	<2	<1	<1	1.4	55
L. Femme Osage Ck.	SW-1002	<4	<8	<1	<1	<1	<1	1.0	48
Femme Osage Slough	SW-1003	25	24	28	<1	<1	<1	<0.2	47
Femme Osage Slough	SW-1004	26	32	34	<1	<1	<1	<0.1	48
Femme Osage Slough	SW-1005	16	16	29	<1	<1	<1	<0.2	51
St. Charles Raw Water	SW-1006	<4	<10	<1	<1	<1	<1	<0.1	48

* Data from Environmental Monitoring Report (US DOE, 1987c)

TABLE 1-2
ANNUAL AVERAGE RESULTS FROM SURFACE WATER SAMPLES COLLECTED FROM WSCP/WSRP AREA**

LOCATION		GROSS ALPHA (pCi/L)	GROSS BETA (pCi/L)	NATURAL URANIUM (pCi/L)	Ra-226 (pCi/L)	TH-230 (pCi/L)	TH-232 (pCi/L)	NITRATE (ppm)	SULFATE (ppm)
WSCP/WSRP AREA									
Dardenne (Schote Ck.)	SW-2001	<3	<8	3	<1	<1	<1	*	52
Lake 36 (IN)	SW-2002	70	42	170	<1	<1	<1	0.8	63
Lake 35 (IN)	SW-2003	12	13	15	<1	<1	<1	1.1	18
Lake 34 (OUT)	SW-2004	19	18	25	<1	<1	<1	4.9	22
Lake 36 (OUT)	SW-2005	21	24	25	<1	<1	<1	0.3	36
Lake 10	SW-2006	<3	<7	2	<1	<1	<1	0.5	9
Dardenne Ck. (HWY 40)	SW-2007	4	9	<1	<1	<1	<1	*	50
Burgermeister Spring	SW-2008	57	39	92	<1	<1	<1	111	53

* Anomalous data presumed to be due to agricultural fertilizer application at these locations make calculation of annual average values suspect.

** Data from Environmental Monitoring Report (USDOE, 1987c).

TABLE 1-3

ANNUAL AVERAGE RESULTS OF NPDES SAMPLING SURROUNDING WSCP/WSRP

LOCATION	pH (SI)	FLOW (GPM)	TOTAL SETTLEABLE SOLIDS (ml/L)	TOTAL SUSPENDED SOLIDS (ml/L)	NATURAL URANIUM (pCi/L) +/- ERROR	GROSS ALPHA (pCi/L) +/- ERROR	NITRATE (mg/L)	TOTAL* NITROAROMATICS (mg/L)
South Ditch NP-001	7.7	40	<0.1	28	680 ± 30	500 ± 30	5.7	0.6<1.3
Frog Pond NP-002	7.9	50	<0.1	18	210 ± 10	110 ± 10	2.4	0.6<1.2
Ash Pond NP-003	7.5	200	<0.1	12	2240 ± 145	2030 ± 130	30	1.5<2.6
Pit 4 NP-004	7.4	25	<0.1	3	9.5 ± 1.0	36 ± 10	1.1	<1.1
South Ditch NP-005	7.7	40	<0.1	30	780 ± 75	560 ± 35	146	1.0<1.9

* First value indicates average, second value estimates upper bound to average including analyses which were below the lower detection limit.

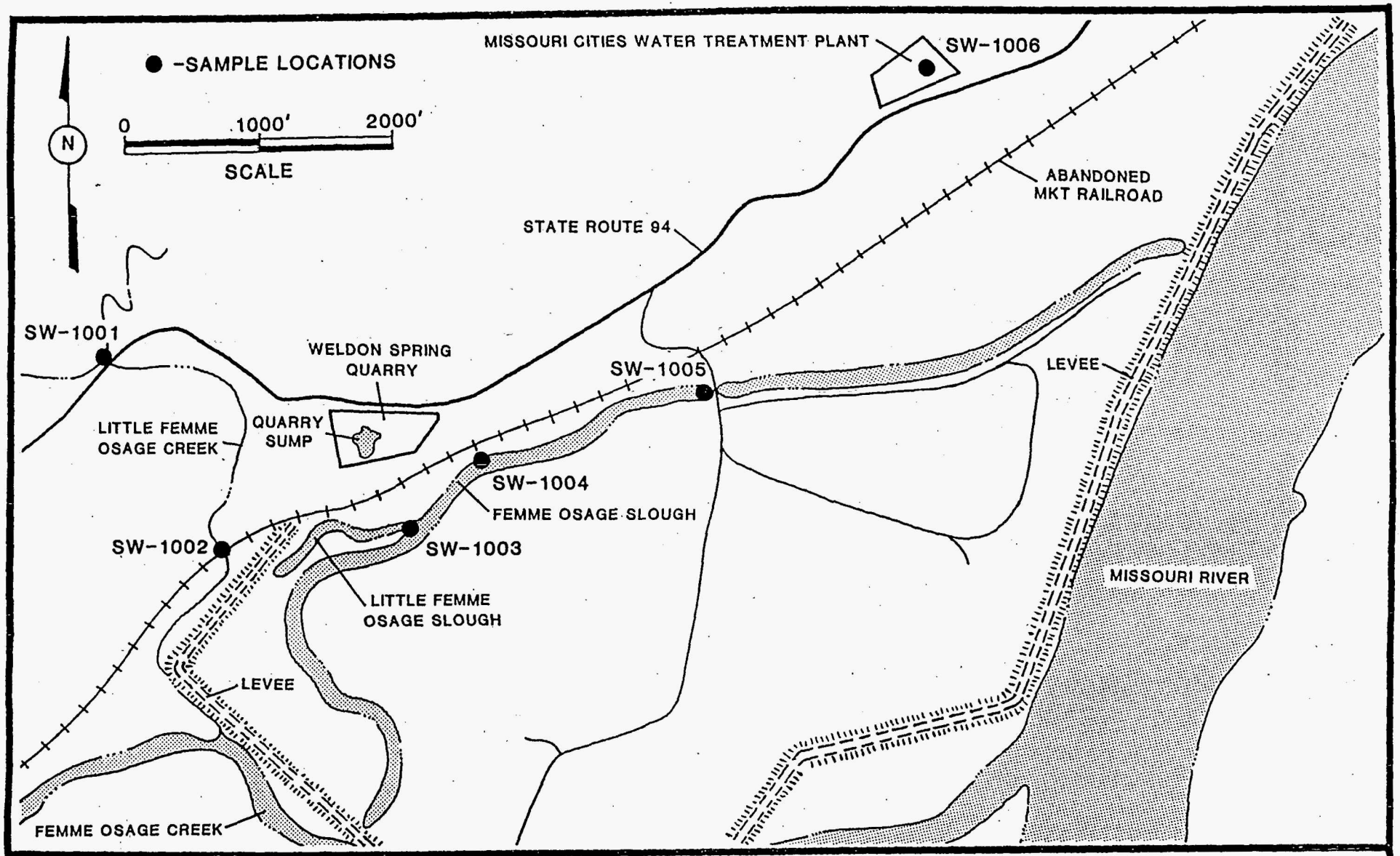


FIGURE 1-4

SURFACE WATER SAMPLING LOCATIONS NEAR THE WELDON SPRING QUARRY

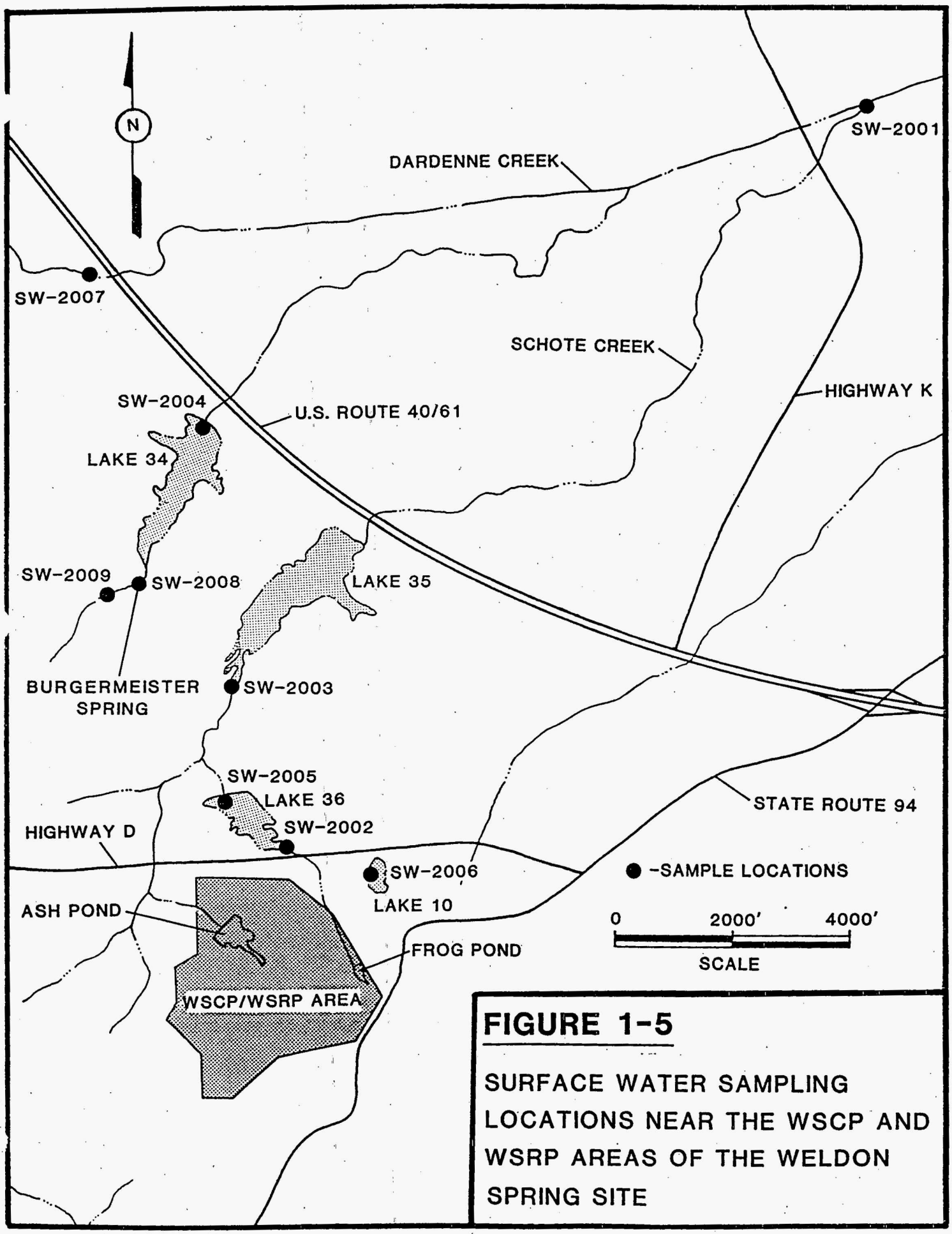


FIGURE 1-5

SURFACE WATER SAMPLING LOCATIONS NEAR THE WSCP AND WSRP AREAS OF THE WELDON SPRING SITE

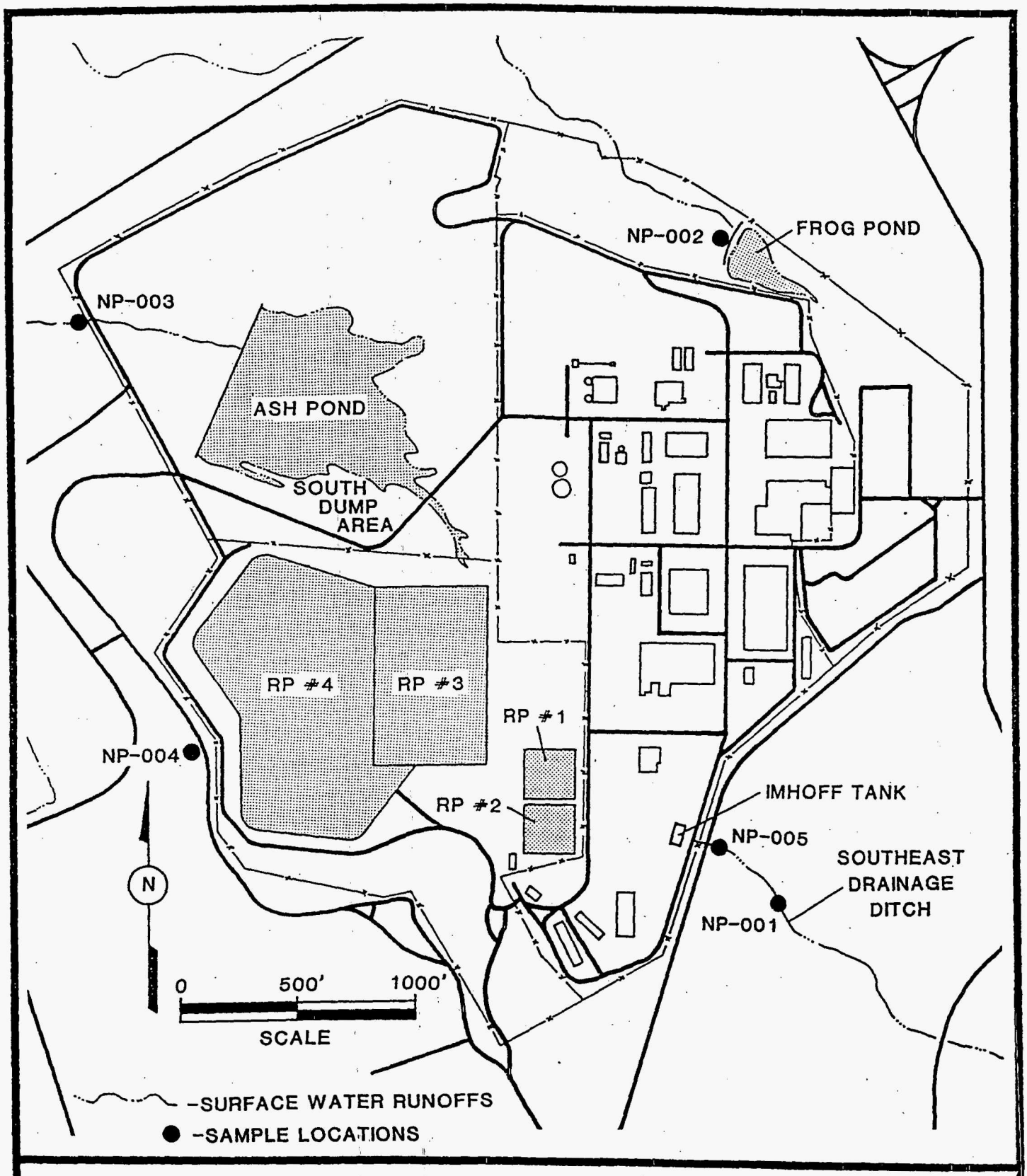


FIGURE 1-6

NPDES SURFACE WATER SAMPLING LOCATIONS

2.0 METHODS

Only terrestrial and aquatic animal specimens were included in the analyses for chemical and radiological uptake. Human consumption of plants from the contaminated areas is considered to be minimal. Although several sharecrop fields are operated by the Department of Conservation in the surrounding areas, they are used exclusively for wildlife forage. The nearest commercial farming areas or private gardens are several miles from the WSS. In addition, no indication of radiological contaminants has been found in any offsite areas used for plant production. Therefore, the present study has been focused on the animal tissue pathway.

2.1 FIELD METHODS

2.1.1 Aquatic Species

Aquatic sampling took place in October and November of 1987. Fish specimens were collected from surface waters impacted by contaminant releases from the WSS in order to determine the extent of radionuclide uptake by game fish. Specimens were collected using the electrofishing technique. Electrofishing utilizes a gas-powered generator to introduce an electric current into the water around the boat. Fish are temporarily stunned, then netted and placed in a water-filled tub in the boat. Fish samples were collected from Lakes 34, 35, 36, and 37 in the August A. Busch Wildlife Area and from the Femme Osage Slough on the Weldon Spring Wildlife Area. This work was accomplished with the cooperation of the Missouri Department of Conservation.

Fish specimens from Frog Pond were also collected by PMC personnel using the electrofishing technique. An attempt was made to collect samples from Raffinate Pits 3 and 4 and from the Quarry Sump. However, these bodies of water did not yield a

single specimen.

Lake 37 in the Busch Wildlife Area was chosen as a background location. Lake 37 is located at the western edge of the Busch Area in a small, isolated watershed which does not receive runoff from the WSS or the abandoned Army Ordnance Works.

According to the bio-uptake sampling plan (DOE, 1987d), five composite samples of fish were to be collected from each location. The five composites were to represent the following fish, prepared as specified:

1) sunfish, filleted
2) sunfish, cleaned (beheaded, scaled, and eviscerated)
3) bass, filleted
4) catfish, filleted
5) mixed species, filleted

The fish species chosen for sampling represented three different patterns of feeding and food preference. All three species are commonly consumed by the public as a result of recreational fishing at the Busch and Weldon Spring Wildlife Areas. Sunfish are omnivorous fish confined to shallow waters. Largemouth bass are predominantly piscivorous in the Busch Wildlife Area lakes. Catfish are predominantly omnivorous bottom feeders. Catfish were expected to be the species most likely to exhibit contaminant uptake due to their proximity to the potentially more contaminated lake sediments. The cleaned (beheaded, scaled, and eviscerated) sunfish composites represented fish commonly used to make "fish cakes", a common way of preparing this smaller fish.

Fish were cleaned and samples prepared either the same day they were collected or the morning following an evening collection. Each composite consisted of a minimum of three fish, totaling at least 800 grams. Samples were placed in plastic bags, weighed,

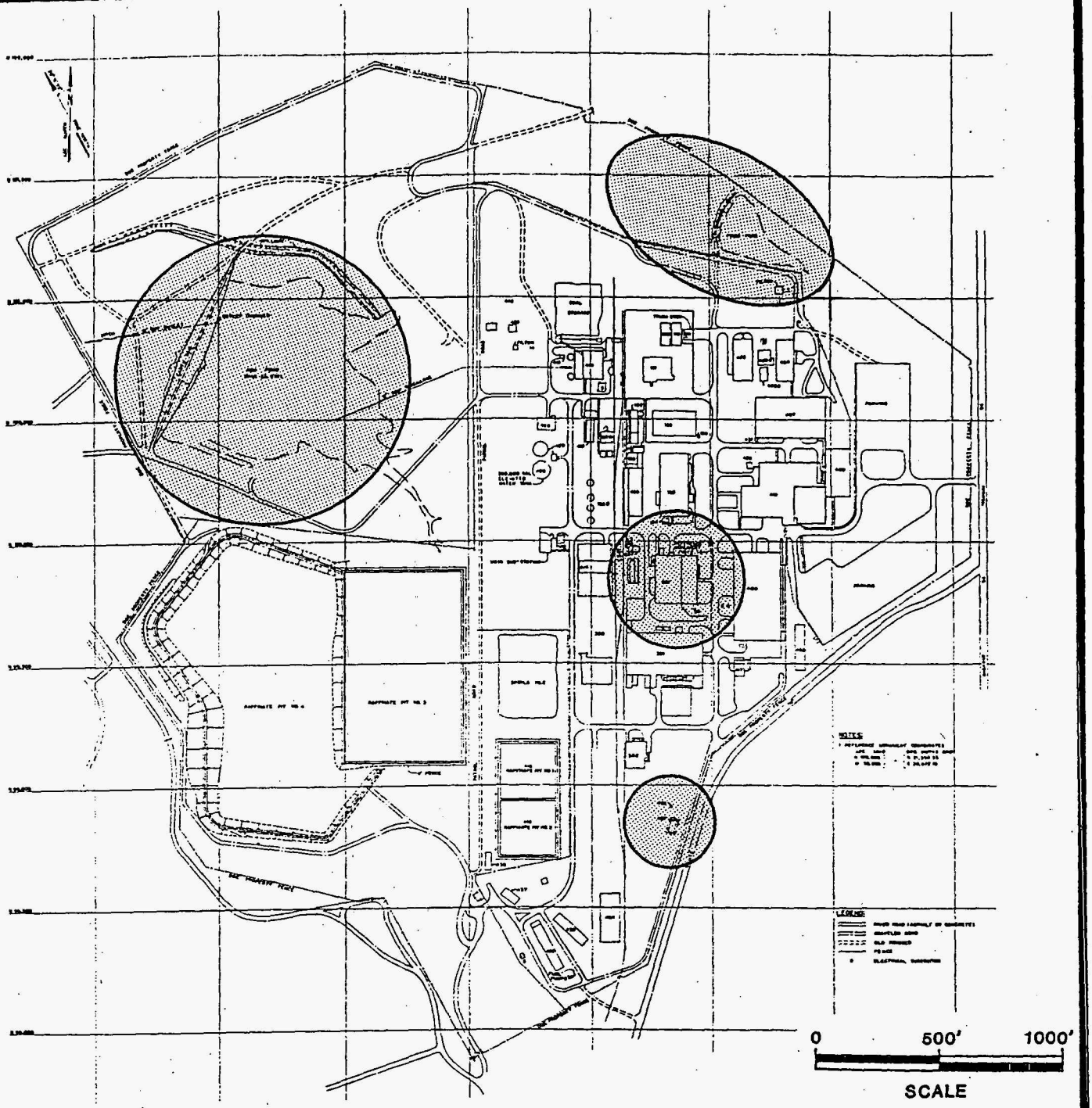
labeled, and immediately frozen. The frozen samples were sent for laboratory analyses within 48-72 hours of sample collection. The original sampling plan was followed whenever possible. However, at some locations substitutions were required due to species unavailability. For example, in Lake 35, crappie fillets were substituted for sunfish fillets. In the Femme Osage Slough, crappie replaced both sunfish composites; carp and largemouth buffalo were collected also because they were common within this body of water. At Frog Pond, sunfish were the only abundant fish and most of them were small in size. Therefore, only the cleaned sunfish composite could be collected.

The composite samples were sent to a subcontracted laboratory, metaTRACE, in Earth City, Missouri. The filleted composites were analyzed for natural uranium. The cleaned (scaled, beheaded, eviscerated) sunfish samples, representing fish that would be ground up to make fishcakes, were analyzed for thorium-230/232 and radium-226 as well as total uranium. The mixed fillet composites were analyzed for PCBs and CLP metals.

2.1.2 Terrestrial Species

Small game mammals (rabbits and squirrels) were collected from the Weldon Spring Chemical Plant (WSCP). Most of the samples were obtained by trapping with live traps using a variety of baits. However, this trapping was not as effective as anticipated, and samples were later obtained by hunting on site. A total of eight rabbits and three squirrels were collected from the WSS. Trapping was concentrated in two areas: the South Dump/Ash Pond area and the Frog Pond area. Hunting was utilized to obtain samples from areas around the chemical plant buildings. Figure 2-1 illustrates these areas.

Small mammal composite samples consisted of three individuals collected from each location. Specimens were cleaned on the day they were collected, placed in plastic bags, labeled, frozen,



SHADED AREAS INDICATE SAMPLING AREAS

FIGURE 2-1

SMALL MAMMAL SAMPLING AREAS AT WSS

and sent to the lab. At the lab, each composite was split into bone and tissue and analyzed separately for total uranium, thorium-230/232, and radium-226. The lab did not analyze for PCBs and metals since there were not enough individual specimens captured to provide the necessary volume of sample tissue.

Larger migratory game animals such as deer, turkey, geese, etc. were not sampled as part of the WSS bio-uptake study. Such animals readily migrate on and off site, spending an unknown proportion of their time on the WSS. An expansion of the bio-uptake study's scope to include larger migratory game animals was dependent upon the data obtained from the smaller terrestrial mammals. No small mammal samples were obtained from the quarry area since trapping in the WSQ area was unsuccessful.

2.2 ANALYTICAL PARAMETERS

The investigation focused primarily on the analysis for uranium in the biological specimens collected. In comparison with the other contaminants present in the WSS, uranium exists at the highest concentrations and quantities, and is one of the most water soluble. In addition, when introduced into the body, uranium is the most soluble of the radionuclides, incorporating into the soft tissues as well as into the bones. All samples were analyzed for total uranium except for the mixed fillet composites which were analyzed for PCBs and metals.

Surface waters at the WSS generally exhibit background concentrations of radium and thorium (DOE, 1987c). Radium and thorium are relatively insoluble and primarily incorporate into the bone. Therefore, only the cleaned sunfish composites which included bone were analyzed for these radionuclides. Small mammals were also analyzed for radium and thorium. Small mammal samples were split by the lab into tissue and bone subsamples and analyzed for all three radiological parameters.

The mixed species fish composites were analyzed for CLP metals and PCBs. Draft versions of the Biological Uptake Plan also included the analysis of biota samples for nitroaromatics, on the assumption that this analysis could be performed by the laboratory. Subsequent research indicated insufficient information concerning the uptake, biodegradation, and metabolism of nitroaromatic compounds by animals and humans, making it difficult to interpret analytical results. In addition, there are no accepted methodologies for the analysis of nitroaromatic compounds in biological tissue. Recovery of target compounds following extraction procedures was estimated to be extremely low. TNT and 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. Therefore, nitroaromatic analyses were not performed as part of this study.

Additional analyses of semi-volatile compounds were considered as part of the sampling plan, but were discounted because of the same factors discussed for nitroaromatics. Information concerning uptake, degradation and metabolism is considered inadequate, and acceptable analytical methodologies have not been developed.

2.3 ANALYTICAL METHODS

Laboratory analytical methods used for the bio-uptake 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 first digested in concentrated hydrochloric acid and then diluted to one liter before analysis by the following methods: total uranium was analyzed according to EPA method 908.0, isotopic thorium by EPA 00/07, radium-226 by EPA 903.0, and metals by EPA CLP protocols. PCB (Aroclor) analyses also followed CLP methods but utilized fish tissue that was not

acid-digested.

Small mammal composite samples sent to the laboratory for analysis were split first into separate bone and soft tissue portions, and then prepared for analysis according to Eastern Environmental Radiation Facility procedures (USEPA, 1984). 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. Radionuclide analyses followed the same methods as listed above for the fish samples.

3.0 RESULTS

3.1 AQUATIC SAMPLES

Twenty-five (25) composite fish samples, representing a total of 184 fish, were sent to the laboratory for analysis. Results from the fish portion of the bio-uptake study are presented in Tables 3-1, 3-2, and 3-3. Table 3-1 presents the sample numbers, radiological results, and the number and type of fish collected from each location. All samples analyzed exhibited no radiological contaminants detected at the lower limits of detection indicated in Table 3-1. Values less than the detection limits for samples from Frog Pond are especially noteworthy in light of the water concentrations of nuclides shown in Table 1-1.

Table 3-2 presents the results of PCB analysis from the mixed species composites. No PCBs were detected in any of the four composite samples analyzed for these parameters with detection limits of 0.04 to 0.06 ug/g (ppm).

Table 3-3 presents the results of CLP metals analyses for the mixed species composites. Many metals naturally occur in biological tissues; therefore, careful comparison with the background location (Lake 37) is necessary in order to interpret these data. Most of the metals detected in the non-background samples occurred in concentrations similar to the background location. Only iron (Fe) concentrations were found to be higher in all samples when compared to Lake 37. Iron was detected in concentrations ranging from 11.7 to 50.7 ug/g compared to 4.89 ug/g at the background location. Elevated background iron levels are not unusual to this area, as evidenced by values for Dardenne Creek in the Phase I Water Quality Assessment Report (DOE, 1987b), (570 - 808 ug/l.)

Chromium was detected in one mixed species composite sample from

TABLE 3-1 FISH RADIOLOGICAL RESULTS

Sample #	Total Uranium	Thorium 230	Thorium 232	Radium 226	Comments
	CONCENTRATIONS pCi/g (wet weight)				
Lake 37:					
BG-3701-1087	ND (0.01)				11 Sunfish Filleted (800g)
BG-3702-1087	ND (0.01)	ND (0.2)	ND (0.3)	ND (0.2)	6 Sunfish Cleaned *(800g)
BG-3703-1087	ND (0.02)				4 LM Bass Filleted (800g)
Lake 36:					
BG-3601-1187	ND (0.01)				8 Sunfish Filleted (800g)
BG-3602-1187	ND (0.01)				10 Sunfish Cleaned *(800g)
BG-3603-1187	ND (0.01)				4 LM Bass Filleted (800g)
BG-3604-1187	ND (0.01)	ND (0.06)	ND (0.02)	ND (0.003)	7 Catfish Filleted (300g)
Lake 35:					
BG-3502-1087	ND (0.02)	ND (0.03)	ND (0.1)	ND (0.3)	9 Sunfish Cleaned *(800g)
BG-3503-1087	ND (0.01)				4 LM Bass Filleted (900g)
BG-3504-1087	ND (0.02)				5 Catfish Filleted (500g)
BG-3505-1087	ND (0.02)				12 Crappie Filleted (800g)
Lake 34:					
BG-3401-1087	ND (0.01)				7 Sunfish Filleted (800g)
BG-3402-1087	ND (0.01)	ND (0.2)	ND (0.05)	ND (0.01)	11 Sunfish Filleted (800g)
BG-3403-1087	ND (0.01)				3 1/2 LM Bass Filleted (800g)
BG-3405-1087	ND (0.01)				8 Crappie Filleted (800g)
Femme Osage Slough:					
BG-SL03-1087	ND (0.01)				3 LM Bass Filleted (800g)
BG-SL05-1087	ND (0.01)				5 Crappie Filleted (800g)
BG-SL07-1087	ND (0.01)				3 1/2 Carp Filleted (1200g)
BG-SL08-1087	ND (0.01)				2 LM Buffalo Filleted (800g)
BG-SL09-1087	ND (0.01)	ND (0.7)	ND (0.3)	ND (0.2)	4 Crappie Cleaned *(900g)
Frog Pond:					
BG-FP02-1187	ND (0.1)	ND (0.2)	ND (0.07)	ND (0.1)	24 Sunfish Cleaned *(800g)

ND = Not detected (detection limits in parentheses)
* = Scaled, beheaded, eviscerated to simulate fishcake preparation.

TABLE 3-2 BIO-UPTAKE PCB RESULTS

Sample #	CONCENTRATIONS (ppm) Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	COMMENTS
Lake 37:								
BG-3706-1087	ND	ND	ND	ND	ND	ND	ND	4 bass, 5 sunfish (800g)
Lake 36:								
BG-3606-1187	ND	ND	ND	ND	ND	ND	ND	2 bass, 2 sunfish, 2 crappie (800g)
Lake 35:								
BG-3506-1087	ND	ND	ND	ND	ND	ND	ND	2 bass, 4 sunfish, 6 crappie (800g)
Lake 34:								
BG-3406-1087	ND	ND	ND	ND	ND	ND	ND	1 bass, 2 sunfish, 4 crappie (800g)
Det. Limits	0.04	0.06	0.04	0.05	0.04	0.04	0.04	

ND = Not detected

TABLE 3-3 BIO-UPTAKE CLP METALS RESULTS FOR MIXED SPECIES COMPOSITE SAMPLES*

	CONCENTRATION (ug/g)																							
Sample #	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Hg	Ni	K	Se	Ag	Na	Tl	V	Zn
Lake 37																								
BG-3706-1087	ND	ND	13.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.23	ND	3423	ND	ND	--	9.1	ND	11.3
Lake 36																								
BG-3606-1187	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 35																								
BG-3506-1087	ND	ND	13.6	ND	ND	ND	ND	ND	ND	ND	50.7	ND	ND	ND	2.1	0.24	ND	2666	ND	ND	--	9.4	ND	9.44
Lake 34																								
BG-3406-1087	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
Det. Limits	20	6	1	20	0.5	0.5	500	1	5	2.5	10	0.5	5	500	1.5	0.1	4	500	0.5	1	500	1	5	2

ND = Not Detected
-- = Analysis not performed
* See Table 3-2 for description of sample make-up

Lake 34 with a concentration above the detection limit.

The metals arsenic (As), mercury (Hg), potassium (K), thalium (Tl), and zinc (Zn) are also shown with concentrations above the limits of detection. Each of these chemical species is also detected in the samples from Lake 37 which is located outside of the drainage of the WSS. For this reason, these concentrations are considered to be natural levels for the metals in fish tissue in this setting.

The lead (Pb) concentrations in fish samples from Lake 36 and 34 are about a factor of eight higher than the detection limit. Lakes 36 and 34 have no point of commonality. They are part of separate drainage basins and have been shown not to be in hydraulic connection through subsurface flow conduits (Dean, 1985). Although lead was not used as part of the former Weldon Spring Uranium Feed Materials Plant, it was commonly used throughout the Army Ordnance Works as a spark-free metal. Lead was a minor component of the impurities contained within the yellowcake processed, and therefore is found at low levels in the raffinate pit sludges.

Reasons were examined to determine any significance and possible sources of the elevated lead levels in fish tissue. Importantly, Phase I Soils studies (DOE, 1988) indicated that no migration of lead has occurred beyond the raffinate pit containment. That same study also reported an average background level of lead naturally occurring in the soils surrounding the WSS of 29 ppm. It also demonstrated that elevated levels of lead in soils occurred onsite in highly localized deposits associated with the Ordnance Works sources.

Monitoring data from the Phase I Water Quality Assessment (DOE, 1987b) indicates that lead is below the level of detection of 5 ug/l in both surface and groundwater from and around the site. The only location where lead has been detected above detection

limits is in Dardenne Creek, downstream from the lakes in question and even further from the WSS.

The above information, combined with the apparent absence of lead in fish tissue from Lake 35 which is immediately downstream of Lake 36, imply that the source of the lead is probably localized and is not from the Weldon Spring Site. Several plausible mechanisms exist that individually or in concert provide explanation for the localized phenomenon of lead uptake into fish tissue. Lead shot has been known to be ingested by waterfowl. In routinely hunted areas, many waterfowl carry a large body burden of lead from hunting injury. Fish feeding on the contaminated carcasses of such fowl would evidence elevated concentrations of lead. Additionally, fish could ingest and digest individual lead pellets which in turn would be assimilated into the tissues and result in elevated lead concentrations. Use of lead materials in fishing equipment is widespread and common. Nationally, lead contamination of the environment is recognized as an issue of concern with lead coming from a wide variety of anthropogenic sources.

Another factor introducing variability into the lead concentration of different samples is based upon the nature of the composite samples themselves. Slightly elevated lead levels in fish tissues from Lakes 34 and 36 are presumed to be partly the effect of statistically variable samples of fish. In order to achieve the goal of the study, i.e., to examine the effect of species of concern to human diets, the metals analysis samples consisted of a composite of three different species of edible fish. Composite samples of 800 grams each were made from the catch that was obtained from each of the lakes. The guideline followed in determining the sample constituents was to incorporate as good a representative mix of these edible species as could be acquired from the catch at each lake. These composites consisted of the following proportions of fish:

- Lake 34
  - 1/2 of a bass
  - 4 crappie
  - 2 sunfish

- Lake 35
  - 2 bass
  - 4 sunfish
  - 6 crappie

- Lake 36
  - 2 ea 1/2 bass
  - 2 crappie
  - 2 sunfish

- Lake 37
  - 4 bass
  - 5 sunfish

Two important elements determined the mix of these samples. First, the samples were to be representative of species which humans eat, and second, the samples were to be representative of the catch obtained at each lake. While these samples represent the kind of variability that would reflect a human diet from the lakes, nevertheless they introduce some variability with respect to different species composition, as well as differences in age, sex, and possibly other factors.

The samplers tried to achieve as uniform a mix of fish as possible. One factor apparent between samples from Lake 34 and 36 is the small number of bass (larger fish had to be cut to achieve correct proportioning). Bass are on the top end of the fish food chain and, given the rule of thumb of 10 fold increase in bioaccumulation in each higher trophic level, these bass may have more lead than the other fish. Also, age is another factor in bioaccumulation. Since larger fish in a species group are

usually older fish, it appears older bass were caught in 34 and 36. For these reasons, it is believed that they may be contributing proportionally higher levels of lead.

Arsenic (As) levels about 14 times the lower detection limit were found in fish samples from Lakes 35 and 37. Arsenic is an element well known for its bioaccumulation capacities. It occurs naturally and also as a result of human activity. Naturally occurring arsenic concentrations on or around the WSS have an arithmetic mean of 6 mg/kg (DOE, 1988). Lake 37 is not influenced by the Weldon Spring Site and, therefore, accumulation of arsenic is clearly a result of other mechanisms. This finding is reinforced by a similar arsenic concentration in fish from Lake 35. This lake is downstream from Lake 36 where the fish did not show accumulations of arsenic above the levels of detection. The Phase I Water Quality Assessment reports all surface water and groundwater samples of the WSS had levels of arsenic below the detection limits (DOE, 1987b). Only water samples taken directly from the Raffinate Pits showed concentrations ranging from below the level of detection up to 38 ug/l, or part per billion concentrations. For these reasons, the arsenic accumulations in fish from Lakes 35 and 37 appear to be unrelated to the Weldon Springs facility.

Chromium (Cr) was detected only in the fish sampled from Lake 34 at slightly less than 3 times the detection limit. Chromium is a naturally occurring element in soils and waters of the area. Natural soil background concentrations at or around the WSS have an arithmetic mean of 24 mg/kg (DOE, 1988). It is found at detectable but low concentrations in all ground and surface waters with about 50 ug/l being a reasonable approximation of the background levels (DOE, 1987b). Chromium has been detected in fish tissues at or slightly above background concentrations in other studies (Wixson, 1982). With the ubiquitous nature of chromium, a single fish sample containing less than 3 times the

detection limit cannot be considered as significant nor can it be attributed to the WSS.

Concentrations of the metals calcium (Ca), potassium (K), and sodium (Na) were anticipated because these metals are essential constituents of living tissues. Their presence at varying levels as indicated in Table 3-3 was expected also.

3.2 TERRESTRIAL SAMPLES

A total of eight rabbits and three squirrels were collected from the Ash Pond area, three rabbits from among buildings at the WSCP, and two rabbits from around the Imhoff Tank drainage. Three squirrels were collected from the Frog Pond area. Table 3-4 presents the results of radiological analyses for these samples. No radiological contaminants were detected at the lower limits of detection as shown in Table 3-4.

No samples were collected off-site or from the quarry area. Trapping at the quarry was unsuccessful.

TABLE 3-4 SMALL MAMMAL RADIOLOGICAL RESULTS

Sample #	Matrix	CONCENTRATIONS (pCi/g) Total Uranium	Thorium 230	Thorium 232	Radium 226
ASH POND AREA					
BG-AP20-1287	Rabbit Tissue	ND (0.02)	ND (0.03)	ND (0.01)	ND (0.01)
	Rabbit Bone	ND (0.3)	ND (0.1)	ND (0.4)	ND (0.1)
WSCP AREA					
BG-IT20-021188	Rabbit Tissue	ND (0.4)	ND (1)	ND (1)	--
	Rabbit Bone	ND (0.08)	ND (1)	ND (1)	--
BG-CP20-021188	Rabbit Tissue	ND (0.04)	ND (1)	ND (1)	--
	Rabbit Bone	ND (0.05)	ND (1)	ND (1)	--
FROG POND AREA					
BG-FP21-1287	Squirrel Tissue	ND (0.09)	ND (0.05)	ND (0.01)	ND (0.01)
	Squirrel Bone	ND (0.03)	ND (0.07)	ND (0.05)	ND (0.07)

ND = Not Detected (detection limits in parentheses)

4.0 DATA INTERPRETATION

The principal objective of the biological sampling program was to establish the fate of the site contaminants in edible biota in the local environment so that their impact could be experimentally measured. The characterization design was based on the direct sampling of edible biota and the analysis of samples for contaminants. Assimilation of contaminants by biota is a complex phenomenon, especially in aquatic organisms that absorb contaminants directly from water as well as from food in their gastrointestinal tract. This section presents a determination of bioaccumulation factors of radionuclides for aquatic species so that a comparison with similar studies can be made. It does not present an analysis of the bioaccumulation for nonradiological chemical species.

The bioaccumulation factor of an organism or tissue is the ratio of a radionuclide in the whole organism or tissue to that in water. A variety of environmental factors can influence the assimilation of contaminants, and hence the bioaccumulation in organisms. For example, the calculation of a radiation dose to man from food chains usually requires that bioaccumulation factors be calculated only for the edible portion of the organism. Whole-body bioaccumulation factors may be quite different from those reported for muscle tissue. When a contaminant accumulates in the bone, its contribution to the whole body concentration is greater than its concentration in the muscle. Therefore, the actual radiation dose to man from the ingestion of the muscle may be much lower than the radiation dose calculated using the whole-body accumulation factor.

Several factors can significantly influence the organism bioaccumulation factors reported in the literature, including the method used to determine bioaccumulation factors, various environmental parameters, the chemical form of the contaminant, and characteristics of individual species. Because of the

uncertainties associated with bioaccumulation factors, there is a tendency to select values that are usually overestimates. It may be impractical to expect validation studies to show close agreement between many of the values found in literature and experimentally measured site-specific values. This conservatism needs to be noted when the data are interpreted.

4.1 PREVIOUS STUDIES

The National Council on Radiation Protection and Measurements (NCRP) has published a reference document on the application of radionuclide transport models from the point of discharge to the environment to the point of intake by man (NCRP Report No. 76, 1984). The report indicated that comprehensive studies of uranium, thorium, and radium in aquatic biota concerning their relative concentrations and their movement through aquatic food chains are not readily available. The report presented limited experimental data for the concentration of uranium and radium in freshwater biota (Table 4-1).

T.L. Gilbert (Argonne National Laboratory) et al. prepared a manual for the U.S. Department of Energy for implementing residual radioactivity guidelines (Gilbert et al., 1985). The manual included various food pathway factors used in deriving the environmental transport factors of residual materials. Table 4-2 lists these bioaccumulation factors for fish which are represented by the ratios of aquatic concentrations to the radionuclide concentration in fresh water.

Since models of aquatic dispersion of radionuclides released to water are very dependent on the exact local conditions of surface or underground flow and on absorptive capacities of prevalent biota, the NCRP and Gilbert documents were used as comparative references for the WSSRAP studies.

Two separate biological sampling studies have been performed at

TABLE 4-1 - RANGE OF BIOACCUMULATION FACTORS FOR URANIUM AND RADIUM IN FRESHWATER BIOTA

BIOTA	URANIUM			RADIUM			
	LAKE MICHIGAN[a] WAHLGREN et al. (1976)	LAKE ISSYK-KUL[a] USSR BONDIETTI et al. (1979)	ZIROVSKI MINING AREA[b] YUGOSLAVIA STEGNER AND KOBAL (1982)	JADUGUDA MINING AREA INDIA BONDIETTI et al. (1979)	AMIMAS RIVER[c] COLORADO-NEW MEXICO ANDERSON (1963)	ZIROVSKI MINING AREA[b] STEGNER AND KOBAL (1982)	PATHFINDER MINING AREA[d] ROPE AND WHICKER (1980)
Fish							
Piscivorous	0.5-0.7						
Planktivorous	0.3-0.6	8					
Omnivorous			0.7-38			42-137	0.3-3.3
Benthic omnivore				3-8	3-8		135
Zooplankton	16-44	80					
Phytoplankton	88-156			40-2600	400-1200		
Algae	51				200-2800		1100-3500
Invertebrates	2-8	40	1-35	1-2	500-1000	650	
Macrophytes	62-215	400			752-1200		960-6900

[a] Large deep oligotrophic lake.

[b] Small productive cold water river.

[c] Small (700 cfs) shallow river with high level of suspended solids.

[d] Small cold water settling pond, maximum depth 4 m.

Source: NCRP, 1985

TABLE 4-2
SELECTED BIOACCUMULATION FACTORS IN AQUATIC SPECIES USED BY ARGONNE NATIONAL LABORATORY (uCi/kg WET WEIGHT TO uCi/l IN WATER)

ELEMENT	FRESHWATER FISH[a]	SALTWATER FISH[a]	CRUSTACEAN[b]	MOLLUSCS[b]
Bi	15	15	1000	1000
Po	500	300	5000	5000
Ra	50	50	100	100
Ac	25	25	1000	1000
Th	30	10000	2000	2000
Pa	10	10	10	10
U	2	10	10	10

[a] Whole fish

[b] Soft parts only

Source: Gilbert, T.L. et al. 1985

the WSS prior to the data collection discussed in this report. Information gathered from these two studies has been used to estimate upper bounds for bioaccumulation factors for aquatic species. The previous studies are shown with values resulting from the current study in subsequent sections.

In 1977, a biological sampling program was initiated by a contractor for the Department of the Army at the WSCP. Ryckman/Edgerly/Tomlinson and Associates (RETA) performed the assessment (RETA, 1978). One hundred eighteen (118) terrestrial and 60 aquatic biological samples were collected from permanent bodies of water and contaminated land areas on-site, drainages, off-site bodies of water receiving drainage from the WSS, and background sites. Water and sediment samples were collected in coordination with biological samples to obtain correlative data on bioaccumulation.

The detailed analytical results of all biological samples taken by RETA are presented in the appendix to the Phase II report (RETA, 1977). The WSSRAP has been unable to locate this detailed data. A summary of that study is available in the Phase III report (RETA, 1978). The summary presents the general relationships between the contaminant levels in the food chain and the water bodies studied based on samples from the study. These relationships are roughly shown in Table 4-3. For comparative purposes, RETA listed numerical values indicating the ratio between the sample concentrations in a common unit, such as parts per million (ppm). As an arbitrary numeric value, an uranium concentration of 100 ppm in the sediment would suggest 1 ppm in water, 100 ppm in macrophyte roots, and 1 ppm in frogs. From these generalized relationships, it was evident during the sampling phase that there was no evidence of biomagnification of contaminants in these samples which are representative of the food-chain.

In 1983 and 1984, the Missouri Department of Conservation (MDOC)

TABLE 4-3
GENERALIZED FOOD-CHAIN RELATIONSHIPS OF CONTAMINANTS BASED ON RESULTS OF THE RETA STUDY

SAMPLE	URANIUM	THORIUM	RADIUM
SEDIMENT	100	100	100
WATER	1	1	1
ALGAE	10-100	10-100	1
INVERTEBRATES	1-10	2-100	1
MACROPHYTE ROOTS	100	10-50	10-50
SMARTWEED	100	- - -	10
FROGS	1	- - -	1
FROG SKELETONS	- - -	0.1	10-100
MUSKRATS	0.1 (EXTERNAL)	- - -	- - -
SKELETON	- - -	20-50	100
KIDNEY	- - -	- - -	- - -
STOMACH CONTENTS	- - -	20-50	100
RACCOONS			
SKELETON	1-10	- - -	1-10
KIDNEY	1-10	1	- - -
STOMACH CONTENTS	1-10	1	- - -

Source: Ryckman, Edgerly, Tomlinson, and Associates, 1978.

collected samples of water, fish, and sediments from various water bodies near the WSS (deRoss, C. 1984). These locations were Lakes 9, 10, 34, 35, and 36, the Femme Osage Slough, and the Big Femme Osage Creek. Approximately ten fish (edible portions only) were composited per sample. Table 4-4 lists the results from the MDOC sampling effort for Lakes 34, 35, and 36, the Femme Osage Slough, and a background lake located north of Jefferson City, Missouri. Natural uranium concentrations in fish ranged from 0.002 to 0.06 pCi/g.

In 1985, an assessment was performed by Argonne National Laboratory (ANL) using the data from MDOC. In addition to the analytical data from the fish, the radiation doses received during recreational activities and from consuming the fish were assessed. Bioaccumulation factors were calculated by the WSSRAP from MDOC samples and analyses of routine water samples. The results ranged from 0.08 to 7.0 (uCi/kg wet weight to uCi/l in water). Higher bioaccumulation factors were seen for samples that were not filleted and submitted with bones in the sample.

Based upon measured concentrations of uranium in the water and fish tissue by MDOC, the detection limit of 0.01-0.05 pCi/g of natural uranium, Ra-226, Th-230, or Th-232 was chosen as an analytical detection limit goal. Also, the dose received under given assumptions by ingesting edible tissue at these concentrations was considered when choosing the detection limit. The radiation dose received by ingesting edible tissue at these concentrations is much less than 1.0 mrem/yr.

TABLE 4-4
NATURAL URANIUM CONCENTRATIONS IN FISH AND WATER BODIES OF BUSCH WILDLIFE AREA

	nat-U IN WATER[b] (pCi/l)	FISH TYPE	nat-U IN FISH[a] (pCi/g)
Lake 34	18-33	Bluegill*	0.06
		Tiger Musky	0.008
		Channel Catfish	0.005
		Grass Carp	0.005
Lake 35	8-21	Largemouth Bass	0.005
		Channel Catfish	0.002
Lake 36	9-53	Largemouth Bass	0.005
		Channel Catfish	0.007
Femme Osage Slough	8-47	Bluegill*	0.02
		Carp	0.012
		Buffalo	0.009
Background (Little Dixie Lake)	--	Bluegill*	0.02
		Largemouth Bass	0.005
		Channel Catfish	0.009

* Bluegills were not filleted, they were decapitated, eviscerated and scaled

Source: (a) deRoss, C. 1984.
(b) DOE, 1987c

4.2 FACTORS INFLUENCING BIOACCUMULATION

The method used to determine bioaccumulation factors can have a significant influence on the calculated value. Although bioaccumulation factors are simple to calculate, compounded uncertainties can vary the results by several magnitudes.

Some of the factors responsible for this variation are:

- Physical state of the sample -- wet, dry or ash,
- Sampling variations,
- Analytical variations,
- Filtered vs unfiltered water,
- Tissue(s) being examined,
- Chemical state of the analyte,
- Habitat of the organism,
- Age and size of the organism, and
- Others.

Bioaccumulation factors are variously calculated using wet weight, dry weight, or ash weight of the biota. Conversion factors are available for converting dry weight to wet weight for most biota. Bioaccumulation factors based on dry weight are higher than those based on wet weight. The data based on samples collected for this study represent the wet weight of the biota.

Sampling and analytical errors can have significant influence in a sampling program. Laboratory error, number of samples, appropriate time scales for movement of biota, and acute releases of radionuclides into the environment are probably the greatest sources of error. The laboratory and sampling protocol used by the analyses herein are described in Section 3.

The use of filtered or unfiltered water samples in the analyses influences the bioaccumulation factor results. Since a

significant fraction of some elements in water may be in the suspended phase, bioaccumulation factors based on filtered samples may be much greater than those based on unfiltered samples. The water concentrations cited in this report represent unfiltered water samples.

The distribution of elements in tissues influences results. A reference to the specific tissue analyzed must be made because whole-body concentrations may be quite different than only muscle tissue concentrations. Tissues and organs have different metabolic requirements for certain elements. A description of samples submitted for analysis is presented in Section 3.

The chemical state of the radionuclide and the chemical composition of the water influence the bioaccumulation of the biota. Mineral content of the water, soluble forms, exchangeable sites, and stable states of the compound may influence the availabilities of contaminants to biota. Also, the location of water stratification and the nature of the habitat of the biota have effects. The feeding habits of an individual species may vary from ecosystem to ecosystem. Benthic feeding, changing food habits, age and size of biota, and seasonal variations of the habitat may have an impact on the data.

4.3 CALCULATED BIOACCUMULATION FACTORS

The bioaccumulation factor of an organism or tissue is the ratio of radionuclide concentration in the whole organism or tissue to that in water. The ratio of the equilibrium concentration of the assimilated nuclide in the organism or tissue to the average concentration of that nuclide in the water during the history of exposure is the theoretical bioaccumulation factor.

For the field study reported here, all analytical results for all radionuclides were less than the lower limit of detection.

Therefore, all calculated bioaccumulation factors represent a maximum which may be equal to or less than the numerical values indicated. A summary table (Table 4-5) presents the calculated maximum bioaccumulation factors for the WSS along with the model values (Gilbert, et al. 1985) and other values based on actual data (NCRP, 1984).

4.4 COMPARISON WITH STUDY RESULTS

The assimilation of an element by biota is calculated by using a single empirical relationship to represent the transfer of the element to an organism from consumption of contaminated foodstuffs and absorption of water. Calculated results from bioaccumulation factors published by the NCRP and Gilbert are compared with the experimental results from the current study. These results are listed in Table 4-6.

The current results, in general, indicate that maximum concentrations (i.e. at the lower limit of detection) are less than those calculated using the transfer factors provided by the Gilbert models. As indicated in the previous discussion, these models are conservative and are meant to be used as a guide for more complex calculational methodologies. Though no positive results were seen in the WSSRAP study, the limits of detection were well within the range of the values published by the NCRP and experimental values from the MDOC. Since the NCRP published complete data sets from biological studies, the current data seem to be more comparable to the values published by the NCRP than the model estimates.

TABLE 4-5

COMPARISON OF BIOACCUMULATION FACTORS (B.F.)

FOR URANIUM

AREA	SPECIES[a]	GILBERT B.F.	NCRP B.F.	WSSRAP[b] B.F.
Lake 34	Crappie (f)	2.0	0.5-0.7	0.4
	LM Bass (f)	2.0	0.5-0.7	0.4
	Sunfish (f)	2.0	0.7-38	0.4
	Sunfish (c)	2.0	0.7-38	0.4
Lake 35	Crappie (f)	2.0	0.5-0.7	1.3
	Catfish (f)	2.0	---	1.3
	Sunfish (c)	2.0	0.7-38	1.3
	LM Bass (f)	2.0	0.5-0.7	0.7
Lake 36	LM Bass (f)	2.0	0.5-0.7	0.4
	Sunfish (f)	2.0	0.7-38	0.4
	Catfish (f)	2.0	---	0.4
	Sunfish (c)	2.0	0.7-38	0.4
Frog Pond	Sunfish (f)	2.0	0.7-38	0.5
Slough	LM Bass (f)	2.0	0.5-0.7	0.3
	Crappie (c)	2.0	0.5-0.7	0.3
	LM Buffalo (f)	2.0	0.7-38	0.3
	Crappie (f)	2.0	0.5-0.7	0.3
	Carp (f)	2.0	---	0.3

(a) Letter in () indicates fillets or cleaned

(b) B.F. are maximum values at the lower limit of detection

Adapted from Gilbert, et al. 1985 and NCRP, 1985.

TABLE 4-6
COMPARISON OF URANIUM CONCENTRATIONS FROM CURRENT AND PAST STUDIES TO CONCENTRATIONS IN WSSRAP AREA WATER BODIES

AREA	SPECIES[a]	SURFACE WATER CONCENTRATION NAT-U(pCi/l)	NATURAL URANIUM CONCENTRATIONS (pCi/g) (WET WEIGHT) EXPERIMENTAL WSSRAP	EXPERIMENTAL MDOC	CALCULATED GILBERT	CALCULATED NCRP[b]
Lake 34	Crappie (f)	25	<0.01	---	0.05	0.01-0.02
	LM Bass (f)	(18 - 33)	<0.01	---	0.05	0.01-0.02
	Sunfish (f)		<0.01	---	0.05	0.02-0.95
	Sunfish (c)		<0.01	---	0.05	0.02-0.95
Lake 35	Crappie (f)	15	<0.02	---	0.03	0.008--0.01
	Catfish (f)	(8 - 21)	<0.02	0.002	0.03	---
	Sunfish (c)		<0.02	---	0.03	0.01-0.6
	LM Bass (f)		<0.01	0.005	0.03	0.008-0.01
Lake 36	LM Bass (f)	25	<0.01	0.004	0.05	0.01-0.02
	Sunfish (f)	(9 - 53)	<0.01	---	0.05	0.02-0.95
	Catfish (f)		<0.01	0.007	0.05	---
	Sunfish (c)		<0.01	---	0.05	0.02-0.95
Frog Pond	Sunfish (f)	210	<0.1	---	0.42	0.15-8.0
Slough	LM Bass (f)	30	<0.01	---	0.24	0.15-0.02
	Crappie (c)	(8 - 47)	<0.01	0.009	0.24	0.15-0.02
	LM Buffalo (f)		<0.01	---	0.24	0.02-1.1
	Crappie (f)		<0.01	---	0.24	0.015-0.02
	Carp (f)		<0.01	0.007	0.24	---

(a) Letter in () indicates fillets or cleaned

(b) Compared to similar species

Adapted from Gilbert, et al. 1985, NCRP, 1985 and deRoss, 1984.

5.0 CONCLUSIONS

This study was undertaken to determine the potential for biological uptake of contaminants either from, or related to, the WSS that may occur in the human food chain. It does not describe all possible bio-uptake routes in the complex aquatic and terrestrial food chains on or around the WSS.

Previous studies on the uptake of radioactive materials at the WSS were reviewed in Section 4. The RETA study conducted in 1978 was primarily a screening process to determine whether or not uptake of radioactive materials was taking place in selected organisms at or around the site. To accomplish this, the study examined a wide range of organisms and the organs and tissues of some animals. The results of that study indicate that measurable but very low levels of contamination were present. Many of the organisms and target organs examined in that study, however, would never significantly impact human health. For example, the RETA study looked for contamination by uranium, thorium and radium in algae, cattail roots, and arrowhead roots. Terrestrial organisms were also examined and low levels of uranium were found in smartweed, goldenrod and animal parts such as raccoon stomach, intestine contents, bones and kidneys. Slightly elevated uranium concentrations were also found in muskrat stomach contents. All positive results were at very low levels and in organs or organisms not considered part of the human diet.

In 1983-84, an additional study was conducted by the MDOC. The only organisms examined in this study were fish. Because the fish samples were filleted, it appears (though not stated in the report) that an attempt was being made to examine the impact of the fish upon the human population. Here, too, it was found that even though concentrations of radioactivity were detectable, these concentrations were very low.

The results of the MDOC study were later analyzed by Argonne National Laboratories to determine the amount of radioactivity that one could receive from eating fish from the area of the MDOC study. Calculations determined that if an individual ate the national average annual per-capita consumption of fish from these sources, the individual would receive only 1/1000 of the background level of radiation generally received by Missouri residents.

It is not surprising to find that the previous reports reviewed in Section 4 described low levels of contamination in some organisms. Plants or animals in intimate contact with the water and/or sludges in the raffinate pits, ash pond or other sites of known contamination generally will have slightly elevated levels of radioactivity caused by either primary or secondary contamination. Fish in some of the slightly contaminated lakes off-site also will acquire slight levels of radioactivity.

The most recent data collected for this report offer an advantage over the previous studies. The new data were acquired in compliance with the latest guidance for sampling and analysis, were handled according to the latest chain of custody requirements and were analyzed according to procedures and instruments that are more accurate than those of the former studies completed five and ten years ago, respectively. For these reasons, it is probable that the most recent data are a more accurate representation of the actual effects upon human health than were the data of former studies.

The following conclusions can be made:

- No significant biological uptake of radiological contaminants was detected in fish collected from the WSS or August A. Busch Wildlife Area, or the Weldon Spring Wildlife Area.

- Two conclusions on the chemical data can be drawn. The amount of bioaccumulation of metals from these lakes is generally small, and even these small variations are probably localized incidents. Other studies (Wixson, 1982) have shown similar low concentrations of chromium, arsenic, lead, and other metals in fish tissue at or slightly above the detection limits. In any case, concentrations of metals in fish tissues from this study are not believed to be due to contamination from the Weldon Spring Site.

- Bioaccumulation factors calculated using data from this study are low compared to factors developed from other investigations. Use of these other factors would result in a conservatively overestimated dose. However, exposures would still be negligible.

- No significant biological uptake of radiological contaminants was detected in small mammals collected from WSS.

- No PCBs were detected in any of the offsite fish samples collected.

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APPENDIX A
QUALITY ASSURANCE

This study followed the same quality assurance (QA) guidelines set up for the Environmental Monitoring Program (US DOE, 1987c). However, no duplicate samples could be sent to the laboratory as a result of the small number of individual samples collected.

All samples were collected according to a site-specific sampling plan approved by EPA and DOE. These procedures were instituted to ensure consistency in sample collection. Samples sent to the laboratory were assigned unique identification numbers and documented by completion of chain-of-custody and laboratory authorization forms.

The laboratory receiving samples undergoes an EPA Laboratory Performance Evaluation and an internal laboratory evaluation annually. The laboratory also maintains an internal quality assurance program that involves routine instrument calibration, source and background counts, yield determinations, and replicate analyses to check precision.

APPENDIX B
LABORATORY DATA

metaTRACE, Inc. ■ 13715 Rider Trail North ■ Earth City, MO 63045 ■ (314) 298-8566

SITE ID: BG-3706-1087
metaTRACE ID: AA04839
DATE SAMPLED: 10/20/87
MATRIX: FISH

PCB's	CONCENTRATION (UG/G)
Aroclor 1016	< 0.04
Aroclor 1221	< 0.06
Aroclor 1232	< 0.04
Aroclor 1242	< 0.05
Aroclor 1248	< 0.04
Aroclor 1254	< 0.04
Aroclor 1260	< 0.04

CLP METALS	CONCENTRATION (MG/KG)
Aluminum	2.76
Antimony	< 4.1
Arsenic	13.9
Barium	5.63
Beryllium	< 0.30
Cadmium	< 0.50
Calcium	98.7
Chromium	< 0.30
Cobalt	< 0.70
Copper	0.22
Iron	4.89
Lead	< 3.6
Lithium	< 5
Manganese	0.50
Magnesium	295.4
Mercury	0.23
Nickel	< 1.4
Potassium	3423
Selenium	< 6.4
Silver	< 0.30
Thallium	9.1
Vanadium	< 0.40
Zinc	11.3

SITE ID: BG-3506-1087
metaTRACE ID: AA04840
DATE SAMPLED: 10/20/87
MATRIX: FISH

PCB's	CONCENTRATION (UG/G)
Aroclor 1016	< 0.04
Aroclor 1221	< 0.06
Aroclor 1232	< 0.04
Aroclor 1242	< 0.05
Aroclor 1248	< 0.04
Aroclor 1254	< 0.04
Aroclor 1260	< 0.04

CLP METALS	CONCENTRATION (MG/KG)
Aluminum	3.27
Antimony	< 4.1
Arsenic	13.6
Barium	5.0
Beryllium	< 0.30
Cadmium	< 0.50
Calcium	366.2
Chromium	< 0.30
Cobalt	< 0.70
Copper	0.50
Iron	50.7
Lead	< 3.6
Lithium	< 5
Manganese	2.1
Magnesium	294.8
Mercury	0.24
Nickel	< 1.4
Potassium	2666
Selenium	< 6.4
Silver	< 0.30
Thallium	9.4
Vanadium	< 0.40
Zinc	9.44

metaTRACE, Inc. ■ 13715 Rider Trail North ■ Earth City, MO 63045 ■ (314) 298-8566

SITE ID: BG-3701-1087
metaTRACE ID: AA04832
DATE SAMPLED: 10/20/87
MATRIX: FISH

Radiochemical	ACTIVITY +/- ERROR (pCi/GRAM)
Uranium, Total EPA 908/ASTM	< 0.01

SITE ID: BG-3702-1087
metaTRACE ID: AA04833
DATE SAMPLED: 10/20/87
MATRIX: FISH

Radiochemical	ACTIVITY +/- ERROR (pCi/GRAM)
Uranium, Total EPA 908/ASTM	< 0.01

metaTRACE, Inc. ■ 13715 Rider Trail North ■ Earth City, MO 63045 ■ (314) 298-8566

SITE ID: BG-3703-1087
metaTRACE ID: AA04834
DATE SAMPLED: 10/20/87
MATRIX: FISH

Radiochemical	ACTIVITY +/- ERROR (pCi/GRAM)
Uranium, Total EPA 908/ASTM	< 0.02

SITE ID: BG-3502-1087
metaTRACE ID: AA04835
DATE SAMPLED: 10/20/87
MATRIX: FISH

Radiochemical	ACTIVITY +/- ERROR (pCi/GRAM)
Uranium, Total EPA 908/ASTM	< 0.02

metaTRACE, Inc. ■ 13715 Rider Trail North ■ Earth City, MO 63045 ■ (314) 298-8566

SITE ID: BG-3503-1087
metaTRACE ID: AA04836
DATE SAMPLED: 10/20/87
MATRIX: FISH

Radiochemical	ACTIVITY +/- ERROR (pCi/GRAM)
Uranium, Total EPA 908/ASTM	< 0.01

SITE ID: BG-3504-1087
metaTRACE ID: AA04837
DATE SAMPLED: 10/20/87
MATRIX: FISH

Radiochemical	ACTIVITY +/- ERROR (pCi/GRAM)
Uranium, Total EPA 908/ASTM	< 0.02

metaTRACE, Inc. ■ 13715 Rider Trail North ■ Earth City, MO 63045 ■ (314) 298-8566

SITE ID: BG-3505-1087
metaTRACE ID: AA04838
DATE SAMPLED: 10/20/87
MATRIX: FISH

Radiochemical	ACTIVITY +/- ERROR (pCi/GRAM)
Uranium, Total EPA 908/ASTM	< 0.02

metaTRACE, Inc. ▪ 13715 Rider Trail North ▪ Earth City, MO 63045 ▪ (314) 298-8566

ES-9-03-16-02

WSSRAP ID	LAB ID	DATE SAM	DATE EXT	DATE ANA	METHOD	MATRIX	PARAMETER	CONC	ERR	UNITS	DL	CATEGORY	COMMENTS
36-3702-1087	AA04833	10/20/87	NA	1/21/88	EPA 00/07	FISH	Thorium 230	ND		pCi/G	0.2	RADIOCHEMICAL	WET WEIGHT
36-3702-1087	AA04833	10/20/87	NA	1/21/88	EPA 00/07	FISH	Thorium 232	ND		pCi/G	0.3	RADIOCHEMICAL	WET WEIGHT
36-3702-1087	AA04833	10/20/87	NA	1/21/88	EPA 903.0	FISH	Radium 226	ND		pCi/G	0.2	RADIOCHEMICAL	WET WEIGHT
36-3502-1087	AA04835	10/20/87	NA	1/21/88	EPA 00/07	FISH	Thorium 230	ND		pCi/G	0.3	RADIOCHEMICAL	WET WEIGHT
36-3502-1087	AA04835	10/20/87	NA	1/21/88	EPA 00/07	FISH	Thorium 232	ND		pCi/G	0.1	RADIOCHEMICAL	WET WEIGHT
36-3502-1087	AA04835	10/20/87	NA	1/21/88	EPA 903.0	FISH	Radium 226	ND		pCi/G	0.3	RADIOCHEMICAL	WET WEIGHT
36-SL05-1187	AA05368	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-SL09-1187	AA05369	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-SL09-1187	AA05369	11/10/87	NA	1/22/88	EPA 00/07	FISH	Thorium 230	ND		pCi/G	0.7	RADIOCHEMICAL	WET WEIGHT
36-SL09-1187	AA05369	11/10/87	NA	1/22/88	EPA 00/07	FISH	Thorium 232	ND		pCi/G	0.3	RADIOCHEMICAL	WET WEIGHT
36-SL09-1187	AA05369	11/10/87	NA	1/17/88	EPA 903.0	FISH	Radium 226	ND		pCi/G	0.2	RADIOCHEMICAL	WET WEIGHT
36-SL03-1187	AA05370	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-SL08-1187	AA05371	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-SL07-1187	AA05372	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3405-1187	AA05373	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3403-1187	AA05374	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3401-1187	AA05375	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3402-1187	AA05376	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3402-1187	AA05376	11/10/87	NA	1/22/88	EPA 00/07	FISH	Thorium 230	ND		pCi/G	0.2	RADIOCHEMICAL	WET WEIGHT
36-3402-1187	AA05376	11/10/87	NA	1/22/88	EPA 00/07	FISH	Thorium 232	ND		pCi/G	0.05	RADIOCHEMICAL	WET WEIGHT
36-3402-1187	AA05376	11/10/87	NA	1/17/88	EPA 903.0	FISH	Radium 226	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3603-1187	AA05377	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3601-1187	AA05378	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3602-1187	AA05379	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3604-1187	AA05380	11/10/87	NA	12/09/87	EPA 908.0	FISH	Total Uranium	ND		pCi/G	0.01	RADIOCHEMICAL	WET WEIGHT
36-3604-1187	AA05380	11/10/87	NA	1/22/88	EPA 00/07	FISH	Thorium 230	ND		pCi/G	0.06	RADIOCHEMICAL	WET WEIGHT
36-3604-1187	AA05380	11/10/87	NA	1/22/88	EPA 00/07	FISH	Thorium 232	ND		pCi/G	0.02	RADIOCHEMICAL	WET WEIGHT
36-3604-1187	AA05380	11/10/87	NA	1/17/88	EPA 903.0	FISH	Radium 226	ND		pCi/G	0.003	RADIOCHEMICAL	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Aluminum	ND		UG/G	20	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Antimony	ND		UG/G	6	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Arsenic	ND		UG/G	1	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Barium	ND		UG/G	20	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Beryllium	ND		UG/G	0.5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Cadmium	ND		UG/G	0.5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Calcium	ND		UG/G	500	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Chromium	ND		UG/G	1	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Cobalt	ND		UG/G	5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Copper	ND		UG/G	2.5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Iron	11.7		UG/G	10	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Lead	4.2		UG/G	0.5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Lithium	ND		UG/G	5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Magnesium	ND		UG/G	500	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/22/88	EPA CLP	FISH	Manganese	ND		UG/G	1.5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/23/88	EPA CLP	FISH	Mercury	0.16		UG/G	0.1	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Nickel	ND		UG/G	4	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Potassium	3530		UG/G	500	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Selenium	ND		UG/G	0.5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Silver	ND		UG/G	1	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Sodium	510		UG/G	500	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Thallium	ND		UG/G	1	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Vanadium	ND		UG/G	5	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	1/20/88	EPA CLP	FISH	Zinc	9.5		UG/G	2	METALS	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1016	ND		UG/G	0.4	PESTICIDE /PCB'	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1221	ND		UG/G	0.6	PESTICIDE /PCB'	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1232	ND		UG/G	0.4	PESTICIDE /PCB'	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1242	ND		UG/G	0.5	PESTICIDE /PCB'	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1248	ND		UG/G	0.4	PESTICIDE /PCB'	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1254	ND		UG/G	0.4	PESTICIDE /PCB'	WET WEIGHT
36-3606-1187	AA05381	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1260	ND		UG/G	0.4	PESTICIDE /PCB'	WET WEIGHT

metaTRACE, Inc. ■ 13715 Rider Trail North ■ Earth City, MO 63045 ■ (314) 298-8566

MSSRAP ID	LAB ID	DATE SAM	DATE EXT	DATE ANA	METHOD	MATRIX	PARAMETER	CONC	ERR	UNITS	DL	CATEGORY	COMMENTS
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Aluminum	ND		UG/G	20	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Antimony	ND		UG/G	6	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Arsenic	ND		UG/G	1	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Barium	ND		UG/G	20	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Beryllium	ND		UG/G	0.5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Cadmium	ND		UG/G	0.5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Calcium	1050		UG/G	500	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Chromium	2.98		UG/G	1	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Cobalt	ND		UG/G	5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Copper	ND		UG/G	2.5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Iron	24.2		UG/G	10	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Lead	4.0		UG/G	0.5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Lithium	ND		UG/G	5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Magnesium	ND		UG/G	500	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Manganese	ND		UG/G	1.5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	12/23/87	EPA CLP	FISH	Mercury	0.27		UG/G	0.1	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Nickel	ND		UG/G	4	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Potassium	3190		UG/G	500	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Selenium	ND		UG/G	0.5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Silver	ND		UG/G	1	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Sodium	ND		UG/G	500	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Thallium	ND		UG/G	1	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Vanadium	ND		UG/G	5	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	1/22/88	EPA CLP	FISH	Zinc	12.3		UG/G	2	METALS	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1016	ND		UG/G	0.04	PESTICIDE /PCB'	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1221	ND		UG/G	0.06	PESTICIDE /PCB'	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1232	ND		UG/G	0.04	PESTICIDE /PCB'	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1242	ND		UG/G	0.05	PESTICIDE /PCB'	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1248	ND		UG/G	0.04	PESTICIDE /PCB'	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1254	ND		UG/G	0.04	PESTICIDE /PCB'	WET WEIGHT
36-3406-1187	AA05382	11/10/87	NA	11/17/87	EPA CLP	FISH	Aroclor-1260	ND		UG/G	0.04	PESTICIDE /PCB'	WET WEIGHT
36-FP02-1187	AA06394	12/04/87	NA	01/19/88	EPA 00/07	FISH	Thorium 230	ND		pCi/G	0.2	RADIOCHEMICAL	WET WEIGHT
36-FP02-1187	AA06394	12/04/87	NA	01/19/88	EPA 00/07	FISH	Thorium 232	ND		pCi/G	0.07	RADIOCHEMICAL	WET WEIGHT
36-FP02-1187	AA06394	12/04/87	NA	01/20/88	EPA 903.0	FISH	Radium 226	ND		pCi/G	0.1	RADIOCHEMICAL	WET WEIGHT
36-FP02-1187	AA06394	12/04/87	NA	12/29/87	EPA 908	FISH	Total Uranium	ND		pCi/G	0.1	RADIOCHEMICAL	WET WEIGHT

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WSSRAP ID	LAB ID	DATE SAM	DATE EXT	DATE ANA	METHOD	MATRIX	PARAMETER	CONC	ERR	UNITS	DL	CATEGORY	COMMENTS
B6-FP21-1287	AA07683	01/06/88	NA	2/1/88	EPA 00/07	SQRL TISSUE	Thorium 230	ND		pCi/G	0.05	RADIOCHEMICAL	
B6-FP21-1287	AA07683	01/06/88	NA	2/1/88	EPA 00/07	SQRL TISSUE	Thorium 232	ND		pCi/G	0.01	RADIOCHEMICAL	
B6-FP21-1287	AA07683	01/06/88	NA	1/29/88	EPA 903.0	SQRL TISSUE	Radium 226	ND		pCi/G	0.01	RADIOCHEMICAL	
B6-FP21-1287	AA07683	01/06/88	NA	2/1/88	EPA 908.0	SQRL TISSUE	Total Uranium	ND		pCi/G	0.09	RADIOCHEMICAL	

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WSSRAP ID	LAB ID	DATE SAM	DATE EXT	DATE ANA	METHOD	MATRIX	PARAMETER	CONC	ERR	UNITS	DL	CATEGORY	COMMENTS
BG-FP21-1287 (B)	AA07685	01/06/88	NA	1/30/88	EPA 00/07	SQRL BONE	Thorium 230	ND		pCi/G	0.07	RADIOCHEMICAL	
BG-FP21-1287 (B)	AA07685	01/06/88	NA	1/30/88	EPA 00/07	SQRL BONE	Thorium 232	ND		pCi/G	0.05	RADIOCHEMICAL	
BG-FP21-1287 (B)	AA07685	01/06/88	NA	1/29/88	EPA 903.0	SQRL BONE	Radium 226	ND		pCi/G	0.07	RADIOCHEMICAL	
BG-FP21-1287 (B)	AA07685	01/06/88	NA	2/1/88	EPA 908.0	SQRL BONE	Total Uranium	ND		pCi/G	0.03	RADIOCHEMICAL	

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WSSRAP ID	LAB ID	DATE SAM	DATE EXT	DATE ANA	METHOD	MATRIX	PARAMETER.	CONC	ERR	UNITS	DL	CATEGORY	COMMENTS
BG-AP20-1287	AA07684	01/06/88	NA	1/30/88	EPA 00/07	RABBT TISSUE	Thorium 230	ND		pCi/G	0.03	RADIOCHEMICAL	
BG-AP20-1287	AA07684	01/06/88	NA	1/30/88	EPA 00/07	RABBT TISSUE	Thorium 232	ND		pCi/G	0.01	RADIOCHEMICAL	
BG-AP20-1287	AA07684	01/06/88	NA	1/29/88	EPA 903.0	RABBT TISSUE	Radium 226	ND		pCi/G	0.01	RADIOCHEMICAL	
BG-AP20-1287	AA07684	01/06/88	NA	2/1/88	EPA 908.0	RABBT TISSUE	Total Uranium	ND		pCi/G	0.02	RADIOCHEMICAL	

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WSSRAP ID	LAB ID	DATE SAM	DATE EXT	DATE ANA	METHOD	MATRIX	PARAMETER	CONC	ERR	UNITS	DL	CATEGORY	COMMENTS
B6-AP20-1287 (B)	AA07686	01/06/88	NA	2/1/88	EPA 00/07	RABBT BONE	Thorium 230	ND		pCi/G	0.1	RADIOCHEMICAL	
B6-AP20-1287 (B)	AA07686	01/06/88	NA	2/1/88	EPA 00/07	RABBT BONE	Thorium 232	ND		pCi/G	0.4	RADIOCHEMICAL	
B6-AP20-1287 (B)	AA07686	01/06/88	NA	1/29/88	EPA 903.0	RABBT BONE	Radium 226	ND		pCi/G	0.1	RADIOCHEMICAL	
B6-AP20-1287 (B)	AA07686	01/06/88	NA	2/1/88	EPA 908.0	RABBT BONE	Total Uranium	ND		pCi/G	0.3	RADIOCHEMICAL	

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MSSRAP ID	LAB ID	DATE SAM	DATE EXT	DATE ANA	METHOD	MATRIX	PARAMETER	CONC	ERR	UNITS	DL	CATEGORY	COMM
B6-CP20-021188	AA09901	03/02/88	NA	03/19/88	EPA 00/07	RABBT TISSUE	Thorium 230	ND		pCi/G	1	RADIOCHEMICAL	
B6-CP20-021188	AA09901	03/02/88	NA	03/19/88	EPA 00/07	RABBT TISSUE	Thorium 232	ND		pCi/G	1	RADIOCHEMICAL	
B6-CP20-021188	AA09901	03/02/88	NA	03/14/88	EPA 908.0	RABBT TISSUE	Total Uranium	ND		pCi/G	.04	RADIOCHEMICAL	
B6-CP20-021188	AA09902	03/02/88	NA	03/30/88	EPA 00/07	RABBT BONE	Thorium 230	ND		pCi/G	1	RADIOCHEMICAL	
B6-CP20-021188	AA09902	03/02/88	NA	03/14/88	EPA 00/07	RABBT BONE	Thorium 232	ND		pCi/G	1	RADIOCHEMICAL	
B6-CP20-021188	AA09902	03/02/88	NA	03/14/88	EPA 908.0	RABBT BONE	Total Uranium	ND		pCi/G	.05	RADIOCHEMICAL	
B6-IT20-021188	AA09903	03/02/88	NA	03/21/88	EPA 00/07	RABBT TISSUE	Thorium 230	ND		pCi/G	1	RADIOCHEMICAL	
B6-IT20-021188	AA09903	03/02/88	NA	03/14/88	EPA 00/07	RABBT TISSUE	Thorium 232	ND		pCi/G	1	RADIOCHEMICAL	
B6-IT20-021188	AA09903	03/02/88	NA	03/14/88	EPA 908.0	RABBT TISSUE	Total Uranium	ND		pCi/G	.04	RADIOCHEMICAL	
B6-IT20-021188	AA09904	03/02/88	NA	03/21/88	EPA 00/07	RABBT BONE	Thorium 230	ND		pCi/G	1	RADIOCHEMICAL	
B6-IT20-021188	AA09904	03/02/88	NA	03/14/88	EPA 00/07	RABBT BONE	Thorium 232	ND		pCi/G	1	RADIOCHEMICAL	
B6-IT20-021188	AA09904	03/02/88	NA	03/14/88	EPA 908.0	RABBT BONE	Total Uranium	ND		pCi/G	.08	RADIOCHEMICAL	