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RAFFINATE PROGRAM

License SUB-1010 Amendment No. 4
1979 Completion Report

INTRODUCTION

Beginning in 1967, Kerr-McGee Nuclear Corporation designed and constructed a conversion plant (Sequoyah Facility) for processing uranium ore concentrates (yellowcake) to produce purified Uranium Hexaflouride (UF_6). The initial step of the conversion process is dissolution of yellowcake, containing approximately 95% uranium oxide (U_3O_8), in nitric acid. Uranium is separated from the impurities present in the yellowcake in a solvent extraction system. The impurities rejected by the solvent extraction system are contained in an aqueous 6% nitric acid solution. This solution (raffinate) is neutralized with ammonia to produce an ammonium nitrate solution.

During 1972, laboratory testing was conducted to further treat the raffinate to eliminate radionuclide content of the solution. This testing demonstrated that radioactivity could be sharply reduced by addition of a soluble barium salt, either barium nitrate or barium chloride. Barium treatment resulted in the removal of radium with the precipitate of barium sulfate. The resultant by-product ammonium nitrate solution was considered to be a valuable material which would be suitable for use as a commercial fertilizing compound. A testing program for land application of treated by-product raffinate as fertilizer was initiated in 1973 and continued through 1979. Results of these programs are discussed below.

Previous Testing (1973-1978)

Land application was initiated in 1973 with by-product treated raffinate from the solvent extraction system of the Kerr-McGee Nuclear Sequoyah Facility (USNRC SUB-1010 Amendment #2 and 3). Preliminary tests were conducted on a Kerr-McGee owned three-acre grassland plot. Treatments to the grassland plot produced a beneficial effect upon growth of forage without any deleterious accumulation of radionuclides or other harmful elements.

In 1974, the testing program for treated raffinate use as fertilizer was expanded to include four test plots ranging in size from .68 to .78 acre (SUB-1010, Amendment #5). Test plots were established with the aid of agronomy consultants from Oklahoma State University in front of the Sequoyah Facility building where the predominant vegetation was bermuda-grass. Plots conformed to the land surface configuration and were terraced and diked to divert surface runoff from each plot through a separate measuring flume and sample collector. Soil moisture sorption cups were installed to extract soil solution samples to determine concentrations of nitrogen and radium in percolate. Yields and chemical analyses of forage produced on test plots were also performed. During the growing season, nitrogen treatment rates to plots were as follow:

Plot 1 - Treated raffinate at saturation dosages - 1200 lbs. N/acre

Plot 2 - Treated raffinate - 400 lbs. N/acre

Plot 3 - Commercial nitrogen fertilizer - 400 lbs. N/acre

Plot 4 - Control - No treatment

Treatments were conducted on the four plots during 1974 (Amendment #5), 1975 (Amendment #6) and 1976 (Amendment #7). Results established that treated, by-product raffinate gave similar forage production, forage quality, and nitrogen recoveries as commercial ammonium nitrate fertilizer. Testing further demonstrated that:

1) Treated by-product raffinate could be produced with a radium content of 3 pCi/ℓ or less which is below the permissible 10 CFR 20 limits for unrestricted release and also below the EPA community drinking water standard.
2) Application of treated raffinate to grasslands showed no harmful effects of accumulations of radionuclides or heavy metals in forage or in surface runoff water from test plots.
3) Forage produced from the treated raffinate was safe for livestock consumption.
4) There was no reason why by-product treated raffinate could not be utilized as a valuable nitrogen resource for improvement of pasture grassland production.

Based upon results of four years of testing and data analyses, a larger scale fertilizer program was initiated in 1977 which included development of 160 acres of Kerr-McGee owned land located directly south of the Sequoyah Facility (Amendment #8). During 1977, site preparation was completed prior to initial raffinate treatments and included placement of: structures for surface runoff water control from the area; tensiometers and soil sorption cups; ground and surface water monitoring system; vegetation and soil sampling locations; and establishment of five separate provinces in the timber and grassland vegetation types present on the area. Prior to raffinate treatment, vegetation in open areas consisted of mixed and unimproved bermudagrass pasture.

Initial rates of treated raffinate application to the 160-acre test area ranged from 1000-1500 lbs. N/acre. During 1978, this rate was reduced to 500 lbs. N/acre as residual soil nitrates from 1977 applications were still present in test area soils (License Renewal, SUB-1010, Amendment #1). Monitoring on the 160-acre test area during 1977 and 1978 confirmed results of previous testing and demonstrated:

1) Treated raffinate use is similar to use of comparable rates of commercial ammonium nitrate fertilizer.
2) The same impacts and fertilizer management practices apply to use of both commercial nitrogen fertilizers and treated raffinates.
3) Even under saturation dosages, no build-up of radionuclides or heavy metals occurred in test area soils or vegetation produced as a result of treated raffinate application.
4) No reason existed why treated raffinate could not be used as a valuable source of nitrogen for pasture improvement and cattle grazing.

<u>1979 Program (Renewed SUB-1010 Amendment #4)</u>

During 1978-79, a cattle testing program was developed in conjunction with the Oklahoma State University Animal Disease Diagnostic Laboratory, Oklahoma and U.S. Department of Agriculture officials, and the U.S. Nuclear Regulatory Commission. This cattle testing program was undertaken to determine effects, if any, of raffinate treated forage on cattle and the human food chain. During 1979, raffinate application was continued on the existing 160-acre area. In addition, the fertilizer program was also expanded to include 270-acres of Kerr-McGee owned land located east of the Sequoyah Facility.

Source material license SUB-1010 Amendment No. 4 was issued by the USNRC April 13, 1979, authorizing treatment of both the 160 and 270-acre areas and food chain testing of raffinate fertilized pasture. In accordance with Amendment No. 4, Condition 2, the following report includes a summary of data collected and analyses of the 1979 program.

A. <u>1979 Environmental Monitoring</u>

1. <u>Physical Area</u>

With the addition of the 270-acre treatment area, additional control structures were developed as required by license amendment. Final area configuration and sampling locations for water, soil and vegetation are shown in Figure 1 (Plot Plan). Location of the two-five acre experimental cattle enclosures on the 160-acre area are also provided. Treatment acreage totaled approximately 261 acres during 1979 and included: 10 acres (experimental cattle pasture); 58.5 acres (Province 1, 2, 3, 4a - 160-acre area) and 192.6 acres (available portion of the 270-acre area).

2. <u>Treatment</u>

Following NRC approval, applications of treated raffinate began May 5, 1979. Prior to N treatment, soil tests were conducted by OSU agriculture extension personnel. Limestone (2 tons ECCE/acre), phosphate ([illegible]0 lbs. P/acre) and potash (80 lbs. K/acre) fertilizers were applied to all areas scheduled for raffinate treatment during 1979. Chemical analyses of the commerical additives applied and cattle mineral and protein supplements provided to both the control and test cattle are presented in Table 1.

Table 1. Analysis of Commerical Fertilizers Applied and Cattle Mineral and Protein Supplements - 1979

	Parameter									
	pCi/gm			Parts per million (ppm)						
	Ra-226	Th-230	Th-232	B	Cu	Mo	Ni	Pb	U	Zn
Commercial Fertilizers (Solid)										
46% Nitrogen (N)[a]	.03	.068	.020	3.4	<.1	.1	3.8	1.2	.22	5.8
Phosphate (P_2O_5)(174 lbs/ac)[b]	15.5	34.2	.35	3.6	45	4.4	6.4	1.9	227	460
Potassium (K_2O)(133 lbs/ac)[c]	.15	.11	.004	7.8	4	.4	2.6	2.1	.42	1.6
Limestone	.05	.032	.003	1.4	8	6.7	6.9	1.4	.20	3.6
Cattle Mineral and Protein Supplements (Solid)										
10% P - Mineral Supplement	1.6	9.62	.10	4.3	43	2.1	3.1	1.6	17	480
Beef Protein Supplement	.003	.018	.005	2.7	4.0	.3	1.7	3.1	.03	25

[a]Control Plot only --
[b]To achieve 80 lbs. P/ac. requires 174 lbs. of P_2O_5.
[c]To achieve 80 lbs. K/acre requires 133 lbs. of K_2O.

During 1979, an average of 600 lbs. N/acre from treated raffinate was applied to the 261 acres in three applications. Three to four weeks were allowed for vegetation recovery between applications to the various subunits. A summary of the 1979 treatment program is provided and includes frequency and volume of raffinate applied (Table 2). Based upon pre-season soil tests, the 160-acre area (province 1, 2, 3, 4a) had been targeted for 400 lbs. N/acre; 270-acre area, 600 lbs. N/acre; and cattle test areas, 200 lbs. N/acre. To achieve these targeted rates, all areas received Application #1 and #2 with the 270-acre expansion area receiving a third raffinate Application beginning September 5, 1979.

The average composition of treated raffinate applied during both the 1978 and 1979 programs is provided in Table 3. During 1979, treated raffinate was obtained from Sequoyah Facility Pond No. 3 (capacity 14.4 x 10^6 gals.). Pond No. 3 will be the source of treated raffinate for the fertilizer release program. The decrease in raffinate N concentration from 1978 values reflected dilution of Pond No. 3 with rainfall during 1979 and resulted in corresponding lowering of values for other parameters. With the method of storage provided by Pond No. 3, it is expected that product raffinate fertilizer will approximate quality measured during the 1979 program. For comparison, at 1979 concentration levels, additions from combined commercial additives (P_2O_5; K_2O; lime) applied to test area soils were 226 times greater for radium and 45 times greater for uranium than additions from treated raffinate (average 600 lbs. N/ac rate). Although levels of radionuclide addition via

Table 2. Summary of 1979 Treated Raffinate Applications.

Application No.	Date Start	Date Complete	Total Vol. Raff. (gals)	Avg. N-Conc. Gms/ℓ	Total N Applied-lbs	Acres Treated*	Lbs. N/acre/ Application	Avg. lbs N/ac Total
#1	5/9/79	6/13/79	228,000	27.4	52,132	261.1	199.6	
#2	6/14/79	8/21/79	242,000	27.3	55,132	261.1	211.1	
#3	9/5/79	9/24/79	180,000	33.0	49,569	192.6	257.4	
Totals/Avg	5/9/79	9/24/79	650,000	29.2	156,833	261.1*		600.5

*Note: Treatment areas 160-acre: 10 acre-Cattle enclosures

: 58.5 acre-Province 1, 2, 3, 4a

270-acre: 192.6 acre-(available)

Total Treatment Acres : 261.1

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Table 3. Comparison of Average Composition of Treated Raffinate Applied During 1978 and 1979 Test Programs.

Year	Parameter								
	Radium Ra-226 pCi/ℓ	Thorium Th-230 pCi/ℓ	Uranium U mg/ℓ	Boron B mg/ℓ	Copper Cu mg/ℓ	Molybdenum Mo mg/ℓ	Nickel Ni mg/ℓ	Total N NO_3 + NH_3 g/ℓ	pH
1979	.65	.028	.044	.07	4.0	5.2	11.8	26 - 33	6.1
1978	1.05	.142	.083	1.2	7.4	20.1	21.8	54.2	7.4

commercial additives greatly overshadows effect of raffinate treatments to soils and vegetation, commercial additive treatment (P_2O_5, K_2O and lime) was required to balance macronutrient availability on the treatment acreage and provide optimum conditions for plant growth.

3. Vegetation

a. Quantitative Analyses

Vegetation studies were conducted during 1979 on the test areas to monitor effects of raffinate treatments on flora composition.

At the start of the fertilizer program in 1977, seven permanent plots were established on the 160-acre area on selected sites which encompassed swards of the predominate species of the study area. Six of the permanent plots were 65 x 65 feet. One was a 20 x 20 foot persimmon grove. The principal vegetation in each permanent plot was identified and counts made by use of a modified point frame. These counts were checked by dividing the plots into eight equal portions and the percentage of each species estimated. Groundcover was based upon a visual rating after several measurements from one square yard subplots were taken. Baseline data for each permanent flora site was collected on June 2 and 3, 1977 prior to any raffinate treatment on the area. Following raffinate treatments, measurements were again taken on September 29, 1977, October 24, 1978, May 14, 1979 and October 25, 1979. The sward composition for these dates is recorded in Table 4.

Table 4 - Sward Composition (%) of Permanent Plots on the 160-acre Test Area

Flora Site 1 Province 1	% of Sward Date Measured				
	6/2/77	9/29/77	10/24/78	5/14/79	10/25/79
Fescue	33	10	10	44	15
Sericea Lespedeza	25	--	--	10	--
Broomsedge	15	10	--	--	--
Lanceleaf Ragweed	10	20	20	--	--
Silverleaf Nightshade	5	--	--	--	--
Bermudagrass	5	30	45	46	65
Leadplant	2	--	--	--	--
Foxtail	2	13	5	--	--
Johnsongrass	1	17	20	--	20
Basal ground cover %	90	80	90	85	95

Flora Site 2 Province 4a	% of Sward Date Measured				
	6/2/77	9/29/77	10/24/78	5/14/79	10/25/79
Bermuda grass	25	97	98	Disrupted by clearing of cattle enclosures	
Korean Lespadeza	10	--	--		
Iron Weed	10	--	1	"	"
Winter Annual Grasses	20	--	--	"	"
Persimmon Sprouts	5	--	--	"	"
Ragweed	5	--	--	"	"
Bracted Plankton	3	--	--	"	"
Others	22	2	--	"	"
Basal Ground Cover	70	95	95	"	"

Table 4 - (Cont'd)

Flora Site 3 Province 3	% of Sward — Date Measured				
	6/2/77	9/29/77	10/24/78	5/14/79	10/25/79
Native Grasses (bluestems)	70	70	80	80	80
Blackberry	5	10	10	10	10
Winged Elm	10	10	5	5	5
Dallisgrass	5	5	5	5	5
Others	10	5	--	--	--
Basal Ground Cover	80	80	80	80	80

Flora Site 4 Province 3	% of Sward — Date Measured				
	6/2/77	9/29/77	10/24/78	5/14/79	10/25/79
Green Briars (15 x 20 Briar Patch) Composition within patch 50%	30	31	21	Disrupted by Clearing	Disrupted by Clearing
Bluestems	50	54	65	"	"
Blackberries	5	4	4	"	"
Winged Elm	2	3	4	"	"
Others	8	8	7	"	"
Basal Ground Cover	70	NR	80	"	"

Table 4 - (Concluded)

Flora Site 5 Province 3	% of Sward Date Measured 6/2/77	 9/29/77	 10/24/78	 5/14/79	 10/25/79
Sericea Lespadeza	30	30	10	20	5
Bermudagrass	30	10	20	20	30
Bluestem	30	50	60	60	60
Others	10	10	10	--	5
Basal Ground Cover	65	100	95	95	100

Flora Site 6
Province 4

This site was lost due to construction of new raffinate pond. (Surrounding area was nearly 100% bermudagrass with a very dense sod).

Flora Site 7 Province 5	% of Sward Date Measured 6/2/77	 9/29/77	 10/24/78	 5/14/79	 10/25/79
Bermudagrass	96	100	98	98	95
Crabgrass	2	--	2	--	5
Others	2	--	--	2	--
Basal Ground Cover	15	100	95	95	85

Some difficulty was encountered in comparing sward composition due to natural seasonal variations. Also, seasonal rainfall and temperatures influence sward composition and basal groundcover. Despite limitations of these measurements, some differences were pronounced and conclusive.

It is quite evident that the raffinate treatments during 1977, 1978 and 1979 on the 160-acre area have resulted in increases in the perennial grasses at the expense of annual weed species. Legumes also tended to decrease and to be replaced by grasses. Basal ground cover increased over the three year period. These changes in sward composition correspond to those widely observed with heavy commercial nitrogen fertilization of pastures and ranges.[1,2,3]

Three permanent plots were established on the 270-acre area in 1979. Permanent plots were located in fescue, native grass and bermudagrass pasture areas. These plots were 65 x 65 feet and the vegetation survey was conducted in the same manner as for permanent plots located on the 160-acre area. Measurements were taken on May 14 and October 25, 1979. The sward composition for these dates is recorded in Table 5.

Despite difficulty associated with naturally occurring variations in sward composition, some striking changes occurred as a result of raffinate treatments. As learned from the previous studies, treated raffinate application greatly reduces broadleaf weeds and favors perennial grasses over annual species. Both bluestems and bermudagrass

Table 5 - Sward Composition (%) of Permanent Plots on the 270-acre Area

Location	% of Sward Pre-inventory May 14, 1979	% of Sward Post-inventory October 25, 1979
Nativegrass Pasture		
Bluestems	40	60
Broomsedge	20	15
Lanceleaf Ragweed	5	10
Iron Weed	3	--
Lead Plant	2	--
Winter Annual Grasses	30	--
Others	0	15
Basal Ground Cover	70	90
Fescue Pasture		
Fescue	65	65
Broomsedge	15	10
Lanceleaf Ragweed	5	--
Iron Weed	5	--
Winter Annual Grasses	10	--
Others	0	25
Basal Ground Cover %	80	90
Bermudagrass Pasture		
Bermudagrass	55	90
Winter Annual Grasses	25	--
Foxtail	5	5
Broomsedge	5	--
Silverleaf Night Shade	5	--
Others	5	5
Basal Ground Cover %	70	95

composition increased during the year on the 270-acre area with bermudagrass essentially a pure stand by the fall of 1979.

b. Chemical Analyses

Vegetation sampling was conducted periodically throughout the 1979 growing season to compare chemical composition of raffinate treated pasture and control pasture vegetation. Results of 1979 vegetation sampling are provided in Table 6. The cattle control pasture was located in Vian, Oklahoma approximately 4 miles east of the Sequoyah Facility. The control pasture vegetation was composed of a native, fescue and bermudagrass mixture and had been used in the past for cattle grazing. Soil tests were performed and commercial N, P, K, and lime fertilizers applied prior to controlled cattle grazing. A rate of 200 lbs. N/acre (commercial N), 80 lbs. P/acre, 80 lbs. K/acre and 2T ECCE lime was applied to the Vian control pasture. To establish similar conditions for testing, the 160-acre experimental cattle pasture (two-5 acre enclosures), received the same application rate for N, P, K, and lime with treated raffinate as the source of N.

In conjunction with the overall raffinate fertilizer management program, it has been established that forage removal is an essential practice to maintain proper nitrogen balance on treatment areas. Following the 1979 growing season, approximately 32,000 bales of bermuda hay were removed and stockpiled on treatment acreage. As shown in Table 6, forage results indicated that even at approximately three times the N application rate used on both cattle test pastures, post-season baled hay quality from the 270-acre raffinate treated

Table 6. Chemical Analyses Vegetation Samples: Cattle Control Pasture; 270-acre and 160-acre Test Plot - (Total Analysis KM Technical - Dry Weight)

Sample Type	Location	Date	Parameter pCi/gm Ra-226	Th-230	µg/gm N	P	K	Ca	Mg	U	Zn	Fe	Cu	B	Mo	Ni	Mn	Pb
Fescue Composite	Control Pasture[a]	5/79	.06	.003	17600	1887	3800	1800	1200	.12	16	1800	11	<1	2.7	1.2	80	3.8
Fescue Composite	270-ac.	5/79	.01	.006	20800	1521	6200	2200	1700	1.2	10	710	6.6	<1	1.6	1.6	120	3.6
Bermuda Composite	160-ac.	6/79	.01	.036	6900	962	9200	2100	2200	.69	21	420	10	<1	5.0	3.6	180	4.1
Composite	Control Pasture	6/79	.001	.035	5100	621	3100	1800	1200	.61	17	1200	8.1	<1	2.4	2.4	90	3.0
Composite	160-ac. (So.)[b]	6/79	.025	.111	22000	2260	14000	11000	1500	.36	30	1100	3.3	3.6	14.0	1.8	340	1.3
Composite	160-ac. - 4a[c]	10/79	.008	.006	21800	1320	17000	4800	3000	2.31	29	170	7.0	<.5	6.5	3.0	170	1.5
Composite	160-ac. - 4	10/79	.007	.010	16200	1190	3500	5000	3000	1.72	21	320	12.	<.5	4.4	1.7	160	4.2
Composite	160-ac. - 5	10/79	.007	.004	11000	1120	5500	1600	1500	.23	17	120	3.5	<.5	6.5	1.0	100	1.0
Composite	160-ac. - 3	10/79	.018	.002	14600	1140	6000	3500	2100	1.13	22	180	6.0	7.9	8.5	.85	170	1.7
Composite	160-ac. (So.)	10/79	.004	.003	14400	840	3200	3400	1800	1.22	20	190	12.0	7.8	3.3	1.1	240	1.8
Composite	160-ac. (No.)	10/79	.006	.068	14500	660	2400	5500	1000	.94	17	1200	9.0	3.3	3.2	2.8	190	2.3
Native	270-ac.	10/79	.002	.005	13300	800	3800	2800	1400	.14	23	140	5.5	6.9	5.5	2.5	350	1.6
Fescue	270-ac.	10/79	.017	.005	24800	1540	11000	5500	3100	3.47	18	190	5.0	9.7	9.5	4.8	180	.75

Table 6. (Cont'd)

Sample Type	Location	Date	Parameter: pCi/gm Ra-226	Th-230	μg/gm N	P	K	Ca	Mg	U	Zn	Fe	Cu	B	Mo	Ni	Mn	Pb
Bermuda	270-ac.	10/79	.009	.003	17800	940	3900	1900	1200	.70	21	100	6.0	6.9	9.0	4.4	100	1.3
Bermuda Hay	270-ac.[d]	10/79	.014	.0011	15600	830	3700	2200	1400	.71	19	75	7.0	4.7	2.8	3.0	90	1.6
Hay	Control Pasture	10/79	.01	.002	16000	1580	6500	2800	3300	.12	30	95	8.0	11.	1.9	1.5	120	1.3

[a] Cattle Control Pasture located in Vian, Oklahoma.

[b] Experimental Pasture - South 5 acres.

[c] 160-acre test area-Province 4a

[d] Quality Analyses:

	270-acre hay	Control Pasture hay
Crude Protein (%)	9.9	10.2
NO_3-N (ppm)	4300	1000
Tot. Dig. Nutrients (%)	48.2	44.1

pasture was similar to Vian control hay. No reason exists why hay from either area could not be used for feeding all classes of livestock, either as a supplement or as a sole source of feed. As demonstrated through testing, overall impacts of raffinate treatments on vegetation are similar to commercial N fertilization and result in increased forage quality and quantity and a shift in plant community composition to more desirable forage grass species. It must also be recognized that this system is dynamic and requires a viable outlet for forage product produced.

4. Soils

a. Soil Mapping - Expansion Area

The 270-acre area was surveyed and mapped according to Soil Conservation Service standard procedures. With the aid of aerial photographs, the area was walked in a grid fashion and periodic borings were made to determine the nature and property of the soils. Whenever changes in soil type or slope of the land were observed, delineations were made on photos. After the entire area was surveyed, soil boundary lines were smoothed and redrawn as shown in the final soils map of the 270-acre area (Figure 2 - p. 32).

The area shown on the map is considerably larger than the 270 acres where raffinate was applied. The additional area was mapped to obtain some continuity in the map itself, to gather soil information over the fault zone, and to determine the extent of additional acres that might be suitable for raffinate treatment within the area. Based upon this survey, sampling of soil over the fault zone was deemed unnecessary due to the inability to determine precise location, irregular nature of soils, and the problem of selecting a representative profile in this area. The majority of soils where raffinate was applied during 1979 were deep, permeable, and productive soils capable of supporting good forage grass growth.

b. Soil Sampling

As a license condition, samples were to be collected on the 270-acre area on soils that were not already represented in the original 160-acre soil survey. The 1979 soil survey revealed no new soils that represented any sizable area, and the Pickwick (PcC) and Vian (VaB, VaC) soil types were re-sampled for profile analysis.

The samples for chemical analysis were composites of five (5) soil borings taken from within the areas mapped. Each sample contained material taken from the boring at each location. Chemical analyses of these pre-season soil samples collected in May, 1979 from the 270-acre and composite samples (0-6 inches) collected from the cattle control pasture are provided in Table 7.

c. Soil Nitrate Levels

A sampling program was undertaken during spring 1979 to monitor soil nitrate nitrogen (NO_3-N) levels in areas which had already received raffinate treatments and which had been overseeded with rye and fescue grass during fall 1978.

Pre-season samples to ascertain soil profile nitrates were collected in Province 4 of the 160-acre area on March 27, 1979 (Table 8).

Table 7. Chemical Analyses of Pre-Season Soil Samples Collected May, 1979 - Sequoyah 270-Acre Test Area and Cattle Control Pasture. (Total Analysis KM Tech Center)

Sample/ Soil Type		Soil Depth (inches)	Soil Reaction pH	Soil Reaction B.I.[d]	pCi/gm Ra-226	pCi/gm Th-230	mg/g N	mg/g P	µg/g K	µg/g Ca	µg/g Mg	µg/g Fe	µg/g U	µg/g Zn	µg/g Mn	µg/g B	µg/g Cu	µg/g Mo	µg/g Ni	mg/g T.O.C.[e]
270-acre test area																				
PC	1	0-6	5.69	6.87	.40	.19	1.06	.36	610	1000	270	20000	1.4	23	310	<.001	.7	.4	4.7	12.5
Pickwick	2	6-12	5.91	6.89	.55	.51	.870	.34	500	1100	240	21000	1.9	21	250	<.001	.8	.4	10.0	11.1
loam	3	12-18	5.13	5.98	.34	.45	.490	.24	740	660	260	16000	.83	20	80	<.001	.6	.1	7.6	6.9
3-5%	4	18-24	5.31	5.31	.55	.35	.61	.20	1000	790	370	28000	1.6	29	50	<.001	12.	.1	12	6.2
	5	24-30	5.77	5.93	.45	.29	.36	.12	1000	890	370	22000	1.2	25	60	<.001	.8	.1	11	3.5
	6	30-36	7.07	--	.68	.24	.15	.11	680	890	270	17000	1.0	19	70	.002	.7	.1	11	1.7
	7	36-42	7.64	--	.43	.15	.15	.15	1100	1000	380	22000	.81	26	90	<.001	.9	.1	9.2	1.4
	8	42-48	7.65	--	.32	.23	.12	.09	960	1100	360	21000	.96	24	80	<.001	10.	.1	8.5	1.3
VaB	9	0-6	5.73	6.62	.40	.11	.75	.28	690	620	280	15000	1.2	22	310	<.001	.8	.2	4.3	9.3
Vian	10	6-12	5.77	6.68	.55	.13	.70	.20	380	620	190	9000	1.1	13	260	<.001	.5	.1	2.7	9.0
silt-	11	12-18	5.84	6.50	.25	.10	.39	.31	690	470	210	18000	.96	26	240	<.001	.7	.2	3.6	5.8
loam	12	18-24	5.67	6.29	.51	.10	.38	.18	670	300	200	16000	1.1	21	270	<.001	.4	.2	3.9	4.3
1-3%	13	24-30	5.30	6.42	.41	.30	.33	.28	330	170	210	12000	.77	13	420	<.001	.4	.1	3.1	2.8
	14	30-36	5.66	6.55	.44	.30	.31	.23	420	140	180	7600	1.1	11	140	<.001	.3	.1	2.8	1.5
	15	36-42	5.65	6.35	.35	.34	.22	.21	880	450	250	17000	1.0	24	290	<.001	.8	.2	2.6	2.5
	16	42-48	5.87	6.50	.33	.35	.19	.17	920	630	310	16000	1.3	24	250	.002	.8	.1	1.2	2.8
Composites																				
	17[a]	0-6	5.13	6.70	.45	.35	.18	.34	560	1300	220	10000	1.8	18	250	<.001	.4	.1	4.7	18.0
	18[b]	0-6	5.23	6.47	.58	.30	1.3	.29	620	1500	260	19000	1.8	27	320	<.001	.5	.4	5.7	16.0
	19[c]	0-6	5.31	7.02	.57	.13	1.2	.21	420	1700	190	8900	1.2	54	220	<.001	.4	.8	3.3	16.00

Note: [a]South unit 270-acre test area.
[b]North unit 270-acre test area.
[c]Cattle Control Pasture - Vian, Oklahoma.
[d]Buffer Index
[e]Total Organic Content

Table 8. Pre-season Monitoring of Nitrates - Province 4, March, 1979

Depth (Inches)	NO_3-N (lbs/A)	Total N %
0-6	143	0.048
6-12	172	0.045
12-18	30	0.048
18-24	18	0.061
24-30	6	0.051
30-36	2	0.093

Province 4 had been treated with approximately 500 lbs. N/acre treated raffinates during 1978 and had been overseeded with rye in the fall of 1978. Excellent, vigorous growth stands were obtained during March and April, 1979. October, 1978 soil samples had indicated large quantities of nitrates still present in the upper soil profile above 24 inches (194-540 lbs. NO_3-N/acre).[4] By April, 1979, the rye had reduced nitrate levels below 12 inches to small quantities. However, high levels remained in the upper 12 inches.

On April 16, 1979, Province 4 was re-sampled by 6-inch increments to the 48 inch depth. By this time nitrate nitrogen had been reduced to low levels throughout the profile. In addition, low soil nitrates were found in both treated and untreated areas of Provine 4a and in the newly established 270-acre area. The highest nitrates found during the April sampling program were from the cattle control pasture near Vian (Table 9).

Soil tests revealed both available P and K levels were too low for maximum production and additive recommendations for these areas were made and commercial additives applied (See Section 2, Treatment).

Additional samples to monitor nitrate nitrogen levels were taken in June (Table 10). By this time, areas had received one raffinate treatment. At this sampling date, with actively growing forage, soil nitrate levels were generally low. Only the timbered strips in Province 3 of the 160-acre area showed any significant soil

Table 9. Chemical Analyses of Pre-Season Soil Samples to Monitor Nitrates (April 16, 1979).

Location	Depth (inches)	Soil Reaction pH	Soil Reaction B.I.	(lbs/Acre) NO_3-N	(lbs/Acre) P	(lbs/Acre) K
160-acre						
Province : 4	0-6	6.7	--	35	41	212
	6-12	6.3	7.0	25	22	163
	12-18	6.4	7.2	19	49	121
	18-24	6.6	--	17	41	118
	24-30	5.8	7.0	3	30	121
	30-36	5.6	6.9	5	16	103
	36-42	6.8	--	9	23	214
	42-48	7.1	--	7	53	174
: 4a Untreated	0-6	6.1	7.0	6	49	196
: 4a Treated	0-6	4.8	6.6	29	52	133
: 1	0-6	5.9	6.9	9	35	159
: 4	0-6	5.0	6.7	17	53	135
270-acre						
Field-1 (North)	0-6	5.3	6.9	9	39	125
Field-2 (North)	0-6	5.5	6.8	7	52	184
Field-3 (South)	0-6	5.3	6.8	12	44	298
Field-4 (Fescue)	0-6	5.2	6.8	5	32	82
Control						
Vian	0-6	5.6	7.0	60	39	256

Table 10. Analyses of Soil Profile Samples and Vegetation Collected June 6, 1979 - (OSU Analyses Available Nutrients).

Description	Location	Depth Inches	pH	lbs./Acre N	lbs./Acre P	lbs./Acre K	Vegetation Sample	ppm NO_3-N
Fescue Meadow	270-acre test	0-6	6.0	38	51	151		
	area	6-12	5.2	21	29	84		
		12-18	5.2	6	21	68	Fescue	7600
		18-24	5.5	3	12	127		
		0-6	5.4	28	30	89		
Bluestem Meadow	270-acre test	6-12	5.0	24	21	56		
	area	12-18	5.1	6	20	62	Bluestem	1000
		18-24	5.4	2	20	116		
		0-6	4.8	44	26	194		
Access Corridors	Province 3	6-12	4.6	49	25	188		
(Rye Areas)	160-acre	12-18	3.8	77	8	153		
		18-24	3.8	84	4	194		
		42-48	5.7	46	2	284		
		0-6	4.8	16	28	146		
Timber between	Province 3	6-12	4.6	21	15	126		
access corridors	160-acre	12-18	--	--	--	--		
		18-24	3.8	79	3	205		
		0-6	5.0	24	52	148		
Cattle test		6-12	4.5	21	29	111		
areas-grazed	160-acre test	12-18	4.4	23	34	73	Grazed bermuda	4600
	area	18-24	4.3	28	31	72		
		0-6	4.9	14	55	160		
		6-12	4.4	21	24	91	Ungrazed	10200
Cattle test	160-acre test	12-18	4.5	64	7	192	bermuda	
areas-ungrazed	area	18-24	5.0	100	7	232		

nitrate levels. P and K readings were still too low for optimum production.

Soil samples were taken from the cattle experimental pasture in August to monitor soil nitrate levels (Table 11). At this sampling date, the north paddock nitrates were nearly depleted, but the south 5-acre paddock contained significant nitrates in the surface 12 inches but none below that depth. Available soil P and K were extremely low in these grazing paddocks which no doubt reduced total forage yields.

d. Post-Season Sampling

Post-season soil samples were collected in October, 1979 from all treatment areas (Table 12). By the end of the season, soil nitrate levels were considerably lower than in past seasons. Significant residual levels, however, were still present in Provinces 4a and 3 of the 160-acre area. On the 270-acre area, surface samples were high in nitrates, but very low nitrates were found below the surface 12 inches. Nitrates were low in October in the north paddock of the experimental cattle pasture, but in the south paddock significant amounts of nitrates were measured throughout the profile.

For the parameters of interest, no unusual levels were observed following raffinate treatments. Changes in soil acidity due to 1979 treatments (Lime, N) can be expected to affect measured levels of these various parameters in all areas treated (including control

Table 11. Monitoring of Nitrates in the Cattle Paddocks 160-acre Area, August, 1979.

Location	Depth (inches)	Soil Reaction pH	Soil Reaction B.I.	(lbs/Acre) NO_3-N	(lbs/Acre) P	(lbs/Acre) K
South Paddock:	0-6	5.6	7.2	85	11	51
	6-12	5.1	7.1	36	4	41
	12-24	5.6	7.0	2	3	38
	24-30	6.8	--	2	1	39
	30-36	6.9	--	3	0	83
North Paddock:	0-6	5.9	6.8	29	13	69
	6-12	5.8	7.0	22	9	54
	12-24	5.8	7.0	2	5	74
	24-30	5.5	7.2	1	4	63
	30-36	6.7	--	1	0	74

Table 12. Chemical Analyses of Post-Season Soil Samples Collected October, 1979 - Sequoyah Test Areas. (Available Nutrients - Agronomic Services Lab., OSU[a]: KM Technical Center Analyses[b]).

Location/ Province	Depth (inches)	Soil Reaction[a] pH	B.I.	(lbs./Acre)[a] NO_3-N	P	K	Ca	Mg	ppm[a] Fe	Zn	Mn
160-acre area											
4a	0-6-C*	6.7	--	90	47	229	4256	127	32.2	1.61	34.7
	0-6	6.3	7.0	30	19	117	2897	92	36.1	1.81	33.4
	6-12	5.0	6.7	15	9	61	1197	116	31.5	0.26	26.5
	12-18	5.2	6.8	24	6	55	879	123	19.6	0.12	11.6
	18-24	4.9	6.9	33	4	70	1064	195	14.6	0.11	9.8
	24-30	5.4	6.7	76	0	193	2504	721	11.9	0.12	9.1
	30-36	5.9	7.0	52	0	208	2903	823	10.5	0.10	19.4
	36-42	7.7	--	60	0	178	3616	765	7.5	0.10	1.5
4 (untreated during 1979)	0-6-C	6.1	7.0	44	46	161	2725	147	39.7	1.36	43.2
	0-6	6.5	--	22	16	147	4150	352	24.4	0.49	23.4
	6-12	6.4	7.2	5	5	73	1931	264	19.4	0.13	8.0
	12-18	5.7	6.7	1	2	101	1732	506	27.4	0.10	3.8
	18-24	6.0	6.7	2	5	259	4347	999	18.4	0.11	1.8
	24-30	--	--	--	--	--	--	--	--	--	--
	30-36	7.5	--	24	0	284	4977	999	7.9	0.08	1.1
	36-42	6.9	--	94	0	302	9000	999	9.2	0.12	0.8
5 (untreated during 1979)	0-6-C	6.4	7.2	35	46	123	2259	89	3.8	1.27	56.3
	0-6	6.6	--	28	24	62	1942	31	35.8	1.28	28.8
	6-12	5.1	7.1	9	15	50	736	28	30.2	0.78	45.1
	12-18	4.6	7.0	19	11	62	648	26	20.4	0.26	58.7
	18-24	4.9	7.1	30	14	110	1540	80	21.4	0.17	64.8
	24-30	5.4	7.0	29	20	135	2368	148	19.9	0.12	31.3
	30-36	5.8	7.2	49	22	137	2398	214	15.4	0.09	8.4
	36-42	5.7	7.2	61	18	143	2382	332	12.7	0.08	3.6

*C-Composite of 20 Cores from the Province

Table 12. (Cont'd)

Location/ Province	Depth (inches)	Soil Reaction[a] pH	Soil Reaction[a] B.I.	pCi/gm[b] Ra-226	pCi/gm[b] Th-230	(lbs./Acre)[a] NO_3-N	(lbs./Acre)[a] P	(lbs./Acre)[a] K	(lbs./Acre)[a] Ca	(lbs./Acre)[a] Mg	ppm[a] Fe	ppm[a] Zn	ppm[a] Mn	μg/g[b] B	μg/g[b] Cu	μg/g[b] Mo	μg/g[b] Ni	μg/g[b] U	mg/g[b] T.O.C.
160-acre area																			
3	0-6-C	4.3	--	.54	.76	44	22	--	--	--	--	--	--	<.5	7.7	2.0	12	1.03	17.9
	0-6	4.3	6.5	.70	.62	90	10	137	739	83	32.3	0.70	76.1	3.0	5.7	<1.0	9.2	.99	6.54
	6-12	4.8	6.9	.68	.56	209	7	100	1920	294	17.6	0.09	36.9	<.5	7.3	<1.0	13	1.49	3.42
	12-18	4.6	6.9	.79	.65	131	9	93	1621	274	14.8	0.10	5.0	<.5	6.8	<1.0	11	.94	2.63
	18-24	4.2	6.2	.47	.61	140	3	118	1145	428	17.6	0.11	2.8	<.5	8.0	<1.0	11	.88	2.17
	24-30	4.2	6.2	.45	.62	196	5	150	2359	498	19.0	0.11	3.0	<.5	9.3	<1.0	13	1.86	3.07
	30-36	4.0	6.2	.58	.23	159	1	122	1689	497	21.9	0.12	3.5	<.5	11.0	<1.0	14	1.10	2.65
	36-42	4.7	6.5	.55	.68	104	0	151	1699	672	14.1	0.10	3.2	<.5	12.0	<1.0	14	3.20	2.01
N-Paddock	0-6-C	6.4	7.1	.35	.66	43	34	112	3564	136	35.91	3.14	33.3	1.0	7.0	1.7	9.4	1.74	19.1
	0-6	5.4	6.7	.21	.59	24	51	67	2411	98	43.1	2.21	46.3	.6	9.0	3.1	7.1	1.36	19.4
	6-12	5.4	6.9	.39	.74	5	10	57	1782	95	34.0	0.22	9.8	<.5	6.5	<1.0	5.5	2.72	8.4
	12-18	5.5	6.9	.45	.67	3	5	55	1143	171	29.0	0.11	8.3	.5	5.0	<1.0	6.4	1.90	9.75
	18-24	6.2	6.9	.40	.63	5	1	208	3982	901	20.0	0.12	20.1	.5	12.0	<1.0	13	1.21	3.63
	24-30	7.1	--	1.40	.75	5	0	200	3933	936	10.2	0.10	6.0	<.5	10.0	<1.0	13	3.55	3.63
	30-36	8.2	--	.57	.70	12	0	246	4720	999	8.5	0.11	2.3	<.5	15.0	1.8	11	1.08	2.15
	36-42	8.2	--	.09	.68	67	0	262	5190	999	10.2	0.11	1.2	.7	13.0	<1.0	11	1.48	1.04
S-Paddock	0-6-C	6.5	--	--	--	67	60	174	3716	125	38.6	2.12	49.6	--	--	--	--	--	--
	0-6	5.7	6.9	--	--	88	14	87	2298	65	34.3	0.40	30.8	--	--	--	--	--	--
	6-12	5.2	6.9	--	--	18	9	52	1162	55	24.6	0.11	8.0	--	--	--	--	--	--
	12-18	5.5	6.7	.70	.85	90	1	197	4353	469	20.7	0.11	7.1	<.5	11	1.3	13	1.89	7.29
	18-24	6.3	7.0	.99	.99	103	0	247	4997	782	12.3	0.11	12.9	<.5	13	<1.0	12	2.02	5.94
	24-30	7.5	--	.75	.81	101	1	230	4499	797	8.8	0.08	3.6	<.5	12	<1.0	11	1.93	3.08
	30-36	7.9	--	.71	.75	158	5	199	4132	746	9.6	0.09	1.5	1.0	11	<1.0	11	1.53	1.78
	36-42	7.9	--	.62	.70	208	3	163	3799	711	8.0	0.09	1.1	<.5	6.0	<1.0	8.6	1.99	1.13
270-acre area																			
Fescue	0-6-C	5.9	7.1	.53	.61	136	34	132	2594	150	32.9	0.89	36.2	<.5	4.3	<1.0	5.1	1.84	11.4
	0-6	5.5	7.1	.62	.58	107	19	102	2379	128	33.2	0.85	37.5	<.5	4.1	<1.0	4.4	1.08	8.96
	6-12	5.7	7.2	.35	.62	29	10	39	2083	66	26.2	0.34	14.9	<.5	3.9	<1.0	3.9	1.57	6.19

*C-Composite of 20 Cores from the Province.

Table 12. (Concluded)

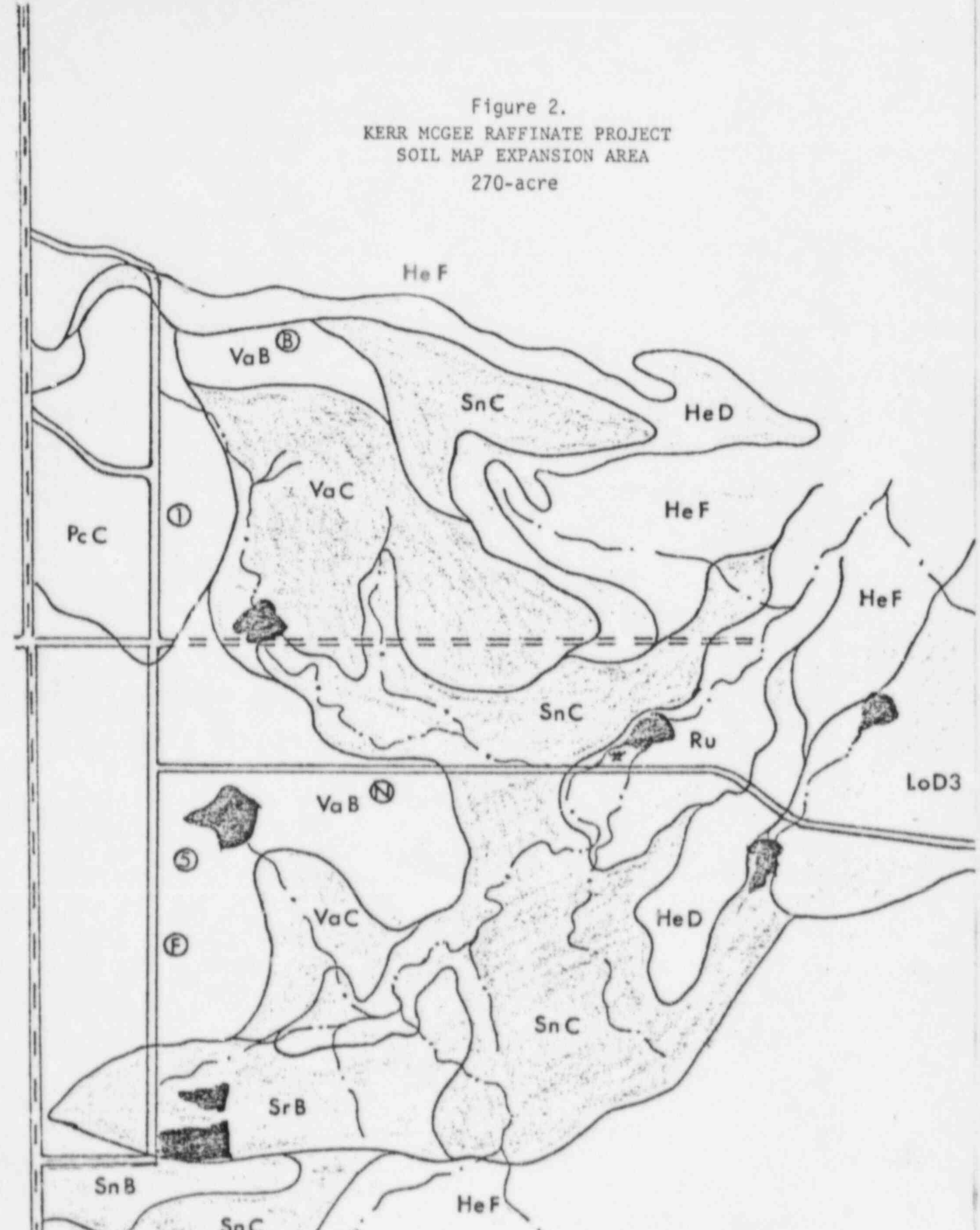
Location/ Province	Depth (inches)	Soil Reaction[a] pH	B.I.	pCi/gm[b] Ra-226	Th-230	(lbs./Acre)[a] NO_3-N	P	K	Ca	Mg	ppm[a] Fe	Zn	Mn	µg/g[b] B	Cu	Mo	Ni	U	mg/g[b] T.O.C.
270-acre area																			
Fescue	12-18	5.8	7.1	.88	.64	3	4	48	1475	125	15.2	0.10	4.1	<.5	3.9	<1.0	5.7	1.57	3.59
	18-24	6.7	--	.58	.82	8	0	159	3669	712	14.2	0.09	6.4	<.5	9.8	<1.0	12	1.66	5.73
	24-30	7.3	--	.86	.68	8	0	177	3877	769	13.2	0.08	12.4	<.5	8.2	<1.0	12	1.4	4.59
	30-36	7.2	--	.32	.67	12	1	156	3363	667	12.2	0.12	13.1	<.5	8.9	<1.0	13	2.2	2.05
	36-42	6.6	--	.84	.81	11	0	183	3737	764	15.5	0.20	14.7	1.8	8.6	<1.0	10	1.89	2.03
Bermuda	0-6-C	6.2	7.1	.51	.71	242	47	191	3713	228	36.4	1.67	51.7	<.5	5.2	<1.0	6.9	2.1	18.8
	0-6	5.1	6.7	.59	.54	414	36	119	2729	192	39.0	1.58	57.3	<.5	5.7	<1.0	6.7	' 0	15.5
	6-12	5.2	6.8	--	--	231	13	83	2059	155	31.9	0.48	18.0	--	--	--	--		--
	12-18	5.2	6.4	--	--	20	7	93	1346	226	23.9	0.13	4.4	--	--	--	--	-	--
	18-24	5.4	6.5	--	--	8	2	116	1550	572	21.2	0.12	3.7	--	--	--	--	--	--
	24-30	5.9	6.8	--	--	13	1	143	2061	837	15.9	0.20	10.6	--	--	--	--	--	--
	30-36	5.6	6.4	--	--	12	0	125	1313	497	11.1	0.12	1.1	--	--	--	--	--	--
	36-42	6.4	7.0	--	--	8	0	113	1673	599	9.6	0.09	2.7	--	--	--	--	--	--
Native	0-6-C	5.9	7.0	.39	.54	152	28	117	2464	117	31.1	1.58	45.7	<.5	6.4	1.0	5.7	1.6	18.6
	0-6	5.9	7.1	.53	.54	158	94	127	2530	112	32.2	0.94	45.7	<.5	4.5	<1.0	6.5	2.5	13.4
	6-12	5.1	--	.52	.62	--	--	--	--	--	--	--	--	<.5	4.1	<1.0	5.2	2.0	6.62
	12-18	5.8	7.0	.78	.57	9	6	49	1308	139	18.5	0.10	7.4	<.5	3.4	<1.0	6.4	1.6	4.04
	18-24	7.2	--	.90	.84	4	1	193	3375	904	10.9	0.11	9.2	<.5	8.2	<1.0	13	2.4	2.02
	24-30	6.9	--	.96	.81	5	1	176	3397	843	13.4	0.09	25.1	<.5	6.6	<1.0	12	2.0	2.7
	30-36	6.5	--	.84	.70	3	1	170	3061	742	16.5	0.11	12.8	<.5	8.6	<1.0	13	2.1	5.24
	36-42	7.4	--	.77	.79	4	2	163	2970	812	13.6	0.16	7.3	<.5	8.9	<1.0	11	2.0	1.82
Control Pasture																			
Vian Control	0-6-C	6.6	--	.93	.61	112	77	200	4340	296	35.0	5.73	45.7	1.4	6.0	<1.0	8.4	1.4	24.9
	0-6	7.1	--	.65	.53	43	80	275	3711	235	36.3	6.74	21.0	.7	7.0	1.4	5.5	1.3	20.4
	6-12	5.9	7.0	.78	.56	4	20	101	2094	129	23.3	0.48	7.9	<.25	4.5	<1.0	6.2	1.9	8.38
	12-18	5.2	6.9	.63	.66	1	9	77	1286	85	19.9	0.18	6.2	.4	6.0	<1.0	5.7	1.9	4.34
	18-24	5.4	6.7	.90	.64	2	3	87	1168	260	15.9	0.13	5.4	1.0	6.0	<1.0	5.8	2.0	3.13
	24-30	5.3	6.0	.93	1.03	2	0	248	3620	923	15.7	0.16	2.6	<.25	14	<1.0	19	2.0	5.78
	30-36	5.5	6.2	1.16	1.09	4	0	244	3602	946	16.2	0.11	1.0	.40	12	<1.0	12	1.9	5.03
	36-42	5.5	6.5	.79	.52	4	0	215	3308	882	18.0	0.12	0.5	<.25	6.5	<1.0	9.9	2.6	2.8

*C-Composite of 20 Cores from the Province.

pasture). Impacts of raffinate treatment (average 600 lbs. N/acre) to soil would be difficult to discern due to levels of impurities (micronutrients) present in commercial lime, P_2O_5, and K_2O added to the test area soils during 1979. At the 600 lb. N/acre raffinate fertilizer rate, commercial additives applied to the treatment areas contributed: 87% B, 40% Cu, 25% Mo, 14% Ni, 98% U, 99.6% Ra-226, and 99.99% of the Th-230 added to soils during 1979. The recommended fertilizer rate (200 lbs. N/acre) for pasture improvement in eastern Oklahoma was applied to both cattle grazing areas. At this raffinate fertilizer application rate, commercial additives (lime, P_2O_5, K_2O) contributed: 95% B, 66% Cu, 49% Mo, 33% Ni, 99.3% U, 99.9% Ra-226, and 99.99% of the Th-230 added to cattle test area soils during 1979. It must be recognized that most of these trace impurities present in both commercial fertilizers and raffinates (i.e. B, Cu, Mo, Fe, and Zn ...) are essential for plant growth while status of others (i.e. Ra, Th, U) is less well defined. However, radionuclides added to soils from treated raffinates when compared to recommended rates of commercial lime, P_2O_5, and K_2O additions are insignificant.

Soil studies conducted during 1979 on the 160-acre area verified effectiveness of fertilizer management practices initiated in 1978. The harvesting of warm season bermudagrass and overseeding pasture with cool season species (i.e. rye and fescue) in the fall of 1978, resulted in significant depletion of residual, soil profile NO_3-N by April, 1979. This practice was continued on the 270-acre area with bermudagrass harvest and subsequent overseeding with rye and fescue grasses in fall, 1979.

Figure 2.
KERR MCGEE RAFFINATE PROJECT
SOIL MAP EXPANSION AREA
270-acre



(See Legend Next Page)

Figure 2 (cont'd)

SOIL MAP LEGEND

Map Symbol	Mapping Unit
HeD	Hector, Linker - Enders Complex, 5-12% Slopes
HeF	Hector, Linker - Enders Complex, 12-40% Slopes
LoD_3	Linker & Sigler Soils, 2-8% Slopes, Severely Eroded
PcC	Pickwick Loam, 3-5% Slopes
Ru	Rosebloom & Ennis Soils, Broken
SnB	Spiro Silt Loam, 1-3% Slopes
SnC	Spiro Silt Loam, 3-5% Slopes
SrB	Stigler Silt Loam, 1-3% Slopes
VaB	Vian Silt Loam, 1-3% Slopes
VaC	Vian Silt Loam, 3-5% Slopes

Drainage

Water Ponds

Unimproved Roads

Gravel Roads

Hard Top Roads

(1) Soil Profile Sample Areas

Permanent Vegetative Plots

(F) Fescue

(N) Native

(B) Bermudagrass

SOIL SERIES DESCRIPTIONS

HECTOR - LINKER - ENDERS COMPLEX 5 - 12% SLOPE (HeD)

HECTOR - LINKER - ENDERS COMPLEX 12 - 40% SLOPE (HeF)

The soils in this complex are stony and very shallow to deep. Any one of them may make up 15 to 40 percent of any given area. Rocks and stones cover 5 to 50 percent of the surface, and range from 3 inches in diameter to 2 feet in diameter.

The individual soil series making up this complex are as follows:

The Hector Series consists of very shallow to shallow, rapidly permeable, somewhat excessively drained soils on uplands. These soils occur on ridgetops and side slopes. They formed in material weathered from sandstone. Soils of the Hector Series typically have a surface layer of fine sandy loam that is grayish brown in the upper part and light yellowish brown in the lower part. Below this is a layer of fine sandy loam mixed with sandstone. Sandstone is at a depth of about 14 inches.

The Linker Series consists of moderately deep to deep, moderately permeable, well-drained soils on uplands. These soils occur on ridgetops and side slopes. They formed in material weathered from sandstone. Soils of the Linker Series typically have a surface layer of light yellowish-brown light loam. The upper part of the subsoil is reddish-yellow loam over light clay loam, and the lower part is mottled brownish-yellow, light-gray, and red light clay loam. Sandstone is at a depth of about 26 inches.

The Enders Series consist of deep, slowly permeable, moderately well drained, sloping to steep soils on uplands. These soils occur on side slopes. They developed in material weathered from shale. Soils of the Enders Series typically have a surface layer of fine sandy loam that is grayish brown in the upper part and very pale brown in the lower part. The subsoil is red clay that is mottled in the lower part. Shale is at a depth of about 40 inches.

Both of these mapping units would be difficult for raffinate application, because of excessive slopes, rocky surfaces and mostly shallow soils over fractured sandstone that could allow raffinate to seep into ground water. These areas would also prohibit application because of dense tree cover. Once removed, these areas would be difficult to reestablish to vegetation. Excessive runoff would also be a problem., and control would require special practices.

LINKER AND STIGLER SOILS 2 - 8% SEVERELY ERODED (LoD_3)

The soils in this undifferentiated group have a surface layer that is eroded and consequently is thinner than that in the profile described as typical of each series. The average composition is 45 percent Linker soils, 30 percent Stigler soils, 15 percent Pickwick soils, and 10 percent Vian.

In most places these soils are moderately to severely eroded. Rills have formed, and there are numerous gullies 2 to 5 feet deep and 4 to 20 feet wide. Sheet erosion between gullies ranges from slight to severe. In the less eroded spots, the surface layer ranges from silt loam to heavy, fine sandy loam. In other areas, the surface layer has been mixed with the upper part of the subsoil, and the texture ranges from loam to light clay loam.

The individual soil series making up this mapping unit are described in other parts of this description legend. This mapping unit is moderately suited for raffinate applications. The soil depth, textures and slopes are suitable for establishment and production of forage species as has been exemplified in the original 160 acres. Caution should be used in applying raffinate over and near the raw eroded areas due to excessive runoff and lack of vegetation to utilize the nutrients applied.

The Pickwick Series consists of deep, moderately permeable, well-drained soils on uplands. They formed in material weathered from sandstone. Soils of the Pickwick Series typically have a surface layer of loam that is light brownish-gray in the upper part, and very pale brown in the lower part. The subsoil is reddish-yellow, clay loam that is mottled in the lower part. Sandstone is at a depth of about 68 inches.

PICKWICK LOAM 2 - 5% SLOPES (PcC)

This soil is well drained. It has the profile described as typical of the Pickwick Series. Included in the areas mapped are small areas of Linker loam and small areas that are moderately eroded. This soil is also very common on the original 160 acres. It has been very satisfactory for raffinate application and has produced excellent bermudagrass and rye crops in previous years.

ROSEBLOOM AND ENNIS SOILS, BROKEN 0 - 15% SLOPES (Ru)

The soils in this undifferentiated group are deep and poorly drained to well drained. The average composition is 30 percent Rosebloom soils, 30 percent Ennis soils, and 40 percent included soils. Any given area may be dominantly Rosebloom soils or dominantly Ennis soils or both soils may occur with the other soils that were included in mapping. About 25 percent of most areas consists of a soil that is similar to the Ennis soils, but is somewhat poorly drained. Other inclusions consist of fine sandy loams, and soils that are similar to Ennis soils but have a darker surface layer. Rosebloom and Ennis soils, broken, commonly occurs as areas 200 to 400 feet wide. The areas are strongly dissected by stream channels and are frequently flooded. The more strongly sloping areas are along stream channels.

The Rosebloom Series consists of deep, very slowly permeable, poorly drained soils on bottom lands. These soils occur along most of the larger streams. They are frequently to occasionally flooded. Soils of the Rosebloom Series typically have a surface layer of light brownish-gray silt loam. Their subsoil consists of gray silty clay loam. Mottles occur throughout the profile.

The Ennis Series consists of deep, moderately permeable, well-drained soils on bottom lands. These soils occur along small drainageways. Soils of the Ennis Series typically have a surface layer of pale-brown silt loam and subsoil of light yellowish-brown heavy silt loam. They are mottled with gray at varying depths below a depth of 30 inches.

Areas of these soils should be avoided when raffinate applications are made; not because of the soil characteristics as much as their position in the landscape.

The Spiro series consists of moderately deep to deep, moderately permeable, well-drained soils on uplands. They formed in material weathered from sandstone, siltstone, and shale. Soils of the Spiro Series typically have a surface layer of grayish-brown silt loam and a transitional sub-surface layer of brown heavy silt loam. The subsoil is light yellowish-brown, silty clay loam. It is underlain by sandstone, at about 30 inches.

SPIRO SILT LOAM 1 - 3% and 5% SLOPES (SnB and SnC)

These soils are well drained. Included in mapping were small areas of Collinsville soils, which make up about 10 percent of the average---soils that are similar to Spiro Soils but are deeper and small areas of Vian silt loam. Both mapping units were similar, except that generally the SnC soil unit had lost more surface soil due to erosion and the depth to bedrock was generally less than the SnB unit.

These soils should be moderately suited for raffinate application. Some caution should be used to limit the application rate. The shallower soil depth could allow for more infiltration into the underlying bedrock. Crop response would not be as great as with having greater depth. Generally in these areas more drainage channels are present which could accelerate runoff and be a problem when excessive rains follow soon after raffinate application.

The Stigler Series consists of deep, very slowly permeable, somewhat poorly drained soils on uplands. These soils occur mainly as broad areas. They formed in clayey shale residuum, alluvium, and loess. Mounds 25 to 75 feet in diameter and 1 foot to 4 feet in height cover 5 to 25 percent of silt loam that is light, brownish gray. The subsurface layer is very pale brown, silt loam. The upper part of the subsoil is very pale brown, silty clay loam, and the lower part is brownish-yellow, silty clay loam or clay that is mottled with gray and red. Shale is at a dpeth of about 67 inches.

STIGLER SILT LOAM 1 - 3% SLOPES (SrB)

This soil is seasonally wet. Included in the areas mapped are small areas of Vian silt loam, 1 to 3 percent slopes, which make up about 12 percent of the acreage. Also included are small areas of mounded areas where the surface layer is more than 30 inches thick. This soil would be good for raffinate application. The seasonal wettness may narrow the choice of acceptable forage species for nutrient removal----i.e., fescue would be better than bermuda.

The Vian Series consists of deep, moderately, slowly permeable, moderately well drained soils on uplands. They formed in loamy alluvium or in loess. Mounds 25 to 75 feet in diameter and 1 to 4 feet in height cover 5 to 20 percent of the surface. Soils of the Vian Series typically have a surface layer of silt loam that is light brownish-gray in the upper part and light gray in the lower part. The uppermost part of the subsoil is very pale brown, heavy silt loam. Below this is brownish-yellow silty clay loam, and below this, coarsely mottled light gray, very pale brown, and yellow, silty clay loam.

VIAN SILT LOAM 1 - 3% SLOPES (VaB)

The areas mapped as this soil include small areas of Stigler silt loam, 1 to 3 percent slopes; Spiro silt loam, 2 to 5 percent slopes; and mounded areas where surface layer is more than 30 inches thick.

VIAN SILT LOAM 3 - 5% SLOPES (VaC)

The areas mapped as this soil include small areas of Spiro silt loam, 2 to 5 percent slopes; areas of Collinsville complex, 5 to 20 percent slopes; soils that are similar to Vian soils but are underlain by sandstone at a depth of about 40 inches; and mounded areas where the surface layer is more than 30 inches.

Both soil units are similar to the series description but vary due to changes in slope. This soil occurred extensively on the 160 acre area and is considered ideal for raffinate applications.

5. Water

a. Surface Water

Results of 1979 surface water monitoring conducted on the 270-acre treatment area and cattle stock ponds are provided in Table 13. A National Pollution Discharge Elimination System (NPDES) permit was issued by U.S. EPA, and was in effect for surface runoff discharges from the 160-acre test area (outfall 002). During 1979, total suspended solids (TSS) exceeded EPA discharge limits during March, May and June. With the exception of one pH value, other parameters monitored (Ra-226, nitrate, COD) did not exceed the permit discharge limits (Table 14). The level of total suspended solids witnessed is typical of agriculture runoff in this area of eastern Oklahoma. Sampling of the Illinois River above the outfall following a runoff event in June, 1979 indicated an in-stream value of 90 mg/ℓ TSS.

Kerr-McGee reported these excursions to both U.S. NRC and EPA and petitioned EPA for exemption to the TSS limit (20 mg/ℓ) in the permit. This petition resulted in change to the TSS discharge limit to 45 mg/ℓ (average). The construction of Sequoyah Facility Pond No. 3 within the 160-acre area also contributed to the TSS level in surface runoff. Re-establishment of vegetation cover should aid in reducing the TSS concentrations in future surface runoff from the area.

Table 13. Results of 1979 Surface Water Monitoring for the 270-acre Treatment Area and Cattle Stock Ponds.

Location	Date	pCi/ℓ Ra-226	Th-230	Parameter mg/ℓ Cu	Mo	Ni	U	NO_3-N	NH_4N	pH
270-acre:										
Pond 1	4/25/79	.238	.024	.005	.007	.006	.002	.5	<.2	9.0
Pond 2	4/25/79	.235	.035	.005	.004	.005	<.002	.8	<.2	8.8
Pond 3	4/25/79	.18	.016	.005	.002	.006	.002	.4	<.4	7.6
Retention Dam	4/25/79	.142	.026	.025	.003	.008	<.002	.4	<.2	7.6
Salt Branch	5/21/79	.11	.026	<.001	<.001	<.001	.003	.2	<.2	7.4
Retention Dam	6/06/79	.42	.017	.001	.011	.002	.002	1.7	.6	6.8
Retention Dam	9/25/79	.80	.015	<.001	.003	.003	.007	< .2	<.2	7.4
Pond 1	10/29/79	.18	.014	<.001	.005	<.001	.021	1.2	<.2	8.8
Pond 2	10/29/79	.181	.033	.034	.002	<.001	.005	6.1	<.2	8.5
Pond 3	10/29/79	.192	.009	.007	<.001	<.001	.003	< .2	.6	7.7
Cattle Stock Ponds:										
Control-(Vian)	5/15/79	.155	.033	<.001	<.001	.001	<.002	.2	<.2	7.4
Exp.-(160-acre)	5/15/79	.15	.029	.004	.004	.012	<.002	.4	<.2	7.4

Table 14. Sequoyah NPDES - Summary Sheet 1978 and 1979 (002 Outfall-160-acre Test Area)

	Permit Cond.	1978 Oct.	1978 Nov.	1978 Dec.	1979 Jan.	1979 Feb.	1979 Mar.	1979 Apr.	1979 May	1979 June	1979 July	1979 Aug.	1979 Sept.	1979 Oct.	1979 Nov.	1979 Dec.
Runoff (160-ac. plot)																
TSS, mg/ℓ																
Avg.	20.						91.		102	31.						
Max.	30.						133.		143	284.						
COD, mg/ℓ																
Avg.	500.						50.		42.	28.						
Max.	XXX						--		--	--						
Sol. Ra-226, pCi/ℓ	3.	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	<0.1	No Discharge	0.4	<0.1	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge	No Discharge
Avg.	10.						0.1		0.9	0.8						
Tot. Ra-226, pCi/ℓ																
Avg.	10.						0.6		0.6	0.3						
Max.	30.						0.8		1.0	2.0						
$NH_3(N)$, mg/ℓ																
Avg.	100.						0.2		0.5	0.3						
Max.	XXX						--		--	--						
$NO_3(N)$, mg/ℓ																
Avg.	10.						5.3		2.7	6.0						
Max.	XXX						--		--	--						
pH (min./max.)	6-9						6.9/7.2		6.5/7.3	6.4/9.2						
Avg. Flow, mgd	XXX						0.02		0.054	0.40						

Overall, 1979 surface water monitoring results confirmed the positive impacts of fertilizer management practices implemented during 1978. These practices included (1) proper timing of N applications (2) monitoring of residual soil NO_3-N levels and (3) plant and residue management. Combined, these practices resulted in reduced NO_3-N in the soil profile and thus reduced NO_3-N available for transport in surface runoff water from treatment areas. Surface water monitoring further demonstrated that application rates (average 600 lbs. N/acre) were compatible with 1979 growing season conditions.

b. Groundwater

Three additional groundwater monitoring wells were completed on the 270-acre area prior to 1979 raffinate treatments. In addition, six existing monitor wells (FTP 1A-6A) located on the 160-acre area were sampled monthly. A new well (FTP-7) was also completed on the 160-acre area in August, 1979 to monitor effects of treatment in timbered areas of Province 3. Results of the 1979 groundwater monitoring program are provided in Appendix A.

Two wells (FTP 2A and 3A) on the 160-acre area continued to exhibit high NO_3-N values even though no raffinate was applied in Province 4 (FTP 2A) and 5 (FTP 3A) during 1979. In 1977, these areas were treated with 1000 lbs. N/acre and 1500 lbs. N/acre of treated raffinate, respectively. Both monitor wells began to exhibit elevated NO_3-N in April, 1978. Although fluctuations below 10 mg/ℓ NO_3-N have occurred, levels during 1979 remained above 10 mg/ℓ NO_3-N.

During 1979, monthly water-level measurements were taken in all six FTP wells to determine mechanisms and extent of NO_3-N transport to groundwater in this area. Because no other wells appeared affected, horizontal NO_3-N movement and transport in groundwater flow is not expected. The localized effect appears attributable to soil profile N migration and vertical transport to groundwater in the area of FTP 2A and 3A. High NO_3-N levels have been persistent in both wells indicating a minimal groundwater flow in the area. Based upon analysis of soil profile NO_3-N values in these areas (see Table 12), NO_3-N continues to be depleted within the effective rooting zone of vegetation. The shallow water table (approximately 15 feet), minimal groundwater flow rates, and permeability of surficial material requires that future N application rates in these areas be properly managed to insure that plant uptake utilizes residual soil NO_3-N and it is unavailable for transport to groundwater.

In April, 1979, well 2A also exhibited increase in uranium levels. The exact cause of this increase is unknown, but based upon continued soil studies, soil profile migration of U would not appear to be the factor responsible for this increase.

Similar patterns of NO_3-N transport to groundwater have been reported with use of commercial nitrogen fertilizer.[5] Proper management and control of soil NO_3-N provides the key for control of nitrogen fertilizer impacts. Fertilizer management techniques currently in use on raffinate treatment areas have been developed to minimize fertilizer impacts on the hydrologic environment and results of 1979 surface and groundwater monitoring confirm the effectiveness of these various techniques.

B. Cattle Testing Program

In 1978, Kerr-McGee Nuclear presented results of the raffinate fertilizer test program to Oklahoma State Agriculture and U. S. Department of Agriculture officials. During 1979, a cattle testing program was developed by Kerr-McGee, Department of Agriculture officials and the Oklahoma State University Animal Disease Diagnostic Laboratory (Stillwater, Oklahoma) to evaluate effects of treated raffinate produced forage on grazing animals and the human food chain.

1. Purchase and Quarantine

Twenty (20) black-white faced, 8 month-old calves were purchased from Buford Quick of Stigler, Oklahoma on April 5, 1979. This group was selected with special attention to homogeneity. Ten (10) males and ten (10) females were purchased. The average weight at purchase was 337 pounds.

The stock was quarantined at the Quick ranch located southeast of Whitefield, Oklahoma for five weeks. At the start of this quarantine period, Dr. John Miller, DVM, Warner, Oklahoma, treated the cattle as follows:

- 5 Way Lepto - Vaccine
- Black Leg - Malignant Edema
- IBR and PI3 Intranasal
- 20 cc Terramycin
- Wormed with Thiobenzol
- Back treatment with Lysoff

Numbered, metal and plastic identification tags were placed on the cattle. Two steers were already present in the herd and eight of the males were castrated at this time to provide equal number of steers (10) and heifers (10). At the end of the quarantine period, (May 10, 1979), Dr. Miller obtained blood, hair, and fecal samples from all twenty animals, with blood samples delivered to OSU Disease Diagnostic Lab for analyses. Worm medication was administered and tick and fly ear tags were placed. Twelve experimental animals (6 male, 6 female) were hot-branded slant-A and the eight control animals (4 male, 4 female) were hot-branded straight-A to provide positive carcass identification. The stock was then weighed prior to truck shipment to the 160 acre Sequoyah test pasture and Vian control pasture. The average calf weighed 418 pounds on May 11, 1979.

2. Cattle Pastures

Prior to cattle introduction, two - 5 acre plots were fenced in Province 4a of the 160-acre test area. This area had received 1000 lbs. N/acre in 1977 and 500 lbs. N/acre in 1978 from treated raffinates insuring that all forage available to the twelve experimental animals was raffinate produced. A holding corral was placed between the two - 5 acre units and stock water was obtained from an existing farm pond available to both grazing units (See Figure 1 for Layout).

The control pasture selected was located near Vian, Oklahoma and owned by J. Cotner, Sr. Fencing was installed in May, 1979, to confine the eight control cattle to a 20-acre pasture section comprised of fescue, bermuda and native pasture grasses. An existing farm pond was available for stock watering.

3. Treatment

Based upon OSU soil tests, the experimental and control pastures were treated with 80 lbs. P/acre, 80 lbs. K/acre, and 2 T. ECCE lime/acre prior to the start of the cattle testing program. On May 9, 1979, the first scheduled 100 lbs. N/acre of treated raffinate was applied to the experimental pasture (N. 5 acre) and 100 lbs. N/acre from commercial N fertilizer (46-0-0) was applied to the Vian control pasture.

The two - 5 acre pasture units on the 160-acre area received the following raffinate treatments during the 1979 growing season:

	Plot	Date	Amount-lbs N/Acre
First Application	#2 Plot (N. 5 acre)	5/09/79	106
	#1 Plot (S. 5 acre)	6/13/79	93.5
Second Application	#2 Plot (N. 5 acre)	7/16/79	89.5
	#1 Plot (S. 5 acre)	8/21/79	110.5

Although some variation in raffinate N concentrations in Pond #3 occurred due to rainfall, an average of 200 lbs. N/acre was applied to experimental grazing units. The Vian control pasture also received 200 lbs. N/acre with the second application (100 lbs. N/acre) completed in July, 1979.

In May and June, 1979, cattle protein and mineral supplements were provided to both control and experimental animals. These supplements were kept to a minimum (3-4 lb/head/day protein) and subsequently, reduced to 1-2 lb/head/day for both groups. Protein supplement was provided to keep cattle in the habit of returning to the corral daily so inspection could be performed. The mineral supplement was given "free choice" at the beginning of the test program and was discontinued in June, 1979. The mineral supplement was felt unnecessary due to the overall quality of forage and was replaced by salt blocks (no mineral added) in both pastures. Chemical analyses of these cattle protein and mineral supplements are provided in Table 1.

Throughout the testing period, the main forage grass available to experimental cattle was raffinate treated bermudagrass while control cattle had a wider variety of native pasture species from which to select. Possible dietary differences are not believed to be significant because later in the growing season, bermudagrass tended to dominate the control pasture growth.

During the testing, both control and experimental pastures required cutting and baling to remove excess forage. The control pasture was cut three times during the summer. The five acre test pastures on the 160-acre area were cut and baled after moving the cattle off and before applying raffinate. Two cuttings were conducted on the experimental pasture areas during 1979.

4. Testing Results

Prior to shipment of cattle to the OSU Disease Diagnostic Laboratory for testing in November, 1979, Dr. Miller (DVM) recorded weights and obtained blood, hair and fecal samples from all twenty cattle involved in the 1979 test. Blood samples were forwarded to the Oklahoma State University (OSU) Disease Diagnositc Laboratory for analyses. A cattle weight summary is provided in Table 15 and indicates that the experimental group on raffinate treated pasture had a higher percent weight gain than control cattle. The average weight of all cattle in mid-November was 665 pounds for an average gain of 247 lbs./head during the six months of testing.

On November 6, 1979, four (4) experimental animals (2 steers; 2 heifers) were transported to the OSU Animal Disease Diagnostic Laboratory for testing. Following processing, required examinations, and selection of representative samples of tissue, blood and bone, remains of these experimental animals were incinerated by Diagnostic Lab personnel.

On November 14, 1979, four (4) control animals (2 steers; 2 heifers) were transported to the Oklahoma State University Meat Processing Laboratory. OSU Diagnostic Lab personnel supervised the taking of appropriate tissue, blood and bone samples and conducted required examinations. In addition, a USDA meat inspection was performed. The remains of these four control animals were processed and donated to a boy's home located in Gore Oklahoma.

Table 15. Cattle Weight Gain Summary - 1979.

Tags	Weight 11/5/79	Weight 5/10/79	Δ W	%Gain	Tested
Experimental					
Y 5 H*	635	375	260		11/6/79
Y 6 H	560	370	190		
Y 7 H	692	460	232		
Y 8 H*	635	395	240		11/6/79
Y 9 H	631	435	196		
Y 10 H	630	395	235		
Y 11 S	719	410	309		
Y 12 S	670	380	290		
Y 13 S	682	405	277		
Y 14 S*	725	460	265		11/6/79
Y 15 S*	630	455	175		11/6/79
Y 16 S	600	350	250		
Sub Total	7,809	4,890	2,919		
Average Experimental	650.8	407.5	243.3	59.7	
Control					
W 1 H*	691	445	246		11/14/79
W 2 H	770	440	330		
W 3 H*	694	430	264		11/14/79
W 4 H	633	420	213		
W 5 S	732	465	267		
W 6 S	693	405	288		
W 7 S*	659	450	209		11/14/79
W 8 S*	618	415	203		11/14/79
Sub Total	5,490	3,470	2,020		
Average Control	686.3	433.8	252.5	58.2	
Total Average (20)	665	418	247	59.1	

*Animal slaughtered for testing at OSU Disease Diagnostic Laboratory.
Y - Experimental
5 - Ear tag number
H - Heifer

The analyses of all twenty (20) cattle blood samples collected in May and November, 1979 are provided in Table 16. All analyses were within expected ranges for cattle blood and none of the blood levels were considered clinically significant (See Appendix B).

Liver, kidney and muscle tissues were examined for lead, copper, molybdenum, cadmium, nickel, zinc and arsenic by the OSU Diagnostic Laboratory. Results of these analyses and techniques employed are provided in Appendix B. Levels of lead, copper, molybdenum, cadmium, nickel, zinc and arsenic were within expected normal background levels for both experimental and control groups.

Necropsy and histopathologic examination for both control and experimental cattle are provided in Appendix C. Tissues examined were normal and were comparable to tissues from cattle slaughtered and used for human consumption.

Results of Ra-226, Th-230, and uranium analyses of cattle kidney, heart, brain, liver, skeletal muscle and bone are provided in Table 17. For the naturally occurring radionuclides examined, ingestion (food and water) and inhalation pathways are recognized as sources for man. Average intake for uranium, Thorium-230 and Radium-226 are on the order of .48, .1, and 1.4 pCi/day, respectively.[6] At a rate of .2 Kg/day meat consumption, an average of .2 pCi Ra-226/day from experimental and .4 pCi Ra-226/day from control cattle would be ingested.[7] Normal dietary intake from other foodstuffs (i.e. cereals, milk, vegetables, etc...) and drinking water could

Table 16. Results of Pre and Post-test Cattle Blood Analyses. (OSU Disease Diagnostic Laboratory)

	Parameter (ppm)											
	Pb(Blood)		Cu(Blood)		Mo(Blood)		Zn(Serum)		Ni(Blood)		U(Blood)	
	*	**	*	**	*	**	*	**	*	**	*	**
Control Cattle:												
W-1	.237	<.03	.210	.618	<.01[a]	.030	1.55	3.3	_b	.10[a]	.002	.0005
W-2	.264	<.03	.325	1.04		.054	1.75	1.9			.001	.001
W-3	.162	<.03	.365	1.14		.036	2.15	2.2			<.0005	.0005
W-4	.192	<.03	.270	.954		.048	1.95	1.7			<.0005	.002
W-5	.204	<.03	.290	.984		.054	1.80	2.7			.002	.001
W-6	.086	<.03	.345	1.314		.060	2.85	3.2			.012	.0006
W-7	.159	<.03	.460	.879		.060	1.65	2.4			.044	.05
W-8	.294	<.03	.155	1.00		.042	2.15	1.8			.002	.002
Average (8)	.200	<.03	.303	.991	<.01	.048	1.97	2.4			.008	.0072
Experimental Cattle:												
Y-5	.285	<.03	.435	.804		.030	2.30	1.9			.0008	.0009
Y-6	.264	<.03	.770	.708		.096	1.75	2.3			.002	.002
Y-7	.111	<.03	.465	1.122		.018	3.05	2.28			.004	.001
Y-8	.234	<.03	.620	.798		.036	1.85	2.20			.003	.0005
Y-9	.237	<.03	.730	1.074		.030	1.90	2.02			.001	.002
Y-10	.249	<.03	.920	1.272		.024	2.00	2.97			<.0005	.0008
Y-11	.228	.084	.420	1.212		.090	2.35	2.10			<.0005	<.0005
Y-12	.231	<.03	.760	1.230		.036	1.25	2.42			.005	.005
Y-13	.093	<.03	.160	.732		.012	2.00	2.61			.005	.002
Y-14	.273	<.03	.620	1.104		.018	1.75	2.25			.001	<.0005
Y-15	.240	<.03	.840	1.200		.006	2.05	2.39			.001	<.0005
Y-16	.210	<.03	.520	1.018		.018	1.40	2.17			.003	<.0005
Average (12)	.221	.03	.605	1.023	<.01	.035	1.97	2.30			.0022	.0013

*Pre-test - Samples collected 5/10/79
**Post-test - Samples collected 11/5/79

[a]All 20 samples were <.01 ppm Mo and .1 ppm Ni.

[b]Attempts to recover nickel from EDTA pre-test blood samples were unsuccessful.

Table 17. Results of Tissue and Bone Sample Analyses - Four Control (W) and Four Expermental (Y) Cattle, 1979.

Experi-mental	Kidney Ra-226 pCi/g	Kidney Th-230 pCi/g	Kidney U µg/g	Brain Ra-226 pCi/g	Brain Th-230 pCi/g	Brain U µg/g	Liver Ra-226 pCi/g	Liver Th-230 pCi/g	Liver U µg/g	Bone Ra-226 pCi/g	Bone Th-230 pCi/g	Bone U µg/g	Skeletal Muscle Ra-226 pCi/g	Skeletal Muscle Th-230 pCi/g	Skeletal Muscle U µg/g	Cardiac Ra-226 pCi/g	Cardiac Th-230 pCi/g	Cardiac U µg/g
Y-5	.003	.0004	.003	.006	.0009	<.001	.001	.0002	.002	.133	.0009	<.001	-0-	.0004	.002	.001	.0004	<.001
Y-8	.002	.0002	.013	.003	.0007	<.001	.001	.0004	<.001	.004	.0008	<.001	.001	.0002	<.001	.003	.0005	<.001
Y-14	.002	.0005	.017	.005	.0006	<.001	.001	.0002	<.001	.098	.0013	.023	.001	.0003	.001	.002	.0005	.003
Y-15	.003	.0005	.036	.002	.0005	.003	.004	.0004	.002	.015	.0014	.026	.001	.0003	.006	-0-	.0004	.003
Average (4)	.003	.0004	.017	.004	.0007	.002	.002	.0003	.002	.063	.0011	.013	.001	.0003	.003	.002	.0005	.002
Control																		
W-1	.002	.0002	<.001	.003	.0005	<.001	.002	.0004	<.001	.12	.0025	<.001	.001	.0007	<.001	.002	.0002	.001
W-3	.005	.0004	<.001	.003	.0009	<.001	-0-	.0002	.011	.12	.0016	<.001	.002	.0004	<.001	.003	.0002	.004
W-7	.012	.0002	.003	.003	.0004	<.001	.001	.0002	<.001	.07	.0004	.002	.002	.0004	<.001	-0-	.0001	.005
W-8	.002	.0002	.002	.003	.0004	<.001	.003	.0001	<.001	.07	.0007	<.001	.001	.0002	<.001	.003	.0003	<.001
Average (4)	.005	.0003	.002	.003	.0006	.001	.002	.0002	.004	.10	.0013	.001	.002	.0004	.001	.002	.0002	.003
Analytical Range(%)	±50-100	±25-50	±33-50	±100	±22-57	±50	±100	±25-100	±33-50	±25-100	±36-75	±33-50	±100	±29-67	±33-50	±100	±40-100	±33-50

be expected to contribute the remainder. For the limits of detection (.001 pCi Ra-226/g) and analytical ranges presented in Table 17, values for both control and experimental cattle tissues are within expected ranges and no marked differences appear between control and experimental cattle tissues examined.

C. Summary and Conclusions

Since 1972, Kerr-McGee Nuclear Corporation has conducted extensive studies of by-product, treated raffinate as an ammonium nitrate fertilizer. Results of eight years of study have established that:

1) By-product, treated raffinate can be consistently produced to contain less than 3 pCi/ℓ Ra-226, which is less than EPA drinking water standards for radium (5 pCi/ℓ).

2) Treated raffinate applications contain much less radioactivity than standard applications of other, commonly used commercial fertilizer products.

3) Even under saturation dosages (1000-1500 lbs. N/acre) and prolonged treatement, levels of heavy metals and radionuclides have remained within expected ranges in treatment area soils and vegetation.

4) Fertilizer management practices required for use of treated raffinate are the same as those required for use of commercial nitrogen fertilizer.

5) Impacts of treated raffinate produced forage on cattle and subsequently, the human food chain are the same as those impacts expected with use of commercial nitrogen fertilizer.

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APPENDIX A

GROUNDWATER MONITORING

Appendix A. Monitor Wells - 1979 - Sequoyah Environmental Surveillance

Location 160-acre	Analysis	Units	January	February 2/15/79	March 3/29/79	April 4/26/79	May 5/31/79	June 6/29/79	July 7/27/79	August 8/23/79	September 9/28/79	October 10/25/79	November 11/30/79	December 12/27/79
FTP - 1A	Uranium	µg/ℓ		150	65.	68.	43.	16.	5.	6.	4.	19	15	20
	NO_3 (N)	mg/ℓ		0.5	0.8	1.5	2.1	3.1	2.7	2.2	1.8	1.7	1.0	1.0
	NH_3 (N)	mg/ℓ	No	0.5	< 0.2	< 0.2	--	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	pH		Sample	6.8	7.2	7.6	--	--	9.1	9.8	6.6	7.5	7.7	7.4
	Cu	mg/ℓ	Taken	0.006	0.001	< 0.001	0.002	0.006	0.001	0.003	0.001	0.001	0.001	.004
	Mo	mg/ℓ		0.010	0.003	0.010	0.005	0.008	0.002	0.001	0.007	0.011	0.001	.002
	Ni	mg/ℓ		0.026	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002	0.007	0.001	< .001
	Tot. Ra-226	pCi/ℓ		0.67	0.42	0.39	0.13	0.012	0.27	0.41	0.19	0.14	0.11	.33
	Th-230	pCi/ℓ		0.026	0.006	0.031	0.019	0.018	0.034	0.028	0.025	0.024	0.018	< .003
	DTW	Ft.		--	19.2	18.8	16.2	12.8	14.0	14.6	15.6	17.1	17.7	15.7
FTP - 2A	Uranium	µg/ℓ	"	43.	29.	340.	782.	151.	53.	61.	172.	480	1040	3070
	NO_3 (N)	mg/ℓ		0.8	34.	79.	59.	55.	45.	29.	22.	18.	16.	20.5
	NH_3 (N)	mg/ℓ		< 0.2	< 0.2	1.4	1.2	1.0	0.8	0.4	0.2	< 0.2	< 0.2	< 0.2
	pH			7.7	9.7	11.1	--	--	10.3	10.7	7.1	9.3	7.6	7.3
	Cu	mg/ℓ		0.003	0.002	0.059	0.004	0.012	0.007	0.005	0.006	0.001	0.003	.006
	Mo	mg/ℓ		0.021	0.003	0.007	0.004	0.002	0.007	0.004	0.010	0.011	0.003	.009
	Ni	mg/ℓ		0.002	0.002	0.006	0.003	0.008	0.004	0.004	0.002	0.006	0.004	.008
	Tot. Ra-226	pCi/ℓ		0.30	0.23	0.36	0.11	0.061	0.53	0.75	0.09	0.17	0.19	.15
	Th-230	pCi/ℓ		0.009	< 0.003	0.013	0.027	0.016	0.009	0.012	0.013	0.009	0.019	.018
	DTW	Ft.		--	15.0	22.1	17.1	15.8	15.0	15.0	15.4	15.6	16.8	15.4
FTP - 3A	Uranium	µg/ℓ	"	18.	41.	7.	11.	16.	7.	4.	2.	8	2	17
	NO_3 (N)	mg/ℓ		84.	96.	35.	13.	31.	55.	119.	61.	46.	46	38
	NH_3 (N)	mg/ℓ		< 0.2	< 0.2	< 0.2	--	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	pH			6.6	7.2	8.2	--	--	7.2	7.2	9.4	7.0	6.9	6.9
	Cu	mg/ℓ		0.004	< 0.001	0.008	< 0.001	0.002	0.008	< 0.091	< 0.001	0.001	< 0.001	.001
	Mo	mg/ℓ		0.004	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	0.004	0.002	0.001	< .001
	Ni	mg/ℓ		0.003	< 0.001	< 0.001	0.002	0.006	< 0.001	< 0.001	0.002	0.001	0.003	.001
	Tot. Ra-226	pCi/ℓ		0.28	0.33	0.36	0.17	0.30	0.48	0.20	0.37	0.28	0.19	.41
	Th-230	pCi/ℓ		0.030	0.034	0.013	0.021	0.018	0.025	0.023	0.029	0.009	0.014	.023
	DTW	Ft.		--	14.8	12.4	12.1	17.6	13.1	13.9	14.6	14.8	14.8	14.2
FTP - 4A	Uranium	µg/ℓ	"	34.	10.	9.	13.	30.	5.	4.	5.	14	16	26
	NO_3 (N)	mg/ℓ		0.7	5.8	4.6	4.2	4.0	2.8	2.2	2.2	2.1	1.8	1.2
	NH_3 (N)	mg/ℓ		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.2	< 0.2	< 0.2	< 0.2	< 0.2
	pH			6.8	8.3	8.9	--	--	9.6	9.6	7.3	7.8	7.4	7.2
	Cu	mg/ℓ		< 0.001	0.006	0.013	< 0.001	0.002	< 0.001	0.001	< 0.001	0.001	< 0.001	.003
	Mo	mg/ℓ		0.006	0.001	0.005	0.002	0.001	0.003	0.002	0.009	0.002	0.005	.004
	Ni	mg/ℓ		0.001	0.011	0.002	< 0.001	0.002	< 0.001	0.003	0.002	0.001	0.002	< .001
	Tot. Ra-226	pCi/ℓ		0.16	0.24	0.43	0.13	0.085	0.37	0.18	0.13	0.18	0.10	.13
	Th-230	pCi/ℓ		0.025	0.024	0.015	0.029	0.021	0.006	0.021	0.038	0.026	0.011	.019
	DTW	Ft.		--	15.8	14.8	13.9	15.1	16.0	16.3	17.6	17.3	16.6	16.1

Appendix 1. (Cont'd)

Location 160-acre	Analysis	Units	January	February 2/15/79	March 3/29/79	April 4/26/79	May 5/31/79	June 6/29/79	July 7/27/79	August 8/23/79	September 9/28/79	October 10/25/79	November 11/30/79	December 12/27/79
FTP - 5	Uranium	µg/ℓ	*	29.	11.	< 7.	9.	9.	2.	3.	4.	7	3	10
	NO_3 (N)	mg/ℓ		0.2	0.4	0.1	0.1	0.1	0.1	0.3	0.3	0.2	0.1	0.2
	NH_3 (N)	mg/ℓ		< 0.2	< 0.2	< 0.2	--	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	pH			6.8	6.5	8.4	--	--	6.8	6.1	6.8	6.4	6.9	6.7
	Cu	mg/ℓ		0.001	< 0.001	0.002	< 0.001	0.005	0.001	0.001	0.001	0.001	0.001	< .001
	Mo	mg/ℓ		0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< .001
	Ni	mg/ℓ		0.002	< 0.001	0.001	< 0.001	0.025	< 0.001	0.001	0.003	< 0.001	0.002	.001
	Tot. Ra-226	pCi/ℓ		0.10	0.27	0.33	0.16	0.21	0.37	0.38	0.26	0.22	0.10	.165
	Th-230	pCi/ℓ		0.012	0.042	0.013	0.021	0.026	0.022	0.023	0.025	0.029	0.010	.013
	DTW	Ft.			19.4	19.9	18.8	19.2	19.6	19.9	20.1	20.2	20.2	20.4
FTP - 6	Uranium	µg/ℓ	*	68.	18.	10.	18.	9.	13.	< 2.	14.	24	10	14
	NO_3 (N)	mg/ℓ		0.2	0.4	0.5	0.8	1.2	1.0	0.8	0.8	0.6	0.2	0.3
	NH_3 (N)	mg/ℓ		< 0.2	< 0.2	< 0.2	--	< 0.2	< 0.2	< 0.2	0.4	< 0.2	< 0.2	< 0.2
	pH			7.4	7.7	8.2	--	--	7.5	7.3	7.3	7.6	7.9	7.8
	Cu	mg/ℓ		< 0.001	< 0.001	0.001	0.001	0.004	0.002	< 0.001	< 0.001	0.001	0.001	.001
	Mo	mg/ℓ		0.006	0.003	0.002	0.002	0.001	< 0.001	< 0.001	0.002	0.001	0.001	.001
	Ni	mg/ℓ		0.004	< 0.001	0.002	0.001	0.002	< 0.001	< 0.001	0.002	0.001	0.003	< .001
	Tot. Ra-226	pCi/ℓ		0.29	0.18	0.34	0.16	0.064	0.59	0.11	0.19	0.11	0.14	.21
	Th-230	pCi/ℓ		0.009	0.033	0.013	0.047	0.015	0.035	0.036	0.014	0.024	0.011	.013
	DTW	Ft.			10.1	10.6	9.9	11.2	11.8	12.3	12.8	12.2	11.2	11.2
FTP - 7	Uranium	µg/ℓ	*								18.	14	10	20
	NO_3 (N)	mg/ℓ									0.2	0.1	< 0.1	0.2
	NH_3 (N)	mg/ℓ								DRY	< 0.2	< 0.2	0.2	< 0.2
	pH										7.7	7.6	7.5	7.8
	Cu	mg/ℓ									< 0.001	< 0.001	0.001	.001
	Mo	mg/ℓ									0.010	0.001	0.001	.001
	Ni	mg/ℓ									0.003	0.002	0.003	< .001
	Tot. Ra-226	pCi/ℓ									0.18	0.08	0.12	.23
	Th-230	pCi/ℓ									0.024	0.041	0.065	.016
	DTW	Ft.									35.2	35.2	--	35.0
Total Rainfall for Month-		ins.	2.13	3.10	2.84	2.32	8.61	4.42	2.43	2.53	.61	3.37	3.11	1.0

Appendix A. (Concluded)

Location 270-acre	Analysis	Units	June, 1979 GW #1	June, 1979 GW #2	June, 1979 GW #3	July, 1979 GW #1	July, 1979 GW #2	July, 1979 GW #3	September, 1979 GW #1	September, 1979 GW #2	September, 1979 GW #3
	Uranium	µg/ℓ	18	4	5	15	17	20	17	1[illegible]	17
	NO_3 (N)	mg/ℓ	.16	15	.5	< .2	9.3	< .2	< .2	6.5	.2
	NH_3 (N)	mg/ℓ	.6	7.1	.9	1.4	< .2	.8	.8	.3	.9
	pH		8.2	7.3	9.3	8.3	7.2	9.5	8.6	7.8	9.[illegible]
	Cu	mg/ℓ	.006	.003	.00[illegible]	.001	.001	.001	< .001	< .001	< .001
	Mo	mg/ℓ	.007	.002	.004	.012	.007	.004	.012	.006	.009
	Ni	mg/ℓ	.001	<.001	.001	.003	< .001	.001	.002	< .001	.001
	Tot. Ra-226	pCi/ℓ	.221	.33	.30	.29	.21	.3[illegible]	.14	.22	.16
	Th-230	pCi/ℓ	.018	.041	.044	.037	.015	.020	.041	.039	.031

APPENDIX B

CATTLE BLOOD AND TISSUE SAMPLES

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

MEMORANDUM

January 16, 1980

To: Mr. Al Dooley

Subject: KERR-McGEE PROJECT - SUMMARY OF DATA

Analysis of liver, kidney and muscle tissues were performed on experimental and control animals under our Case Numbers 29962, 29963, 29964, 29965, 30265, 30267, 30268, 30269. None of the levels of lead, copper, molybdenum, cadmium, nickle, zinc, or arsenic, appear to be clinically significant or higher than we would probably consider normal background levels. Statistical analyses, while not performed, would likely indicate no statistical differences between the test and control animals.

The blood samples analyzed from the experimental and control animals under Case Numbers 24610 and 29971 also indicate that there would likely be no statistically significant differences between the experimental and control animals regarding blood lead, copper, molybdenum, zinc, and nickle levels. In my opinion, none of the blood levels encountered would be considered clinically significant.

William C. Edwards
William C. Edwards, DVM
Veterinary Toxicologist

Accession No: 79-11-0105

Case Nos. 29962 30266
29963 30267
29964 30268
29965 30269

Oklahoma State University

STILLWATER, OKLAHOMA 74074
(405) 624-6623

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

TOXICOLOGY REPORT

___ Preliminary x Final

Veterinarian N/A Owner Kerr-McGee

SPECIMEN		ANALYTICAL METHODS	CONDITION
__ Water	__ Stomach Contents	x Atomic Absorption	x Sample Satisfactory
x Liver	x Kidney	__ Gas Chromatography E.C.	__ Sample Unsatisfactory
__ Brain	__ Blood	__ Gas Chromatography Flame	
__ Serum	__ Fat	__ Gas Chromatography N-P	
__ Milk	__ Urine	__ Scanning uV	
__ Feces	__ CSF	__ HP Liquid Chromatography	__ Sample Referred
__ Feed	__ Other	__ Ion Specific Electrode	__ Sample Disposed of
X Muscle		__ TLC	x Sample Stored* (3 months)
		__ Bench Chemistry	
		__ Other	

*Samples will be stored 3 months & discarded unless otherwise instructed.

RESULTS AND COMMENTS

Case No.		Eartag
	29962	Y-15
	29963	Y-14
	29964	Y-8
	29965	Y-5
	30266	W-7
	30267	W-3
	30268	W-1
	30269	W-8

Results of Lead, Copper, Molybdenum, Cadmium nickle, Zinc and Arsenic on Liver, Kidney and Muscle are attached.

*Toxicology Charges only $3360.00 (All Charges on Case No. 29962)

Date Completed 12-10-79

* Please wait for statement before paying.

William C Edwards
Veterinary Toxicologist
William C. Edwards, DVM

Experimental:

Case No.	29962	Eartag No.	Y-15
	29963		Y-14
	29964		Y-8
	29965		Y-5

Controls:

Case No.	30266		W-7
	30267		W-3
	30268		W-1
	30269		W-8

Heavy and trace metal analyses were performed on Kidney, Liver and Muscle tissues on the above cases.

All values are in ppm on a wet weight basis. The analyses were performed with a Model 460 Perkin-Elmer Atomic Absorption Spectrophotometer.

1) Lead analyses -

Nitric acid digests of Muscle, Liver and Kidney were analyzed using graphite furnace with the following conditions:

Dry	110°C	25 sec
Char	525°C	50 sec
Atomize	2300°C	10 sec

Wave length 283.3 with background correction.

	Experimental	Controls
Average Kidney Lead	0.23 ppm	0.50
Average Liver Lead	0.065	0.58
Average Muscle Lead	$<$0.02	0.12

All values for experimental and control animals were less than 1.00 ppm. The averages are somewhat misleading in that several of the experimental and control tissues were less than 0.02 ppm (20 ppb). These values appear to be well within normal limits.

2) Zinc Analyses -

Zinc analyses were performed by atomic absorption spectrophotometry utilizing acetylene flame on nitric acid tissue digests. Wave length 213.9 with background correction.

	Experimental	Controls
Average Kidney Zinc	19.9	18.27
Average Liver Zinc	33.92	42.65
Average Muscle Zinc	36.10	45.72

These values appear to be well within normal limits.

3) Copper Analyses -

Copper analyses were performed by atomic absorption spectrophotometry utilizing acetylene flame on nitric acid digests. Wave length 324.7 with background correction.

	Experimental	Controls
Average Kidney Copper	9.52	5.16
Average Liver Copper	27.17	35.35
Average Muscle Copper	5.07	3.62

These values appear to be well within normal limits for the above tissues.

4) Cadmium Analyses -

Cadmium analyses were performed by atomic absorption spectrophotometry utilizing the graphite furnace with following conditions:

Wave length 228.8 with background correction.

Dry	110°C	20 sec
Char	200°C	15 sec
Atomize	2100°C	8 sec

	Experimental	Controls
Average Kidney Cadmium	1.25	0.875
Average Liver Cadmium	0.225	0.250
Average Muscle Cadmium	0.06	0.08

These values appear to be within normal limits.

5) Molybdenum Analyses -

Molybdenum Analyses were performed by atomic absorption spectrophotometry utilizing the graphite furnace and nitric acid tissue digests.

Wavelength 313.3 with background correction.

Dry	105°C	30 sec
Char	1800°C	30 sec
Atomize	2700°C	10 sec

	Experimental	Controls
Average Kidney Molybdenum	1.35	5.04
Average Liver Molybdenum	1.83	4.58
Average Muscle Molybdenum	0.90	3.89

These values appear to be within normal limits. We did encounter difficulties on the molybdenum analyses and suspect that the experimental values are lower than actual due to problems with background correction.

6) Arsenic Analyses -

Arsenic analyses were performed by atomic absorption spectrophotometry utilizing the graphite furnace.

The arsenic analyses were performed on nitric acid digests with nickel nitrate added as a stabilizer.

Wave length 193.7 with background correction.

Dry	$100^{o}C$	30 sec
Char	$1000^{o}C$	40 sec
Atomize	$2400^{o}C$	10 sec

	Experimental	Controls
Average Kidney Arsenic	<0.02	0.04
Average Liver Arsenic	<0.02	0.06
Average Muscle Arsenic	<0.02	0.10

These values are well within normal limits.

7) Nickel Analyses -

Nickel analyses were performed by atomic absorption spectrophotometry utilizing the graphite furnace.

Wave length 232.00 with background correction.

Dry	$110^{o}C$	20 sec
Char	$200^{o}C$	15 sec
Atomize	$2100^{o}C$	13 sec

	Experimental	Controls
Average Kidney Nickel	0.100	0.160
Average Liver Nickel	0.135	0.065
Average Muscle Nickel	0.160	0.15

These values appear to be within normal limits for nickel. We did encounter problems with nickel analyses most likely due to interferences from iron.

All values ppm wet weight

	Kidney Cd	Liver Cd	Muscle Cd	Kidney Cu	Liver Cu	Muscle Cu
29962 (Y-15)	1.40	0.30	0.10	5.10	25.30	5.30
29963 (Y-14)	1.70	0.20	<0.02	9.50	20.20	5.80
29964 (Y-8)	0.70	0.20	0.10	9.50	17.90	5.60
29965 (Y-5)	1.20	0.20	<0.02	6.80	20.00	3.60
Average	1.25	0.225	0.06	9.525	27.175	5.075

	Kidney Cd	Liver Cd	Muscle Cd	Kidney Cu	Liver Cu	Muscle Cu
30266 (W-7)	0.70	0.30	0.10	9.50	16.00	2.20
30267 (W-3)	1.10	0.20	0.10	6.45	33.00	5.80
30268 (W-1)	0.80	0.40	0.10	4.33	39.60	2.90
30269 (W-8)	0.90	0.10	<0.02	5.17	52.80	3.6
Average	0.975	0.25	0.08	5.1625	35.35	3.625

	Liver Ni	Kidney Ni	Muscle Ni	Liver Mo	Kidney Mo	Muscle Mo
29962 (Y-15)	0.15	0.12	0.09	1.94	1.09	0.98
29963 (Y-14)	0.09	0.042	0.27	1.05	0.94	0.01
29964 (Y-8)	0.09	0.16	0.19	2.25	1.84	1.32
29965 (Y-5)	0.084	0.08	0.09	2.07	1.55	1.31
Average	0.1035	0.1005	0.16	1.8275	1.355	0.905
30266 (W-7)	< 0.02	< 0.02	0.06	4.79	4.99	3.32
30267 (W-3)	< 0.02	< 0.02	< 0.02	5.14	3.51	4.81
30268 (W-1)	< 0.02	0.5 ppm	< 0.02	3.92	3.79	3.79
30269 (W-8)	0.2 ppm	0.1 ppm	.5 ppm	4.46	7.87	3.65
Average	.065	0.16	0.15	4.5775	5.04	3.8925

All values ppm wet weight

	Kidney Zn	Liver Zn	Muscle Zn	Kidney Lead	Liver Lead	Muscle Lead
29962 (Y-15)	17.3	37.6	14.3	<0.02	<0.02	<0.02
29963 (Y-14)	23.9	41.4	41.9	0.10	<0.02	<0.02
29964 (Y-8)	21.3	30.6	46.0	0.20	<0.02	<0.02
29965 (Y-5)	17.1	26.1	42.2	0.60	0.20	<0.02
Average	19.9	33.925	36.1	0.23	0.065	<0.02
30266 (W-7)	15.5	29.0	45.8	0.90	0.60	<0.02
30267 (W-3)	19.0	35.1	48.9	0.30	0.80	0.20
30268 (W-1)	19.4	57.4	44.2	0.40	<0.02	<0.02
30269 (W-8)	19.2	49.1	44.0	0.40	0.90	0.20
Average	18.275	42.65	45.725	0.5	0.58	0.12

	Liver As	Kidney As	Muscle As
29962 (Y-15)	<0.02	<0.02	<0.02
29963 (Y-14)	<0.02	<0.02	<0.02
29964 (Y-8)	<0.02	<0.02	<0.02
29965 (Y-5)	<0.02	<0.02	<0.02
Average	<0.02	<0.02	<0.02
30266 (W-7)	0.1	.02	0.1
30267 (W-3)	<0.02	<0.02	0.1
30268 (W-1)	0.1	<0.02	0.1
30269 (W-8)	<0.02	0.1	0.1
Average	0.06	0.04	0.1

APPENDIX C

CATTLE NECROPSY AND

HISTOPATHOLOGIC EXAMINATIONS

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

MEMORANDUM

January 16, 1980

To: Mr. Al Dooley

Subject: KERR McGEE PROJECT - SUMMARY OF DATA

Based on necropsy and histopathologic examinations, it is our opinion that the various organs and tissues of the cattle entered under our Diagnostic Laboratory Numbers 29962, 29963, 29964, 29965, 30266, 30267, 30268, and 30269, did not have any clinically significant pathologic changes. Furthermore, there were no departures from normal that were greater than those commonly observed in tissues from cattle slaughtered and used for human consumption.

E. L. Stair, Jr., DVM, PhD
Veterinary Pathologist

D. L. Whitenack, DVM, PhD
Veterinary Pathologist

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 16, 1979

Kerr McGee Center
Mr. Al Dooley
Oklahoma City, SOklahoma 73125

Case No. 29962
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: One lymphoid nodule is present in the lamina propria of the reticulum.

There are no visible lesions in the esophagus, rumen and spiral colon. One crypt abscess is present in the section of the ileum. Numerous Besnoitia are present in the mucosa.

One nematode larva is embedded in the abomasal mucosa.

Numerous parabronchial lymphoid follicles are present in the lung; some of these are between the epithelium and the muscularis mucosa; others are outside the muscularis mucosa. The great majority of these are found in association with terminal bronchi and bronchioles.

There are no visible lesions in the sections of bone and the bone marrow.

The prescapular and mesenteric lymph nodes did not have any visible lesions.

There are no visible lesions in the spleen.

A few sarcocysts were present within the fibers of the diaphragmatic muscle.

There are no visible lesions in the liver and kidney.

Five sarcocysts were present in the section of cardiac muscle. There are no visible lesions in the Gasserian ganglion and its peripheral nerve rootlets.

COMMENTS: All of the lesions are considered to be incidental findings and are not the result of the treatment that this animal received as an experimental subject.

HISTOPATHOLOGIC DIAGNOSIS: Normal tissues.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/iw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 30, 1979

Kerr McGee Center
Mr. Al Dooley
123 Robert S. Kerr Ave.
Oklahoma City, Oklahoma 73125

Case No. 29964
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: This case was an experimental heifer from the Kerr-McGee project. Her eartag number was 8.

Esophagus - No visible lesions.

Reticulum - There were moderate numbers of widely scattered foci of necrosis and a neutrophilic cell response in the surface epithelium. These foci did not extend the full width of the epithelium.

Rumen - There were similar lesions as those in the reticulum in the mucosa of the rumen. These consisted of widely scattered foci of necrosis and neutrophilic cell infiltrate.

Abomasum - There were moderate numbers of eosinophils and fewer numbers of plasma cells located primarily at the base of the mucosa adjacent to the muscularis mucosa.

Lymph nodes - There were eosinophils in the medulla and a small amount of hemosiderin.

Skeletal muscles - There were a few numbers of sarcocysts in myofibers.

Cardiac muscle - Only a few sarcocysts in muscle fibers.

Bone marrow - No visible lesions.

Liver - There were a few foci of mononuclear cell infiltrate in the parenchyma of the liver lobules.

Spleen - No visible lesions.

Kidney - No visible lesions.

Lung - There were a few medium sized vessels that had hypertrophy of the media. There were focal accumulations of lymphoid cells at the periphery of bronchioles.

Peripheral nerve - No visible lesions.

Ganglion - No visible lesions.

Bone - No visible lesions.

Uterus - No visible lesions.

CONCLUSIONS: There was no indication of a disease process in the tissues examined.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 30, 1979

Kerr McGee Center
Mr. Al Dooley
123 Robert S. Kerr Ave.
Oklahoma City, Oklahoma 73125

Case No. 29963 (Y-14)
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: This was an experimental steer from the Kerr-McGee project. This steer did not have an ear tag number, but did have a white ear tag in the left ear.

Esophagus - There were a few sarcocysts in muscle fibers. There were no visible lesions in the mucosa.

Reticulum - There were scattered small foci of necrosis and a neutrophilic cell infiltrate in the epithelial layer of the mucosa. These were confined to the surface and did not extend through the mucosal layers.

Rumen - There were similar lesions in the epithelial layer of the rumen as were in the reticulum. There also were small foci of necrosis and neutrophilic cell response and these were confined to the epithelial surface.

Abomasum - There were moderate numbers of lymphoid nodules in the deeper and middle layers of the mucosa. The nodules in the deep layer extended to the muscularis mucosae. There was a thin zone of eosinophils at the periphery of the lymphoid nodules.

Ileum - There were numerous eosinophils in the mucosa. The crypt epithelium of the ileum extended into Peyer's patches and were dilated containing necrotic cellular remnants.

Spiral colon - There were a few clumps of coccidial forms in the epithelial cells of the mucosa. There were a few lymphoid nodules in the mucosa. There were moderate numbers of eosinophils and fewer lymphodycte diffusely scattered in the lamina propria.

Lymph nodes - No visible lesions.

Ganglion - No visible lesions.

Peripheral nerve - No visible lesions.

Spleen - No visible lesions.

Skeletal muscle - There were moderate numbers of sarcocysts in muscle fibers and there were no cellular reactions associated with these parasites.

Cardiac muscle - There were a few sarcocysts in muscle fibers.

Liver - No visible lesions.

Lung - There were focal lymphoid cell accumulations at the periphery of bronchioles. There was hemorrhage in airways which was considered to be terminal and resulted from aspiration of blood.

Kidney - No visible lesions.

Bone marrow - No visible lesions.

Brain - Extensive hemorrhage in meninges resulting from stunning with a captive bolt. There were no visible lesions in parenchymal tissue.

Bone - No visible lesions.

CONCLUSIONS: All the changes observed were considered to be incidental findings and not specific for a disease process.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

December 14, 1979

Kerr-McGee Center
Mr. Al Dooley
Oklahoma City, Oklahoma 73185

Case No. 29965
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: One Besnoitia cyst is present in the mucosa of the spiral colon; otherwise, this tissue has no visible lesions.

There are no visible lesions in the ileum, rumen, uterus, trigeminal nerve, Gasserian ganglion, a section of bone taken from the costochondral junction, prescapular and mesenteric lymph nodes, ovary, kidney, spleen, liver, heart, and esophagus. There is a single cross section of a hypoderma larva in the esophagus. This is present within the esophageal submucosa and there is no reaction to this organism.

Three lymphoid nodules are present in the lamina propria of the reticulum.

One oblique section of a nematode larva is present in the gastric pits and one bascess is present in the lumen of a gastric gland.

Alternating areas of atelectasis and emphysema are present in the lung; this is a terminal change due to either extremely deep or variable respiration at the time of death and the addition of a compression artefact required for cutting out the blook of tissue and fixation.

Three sarcocysts are present in the sections of diaphragmatic muscle.

Subpial hemorrhage is present along the ventral aspect of the brain stem as a result of the blow of the stunning gun used for euthanasia.

Case No. 29965

COMMENTS: The histologic appearance of the tissues is within normal limits for an animal of this age and condition. The tissues do not reflect any changes that could be construed as resulting from experimental manipulation.

HISTOPATHOLOGIC DIAGNOSIS: Normal tissues.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/sm

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

December 21, 1979

Kerr-McGee
Mr. Al Dooley
Kerr-McGee Center
Oklahoma City, Oklahoma 73125

Case No. 30266
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: There is one cross section of a hypoderma larva in the esophageal submucosa, and this is accompanied by a moderate perivascular infiltration around the capillaries, arterioles and venules within the immediate vicinity of the larva. Infiltrative cells are lymphocytes, plasma cells and eosinophils.

Eleven minute foci of epithelial necrosis which involves the stratum corneum and stratum spinosum is present in the epithelium of the reticulum. These foci also have an associated and/or infiltrative neutrophilic response. Twenty-six similar foci are seen within the epithelium of the rumen.

Two lymphoid nodules are present in the abomasal submucosa and there is a mild eosinophilic infiltrate within the abomasal lamina propria.

Three Besnotia cysts are present in the ileal mucosa.

Three lymphoid nodules are present in the submucosa of the spiral colon.

There are no visible lesions in the heart, mesenteric lymph node, bone marrow, bone, spleen and prescapsular lymph node.

Eight lymphoid nodules are present in areas adjacent to the air passages and vessels of the pulmonary lobules.

Six lymphoid aggregates are present adjacent to the arcuate vessels of the kidney; tubules at the midpoint of the renal medulla contain mineralized casts. The diaphragmatic skeletal musculature contains some swollen eosinophilic fibers in which longitudinal and cross striations are still evident (these are considered to be contraction artefacts).

Subdural, subpial and perivascular hemorrhages into the neuropil of the brain are obvious. The hemorrhages occur along the ventral aspect of the brain and spinal cord and the hemorrhages into the neuropil are within the thalamus.

These hemorrhages undoubtedly occurred as a result of the stunning gun that was used to kill this calf.

There are no visible lesions in the trigeminal nerve. Hemorrhage is present in the Gasserian ganglion.

HISTOPATHOLOGIC DIAGNOSIS: The appearances of the tissues are within normal limits and do not represent significant departures from tissues which would be obtained from abbatoirs and used for human consumption.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

December 19, 1979

Mr. Al Dooley
Kerr McGee Center
Oklahoma City, Oklahoma 73125

Case No. 30267
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: Fourteen sarcocysts are present in the skeletal musculature of the esophagus; one focus of lymphocytes and reticuloendothelial cells is present in the submucosa.

There are no visible lesions in the reticulum, uterus, ovary, Gasserian ganglion, Trigeminal nerve, spleen and bone marrow.

One focus of lymphocytes and reticuloendothelial cells is present between planes of smooth muscle bundles of the ruminal wall. Seven foci of neutrophilic infiltration are present within the stratum corneum of the ruminal papillae.

The abomasal mucosa contains two cross sections of nematode larvae and seven lymphoid nodules are present in the lamina propria and submucosa.

There are no visible lesions in the ileum; there is some postmortem sloughing of the epithelium over the tips of the villi (this is a common finding where tissues from the gastrointestinal tract are not taken immediately after death).

Two lymphoid nodules are present in the lamina propria of the spiral colon.

Five lymphoid nodules are adjacent to the small bronchi and bronchioles of the lung; some artifactual atelectasis (compression) is evident in the lung.

On the cross section, numerous rounded deeply eosinophilic skeletal muscle fibers are present in the diaphragm; twenty-eight sarcocysts are present in this tissue.

Three small foci of lymphocytes, reticuloendothelial cells, and polymorphonuclear cells are present in the section of liver.

Numerous polymorphonuclear cells (eosinophils) are present in the pericapsular connective tissue surrounding the mesenteric lymph node; there are no visible lesions within the lymphoid tissues of the node.

Multiple randomly distributed lymphoid foci are present in the renal cortex and this change is especially prominent adjacent to the arcuate vessels (this finding is so common as to be considered virtually normal in the bovine).

Subpial hemorrhages are present in the sections of brain and cervical spinal cord; this type of change is to be expected where an animal is euthanitized with a stunning gun.

HISTOPATHOLOGIC DIAGNOSIS: The appearances of the tissues are within normal limits and approximate those of cattle used for human consumption.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

December 13, 1979

Mr. Al Dooley
Kerr-McGee Center
Oklahoma City, Oklahoma 73125

Case No. 30268
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: Ear Tag #W-1. This was a control animal.

Esophagus - In the submucosa there were foci and perivascular cuffings of lymphocytes and eosinophils. This reaction was considered to be induced by migrating Hypoderma larvae.

Reticulum - There was small pyogenic foci in the squamous epithelium. These were scattered throughout the section of reticulum and were similar to those in the experimental animals.

Rumen - There were similar small pyogenic foci in the squamous epithelium as observed in the reticulum of this calf and in the experimental calves.

Abomasum - There were focal lymphoid nodules at the base of the mucosa and these were lying against the muscularis mucosae. There were a few eosinophils and lymphocytes diffusely scattered in the submucosa.

Ileum - There were moderate numbers of eosinophils diffusely scattered in the lamina propria.

Spiral Colon - A few eosinophils in the lamina propria and a few focal lymphoid nodules at the base of the mucosa.

Uterus - No significant lesions.

Liver - No significant lesions.

Cardiac Muscle - There were a few sarcocysts in myofibers. One sarcocyst was found in a Purkinji fiber.

Case No. 30268
Ear Tag #W-1

Ovary - There was a corpus luteum in the ovary and several fibrosed Corpora. There were normal follicles in different stages of development.

Lymph Nodes - No significant lesions.

Lung - There were focal lymphoid nodules at the periphery of some bronchioles.

Skeletal Muscle - There were swollen, intensely eosinophilic muscle fibers dispersed between less eosinophilic fibers. There were considered to be red and white fibers which is normal.

Spleen - No significant lesions.

Kidney - A few foci of lymphoid cell accumulations at the corticomedullary junction.

Bone Marrow - Normal.

Brain - Meningeal hemorrhage resulting from stunning of the heifer.

Ganglion - No visible lesions.

Peripheral Nerve - No visible lesions.

Bone - No visible lesions.

HISTOPATHOLOGIC DIAGNOSIS: This was a control animal on the Kerr-McGee study.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/sm

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

December 13, 1979

Mr. Al Dooley
Kerr-McGee Center
Oklahoma City, Oklahoma 73125

Case No. 30269
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

HISTOPATHOLOGIC EXAMINATION: This was a control animal from the Kerr-McGee study. Ear Tag #W-8.

Esophagus - There were numerous foci of eosinophils and lymphocytes around blood vessels widely scattered in the submucosa. The submucosa was edematous. This lesions was considered to be the result of Hypoderma larvae migration. The mucosa was normal. There were a few sarcocysts in muscle fibers.

Reticulum - There were only a few foci of neutrophil accumulations in the epidermis. These lesions were observed in control and experimental animals.

Rumen - Similar pyogenic foci were in the epidermis. Control and experimental animals had these lesions in the epidermis of the rumen.

Abomasum - There were a few focal lymphoid nodules at the base of the mucosa. These were laying against the muscularis mucosae. There were slight numbers of eosinophils diffusely scattered throughout the mucosa.

Ileum - There were moderate numbers of eosinophil-type cells in the lamina propria. There also were lymphocytes and a few plasma cells in the lamina propria.

Spiral Colon - There were a few lymphoid nodules in the mucosa. There were moderate numbers of eosinophils and lymphocytes in the lamina propria.

Cardiac Muscle - There were a few sarcocysts in myofibers.

Case No. 30269
Ear Tag #W-8

Lung - A fe·· bronchioles had focal accumulations of lymphocytes at the periphery of the bronchiole. The lung tissue was collapsed.

Kidney - A few foci of lymphoid cells at the corticomedullary junction.

Lymph Nodes - No significant lesions.

Skeletal Muscle - Few sarcocysts in muscle fibers.

Bone Marrow - Normal.

Brain - Marked meningeal hemorrhage resulting from stunning. No other visible lesions.

Ganglion - No visible lesions.

Nerve - No visible lesions.

Bone - No visible lesions.

HISTOPATHOLOGIC DIAGNOSIS: Control animal in the Kerr-McGee study.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/sm

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 6, 1979

Mr. Al Dooley
Kerr McGee Center
123 Robert S. Kerr Ave.
Oklahoma City, Oklahoma 73125

Case No. 29962
Owner: Kerr McGee
PRELIMINARY REPORT

Dear Mr. Dooley:

NECROPSY EXAMINATION: This was one of the Kerr-McGee experimental steers, eartag no. 15 submitted for necropsy. After stunning with a captive bolt pistol and bleeding out, the steer weighed 569 pounds.

On necropsy there was adequate fat in all the body stores.

There were no visible lesions in any of the thoracic organs. The lungs were collapsed and all lobes were light pink.

The heart was normal.

The reticulum, omasum and rumen contained roughage. There were several hemorrhage ulcers in the mucosa of the abomasum. These were primarily in the fundus.

The small intestine, cecum and large intestine contained normal appearing ingesta.

There were no visible lesions in the liver, kidneys or spleen.

TENTATIVE DIAGNOSIS: Ulcerative abomasitis and all over organs in normal limits. Kerr-McGee project. Animal was killed and tissues collected per protocol.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/jc

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 26, 1979

Note: Y-14 Experimental
Case No. 29963
Owner: Same
PRELIMINARY REPORT

Mr. Al Dooley
Kerr McGee Center
123 Robert S. Kerr Ave.
Oklahoma City, Oklahoma 73125

Dear Mr. Dooley:

NECROPSY EXAMINATION: This was the steer that lost its ear tag enroute to the laboratory. Also, inadvertently a necropsy report was not written out. According to Dr. Wilson's memory, there were linear ulcerations of the abomasal mucosa; these were approximately 6 cm long by 3-4 mm wide.

The steer was in good physical condition. The appearances of the organs and tissues were within normal limits.

TENTATIVE GROSS POSTMORTEM DIAGNOSIS: Normal tissues.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 6, 1979

Mr. Al Dooley
Kerr McGee Center
Oklahoma City, Oklahoma 73125

Case No. 29964
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

NECROPSY EXAMINATION: This was a heifer from the 4 Kerr-McGee experimental cattle delivered to the laboratory on November 5, 1979. Her eartag number was 8. After bleeding out, she weighed 590 pounds by our scale.

The heifer was alert and had no clinical signs.

Upon opening the carcass, there was adequate fat in all body stores. The lungs were normal as was the heart.

There were no visible lesions in the liver, kidneys or spleen.

The rumen, reticulum, omasum and abomasum contained feed. There were moderate numbers of small punctate raised nodules in the abomasal mucosa indicative of *Ostertagia sp.* infection. There were a few 4 mm in diameter raised nodules on the mucosa of the small intestine indicative of *Esophagostonum sp.*

The content of the small intestine, cecum and large intestine was normal.

TENTATIVE DIAGNOSIS: Kerr-McGee experimental animal killed and tissues collected per protocol.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 8, 1979

Kerr McGee Center
Mr. Al Dooley
Oklahoma City, Oklahoma 73185

Case No. 29965
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

NECROPSY EXAMINATION: This horned Angus-Hereford cross (heifer ear tag #5) weighed 544 pounds and was in good physical condition on receipt. The appearance of all the tissues and organ systems were within normal limits.

TENTATIVE GROSS POSTMORTEM DIAGNOSIS: The appearance of all the tissues and organ systems was within normal limits.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 19, 1979

Kerr McGee Center
Mr. Al Dooley
Oklahoma City, Oklahoma 73125

Case No. 30266
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

NECROPSY EXAMINATION: This was one of the control animals on the Kerr-McGee project. The animal was killed at the OSU Meats Lab and the needed tissues were collected. Ear tag number was W-7.

There were moderate numbers of small raised nodules in the mucosa of the abomasum. These were nodules of Ostertagia sp. The content of the gastrointestinal tract was normal.

There were no visible lesions in the tissues collected for analysis.

TENTATIVE DIAGNOSIS: Control animal on Kerr-McGee project. Slaughtered at the OSU Meats Lab. All tissues within normal limits on postmortem examination.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 19, 1979

Mr. Al Dooley
Kerr-McGee Center
Oklahoma City, Oklahoma 73125

Case No. 30267
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

NECROPSY EXAMINATION: The carcass was in good flesh. A few Ostertagia nodules were present in the abomasal mucosa. The remainder of the organs and tissues were grossly normal.

This animal had white ear tag #3.

TENTATIVE DIAGNOSIS: Control animal; killed for collection of samples.

Sincerely,

D. L. Whitenack

D. L. Whitenack, DVM, PhD
Pathologist

DLW/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 16, 1979

Mr. Al Dooley
Kerr McGee Center
Oklahoma City, Oklahoma 73125

Case No. 30268
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

NECROPSY EXAMINATION: Ear tag #W-1. The carcass was in good flesh.

Four hypoderma larvae were found in the esophageal submucosa. A moderate infestation of ostertagia larvae was found in the abomasal mucosa.

The appearance of the remaining organs and tissues was within normal limits.

TENTATIVE DIAGNOSIS: Control animal. Killed for collection of tissue samples.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/jw

Oklahoma State University

OKLAHOMA ANIMAL DISEASE DIAGNOSTIC LABORATORY

STILLWATER, OKLAHOMA 74074
(405) 624-6623

November 16, 1979

Mr. Al Dooley
Kerr McGee Center
Oklahoma City, Oklahoma 73125

Case No. 30269
Owner: Same
PRELIMINARY REPORT

Dear Mr. Dooley:

NECROPSY EXAMINATION: Steer with eartag # white 8. The carcass was in good flesh. A small 8 cm. diameter bruise was present over the right tuber ischii.

A yellow gelatinous infiltrate was prsent in the loose areolar connective tissue around and throughout the length of the esophagus. A large number (40 or more) Hypoderma larvae were present in the esophageal mucosa.

The appearance of the remaining tissues and organs was within normal limits.

TENTATIVE DIAGNOSIS: Control animal; killed for collection of tissues.

Sincerely,

E. L. Stair, Jr., DVM, PhD
Chief Pathologist

ELS/jw

FROM	DATE OF DOCUMENT	DATE RECEIVED	NO
Kerr-McGee Nuclear Corp.	4/15/80	4/21/80	16082
	LTR x / MEMO / REPORT / OTHER		
TO	ORIG 1	CC 7	OTHER
Crow	ACTION NECESSARY ☐ / NO ACTION NECESSARY ☐	CONCURRENCE ☐ / COMMENT ☐	DATE ANSWERED / BY:
CLASSIF un / POST OFFICE / REG. NO	FILE CODE 40-8027		

DESCRIPTION (Must Be Unclassified)	REFERRED TO	DATE	RECEIVED BY	DATE
copies of the completion of report for the 1979 raffinate fertilizer program .	Reg File cy	4/23		
	FCUF (4)			
ENCLOSURES	I&E (2)			
	PDR			
	LPDR			
REMARKS				
			16082 DLC	

U. S. NUCLEAR REGULATORY COMMISSION

MAIL CONTROL FORM

FORM NRC-326 (1-75)

KERR-McGEE NUCLEAR CORPORATION
KERR-McGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

May 22, 1980

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. W. T. Crow, Section Leader
Uranium Process Licensing Section
Uranium Fuel Licensing Branch
Division of Fuel Cycle and Material Safety
United States Nuclear Regulatory Commission
Washington, DC 20555

Re: Docket #40-8027

Dear Mr. Crow:

Kerr-McGee Nuclear Corporation requests that operating license SUB-1010, DOCKET 40-8027, be amended to permit disposal of raffinate sludge in a below grade pit to be constructed on Kerr-McGee property approximately one mile southeast of the existing facility. An Environmental Report on the proposed activity is attached for your review.

Condition #13 of the license SUB-1010 requires that all radioactive sludges in the existing surface ponds be removed and disposed of in a manner requiring approval of the Commission. Several alternative plans have been studied with the selected plan representing minimum environmental impact and maximum safety. The filing fee of $3,500 is also attached.

Your early attention to this request will be greatly appreciated; and if additional information is required, please let me know.

Sincerely,

W. J. Shelley

W. J. Shelley, Director
Regulation and Control

WJS/hmw

Attachments

~~8006101611~~

1642

KERR-McGEE NUCLEAR CORPORATION
ENVIRONMENTAL REPORT
FOR
SEQUOYAH FACILITY RAFFINATE SLUDGE DISPOSAL

1.0 PROPOSED ACTIVITY

1.1 Purpose

Condition #13 of Source Material License SUB-1010, dated October 7, 1977, requires that all radioactive sludges in the existing surface ponds be removed and disposed of in a manner requiring approval of the Commission. In response to this requirement, Kerr-McGee Nuclear Corporation requests an amendment to SUB-1010 permitting raffinate sludge disposal in a below-grade pit to be constructed on Kerr-McGee property approximately one mile southeast of the existing facility.

1.2 The Process

The development of an acceptable process for disposal of solvent extraction raffinate is described in Sequoyah FES (NUREG-75/007). The process of choice consists of neutralization of the raffinate with anhydrous ammonia, separation of the precipitated hydrous oxides by sedimentation, treatment of the neutral liquor with barium salts to remove Radium-226, distribution of the resulting clear dilute nitrate solution as fertilizer, and solidification and burial of the precipitated hydrous oxides and radionuclides.

The acidic raffinate from the solvent extraction process is allowed to flow by gravity to one of two surface ponds where anhydrous ammonia is added to maintain a pH of 5 to 8. The metal contaminants in the raffinate precipitate out of the solution as the pH rises and are allowed to settle to the bottom of the ponds as a sludge. The neutralized raffinate liquid is then pumped from the top of the pond through a barium treatment facility for removal of Radium-226.

A barium-radium precipitate is separated by centrifuging and collected in 55-gallon drums and held for shipment to an off-site licensed burial facility. After sampling and analyzing for radium removal assurance, the treated raffinate is available for use as a fertilizer.

1.3 Sludge Disposal

At the current plant production capacity of 9,090 MTU per year, sludge is generated at a rate of 2.3 million gallons per year. It is estimated that there was a total of 10 million gallons of sludge in inventory in pond 2 at the end of 1979. At the projected end of plant life, in the year 2000, an estimated 56 million gallons will have been generated for burial. A typical chemical analysis of the sludge is shown in Table 1 on page 12.

The program for removal and disposition of the radioactive sludges consists of the following:

1. The sludge in pond 1 is to be transferred by a barge-mounted pump to pond 2 to permit modification of pond 1 to become Clarifier A as approved in a previous license amendment.
2. The inventory of sludge in pond 2 and sludge subsequently deposited in Clarifier A will be transferred at the rate of 20,000 gallons per day to large cone-bottom dewatering tanks adjacent to Clarifier A where excess water will be allowed to separate and return to Clarifier A.
3. The dewatered sludge (approximately 60% H_2O) will then be pumped from the dewatering tanks via a pipeline through a booster station to the disposal site approximately one mile away.
4. At the disposal site the sludge will enter a ribbon blender where it will be mixed with an equal volume of Portland cement and/or another material with equal or better radon stabilization characteristics. (Experiments with clay additions as a diluent have shown some promise for additional radium stability.)
5. The sludge-cement mixture will flow by gravity to 4' x 4' x 8' forms erected in the disposal pit.

6. After solidification, the blocks will be covered with polyethylene film to minimize leaching of nitrate and radium by rainwater.
7. The disposal pit will be constructed in phases to permit layering of the solidified sludge in a running brick pattern as shown on Drawing 290-C-1014. This method of placement will permit isolation of run-off water from clean rain water and at the same time permit surface reclamation of each completed block pattern as the solidification progresses.

1.4 The Disposal Pit

The initial excavation for sludge disposal will be approximately 400' x 500' x 60' deep with side slopes of 3H to 1V. The sides and bottom of the opening will be provided with a 5-foot compacted clay liner (permeability of 10^{-9} cm/sec) covered by a 30-mil reinforced Hypalon membrane liner (see attached Drawings 290-C-1013 and 1014). The Hypalon liner is recommended by the manufacturer for prevention of diffusion of nitrate ion through the clay. The disposal pit will be constructed in phases with a barrier wall provided to separate possibly contaminated water from relatively clean rainwater as shown on Drawing 290-C-1014. The phased approach to pit construction will provide minimal surface disturbance and permit early land reclamation of phases as they are completed. The land reclamation will consist of backfilling as shown on the drawing and topsoil replacement and reseeding to restore native vegetation. The attached Exhibits A and B present the specifications for the disposal pit construction and the Hypalon liner.

2.0 THE SITE

2.1 Location of the Disposal Pit

The raffinate sludge disposal pit is located in the southeast corner of Section 22, T12N, R21E, Sequoyah County, Oklahoma. When fully developed, the disposal pit will occupy approximately 14 acres on the summit of a prominent hill about one mile southeast of the existing Kerr-McGee Sequoyah Facility. The summit elevation is 700 feet above sea level and marks the highest point in the immediate area of the facility. Kerr-McGee either owns or has options to buy all lands adjacent to the pit location shown on map 290-C-1011, Rev. 1.

The site area of approximately 25 acres will be secured from public access by 8-foot security fencing provided with single vehicle and personnel entry gates that will remain locked except when attended by operating personnel.

2.2 Geology and Hydrology

Fifteen holes were drilled in the area of the disposal site to provide detailed geologic and hydrologic data. The area is underlain by the Atoka Formation of Pennsylvanian Age. About 240 feet of the Atoka was penetrated during the drilling program and is characterized by irregularly-bedded, discontinuous units of sandstone, siltstone, and shale. The disposal pit will bottom in the upper sandstone unit. Observation well data have established a groundwater system at approximately 35 feet below the pit bottom. Transmissivity tests have permitted calculations to be made that indicate a groundwater velocity of .009 feet per day toward the north of the disposal pit location. Details of the geology and hydrology of the site are presented in the attached Hydrologic Assessment (Exhibit C).

3.0 ENVIRONMENTAL IMPACTS

3.1 Site Preparation

Construction of the pit for sludge disposal is expected to have only a relatively minor and temporary impact on the environment. The only possibly significant disturbance is expected from excavation equipment during initial clearing of small amounts of timber along a temporary access road and around the summit of the hill in preparation for storage of top soil and overburden for later reclamation use. There is no impact expected on the wildlife in the area. Because the disposal pit is located atop a wooded hill, the aesthetic value of the area is expected to be maintained.

3.2 Sludge Disposal Operations

3.2.1 Land Use. At some time in the recent past, the disposal pit area had been used for cattle grazing as evidenced by a small watering pond constructed on a higher portion of the hill. The watering pond was drained in late 1978 by Kerr-McGee by removing the small temporary run-off dam. As a result of the proposed action, the affected area will be permanently removed from the possible grazing capabilities of the area. No other potential high-value land uses will be preempted by siting and operation of the disposal pit.

3.2.2 Water Use. The 56 million gallons of sludge transferred to the disposal pit contain approximately 34 million gallons of water that will be stabilized by solidification and thereby removed from the surface water system. Rainwater collected in the pit will be analyzed and uncontaminated water will be returned to natural drainage outside the pit walls. Contaminated water will be returned via pipeline to the raffinate treatment facilities at the plant site. No other surface water impacts are expected.

Full protection of groundwater is provided by the relatively impermeable clay liner, the Hypalon membrane liner, the solidification of the sludge, and the site location at 35 feet above the groundwater level.

By virtue of its elevation, the site is totally safe from flooding that would result from 100-year and 500-year rainfall events.

3.2.3 Biological Impact. The proposed action of pumping sludges, and the solidification and deposition of the sludges in an open pit does not result in gaseous or liquid effluents and, therefore, produces no impacts on the biota.

3.2.4 Radiological Impacts. No changes are expected in the airborne or waterborne radioactivity levels of the area as a result of this action. Dose rates to personnel operating the sludge system will be similar to dose rates resulting from handling uranium compounds of the same uranium concentration in slurry form. It is estimated that an operator working in the disposal pit around solidified sludge would be exposed to less than 2 millirem per hour of gamma radiation. Exposure rates will be verified when the system is put into operation.

Radon levels are expected to be insignificant; however, measurements will be made for verification as significant quantities of solidified sludge accumulate in the disposal pit.

4.0 ENVIRONMENTAL MONITORING PROGRAM

During the investigation of geologic and hydrologic conditions of the disposal pit location, nine wells were completed as observation wells around the periphery of the affected area. The wells that will be used for groundwater observation (S-4 through S-9 and S-10C, 11C, and 12C) are located on Drawing No. 290-C-1013. Analysis of initial groundwater samples from the observation wells is presented in Table 2 on page 13, attached. Groundwater sampling and analysis will be performed on a monthly basis to assure absence of groundwater contamination.

5.0 ENVIRONMENTAL IMPACTS OF ACCIDENTS

The entire sludge disposal system will be under control of the plant operations and the existing plant safety practices will apply. However, in the interest of safety, several possible scenarios which could result from operational errors or equipment malfunctions have been postulated and reviewed for possible effects on the surrounding environs. These scenarios are discussed in the following paragraphs.

5.1 Pipeline Rupture

A pipeline rupture would allow wet sludge to penetrate the earth around the pipeline and possibly result in surface and groundwater contamination. To prevent this unlikely event, the pipeline will be pressure tested prior to initial use and on a monthly basis when in use. Back pressure devices will be installed that will stop the pump when an abnormally low pressure is encountered. If a leak or rupture is indicated and cannot be located by visual inspection of the pipeline route, segmented pressure testing will be used to pinpoint the problem area. After system repair, the area would be decontaminated in accordance with applicable regulations.

5.2 Solidification System Failure

Failure of the solidification system could result in deposition of wet sludge in the disposal pit. This material would be recovered by pumping it from the pit to either the dewatering tanks adjacent to Clarifier A or the solidification system prior to redeposition in the pit.

5.3 Hypalon Lining Rupture

Rupture of the Hypalon lining of the pit would break one level of containment, but is backed by the clay liner to prevent groundwater contamination. Frequent visual inspections of the liner will be made and repairs performed as required to maintain its integrity.

5.4 Catastrophic Failure

In the extremely unlikely event that all disposal pit containment failed simultaneously, the only contamination that would occur would be from the relatively small amount of material not yet solidified. If required, the solidified blocks could be retrieved for placement in a different area.

5.5 Maximum Credible Failure

A review of scenarios for possible failures of the containment system after reclamation results in the following projection of conditions that are considered to be the maximum credible failure that might result in groundwater contamination:

a. Extreme weather conditions might cause cracking of the 5-foot clay cover.
b. Surface water might seep into the pit and become contaminated with nitrate and radium.
c. The water pressure in the pit could build up over a long period of time.
d. The Hypalon liner could rupture and allow the contaminated water to contact the lower 5-foot clay liner.
e. The water could slowly seep through the clay and the sandstone and shale and eventually reach the groundwater.

Consideration of each of the above items will show the extremely low credibility of the failure.

a. The clay might crack under the conditions of extreme drought, but these dry conditions would not provide significant water for seepage into the pit. As conditions of drought decreased, the additional moisture would result in swelling of the clay and a healing of the cracks.
b. If surface water were to seep below the clay cover, a large proportion of the seepage would be absorbed into the solidified sludge and held there through capillary action.
c. The water pressure would build up only under specific conditions of maximum seepage in and no seepage out after the maximum amount of absorption by the solids in the pit.
d. Unless a catastrophic event such as an earthquake took place, the likelihood of leakage throught the Hypalon is low and then only at small openings in the liner.
e. The permeability of clay is so low (10^{-9} cm/sec) that it is considered a sealant for water retention systems. Clay also exhibits a strong ion exchange affinity for radium and therefore would act as a decontamination agent for the water as it slowly seeped through the clay to the sandstone and shale layers below.

The sandstone and shale thickness above groundwater is currently 35 feet. Standard hydrological calculations were used to estimate that under worst case conditions it would take approximately 531 years for leakage water from the pit to reach the groundwater level and approximately 240 years to reach a point 800 feet away from the center of the pit. This data is presented in Exhibit C attached.

6.0 ECONOMIC AND SOCIAL IMPACTS

Economic and social benefits of facility operations are outlined in Section IX of the Final Environmental Statement Related to the Sequoyah Uranium Hexafluoride Plant (Docket No. 40-8027). The sludge disposal system will permit continuation of those benefits. The construction phase will provide additional income to local construction firms and the operating phase will add up to four additional jobs at the plant. The new jobs at the plant will be filled by the local residents and thus result in no net influx of of people to the area. As a result, there will be no effect on housing, service industries, or municipal services. The community would benefit through knowledge that the low-level radiation wastes of the facility are permanently placed and carry no liability for future generations. The cost of sludge disposal (including initial construction, 20 years operation, and final reclamation) is estimated at approximately $35 million. It is expected that at the end of plant life and after reclamation is completed, the 25-acre area involved will be deeded to the State to insure against possible alternate uses in perpetuity.

7.0 DECOMMISSIONING AND RECLAMATION

Decommissioning the sludge disposal systems will follow the plan submitted March 14, 1978 as Appendix C to SUB-1010 Docket No. 40-8027. The disposal pit will be reclaimed as shown on Drawing No. 290-C-1013. All affected areas will then be reseeded to restore native vegetation.

A final radiological survey will be made to assure that reclamation has returned the area to background levels. The observation wells and security fencing will remain until such time that sampling results warrant removal and/or total abandonment.

8.0 ALTERNATIVES TO THE PROPOSED ACTION

Alternatives for disposal of raffinate wastes have been studied and are presented in Section IX of the Sequoyah FES (NUREG-75/007). Each of the alternatives, except deep well disposal, produces residual solids requiring permanent disposal. The only known acceptable method for disposal of these residual solids is burial in the earth to provide isolation from the biosphere. Several methods of burial have been considered and are presented in the following paragraphs.

8.1 Combine with Mill Tailings

Sludge might be returned to Kerr-McGee's Uranium Mill near Grants, NM. Tests were performed at the mill with samples of the raffinate sludge to determine compatibility with the mill process. A shipping method was determined in conjunction with shipment of wet yellowcake from the mill and hauling sludge on the return trip. This option is not available because of a moratorium in the State of New Mexico on receiving radioactive wastes from another state.

8.2 Storage in an Abandoned Mine

A survey was made of abandoned mines in the Sequoyah area. Two mines owned by St. Clair Lime were investigated near Sallisaw for suitable geology and hydrology. Both structures appeared to be more than adequate based upon results of this superficial inspection. The owner was not interested in selling either of the abandoned mines since additional undeveloped reserves remained that might command a viable market at a later date.

8.3 Commercial Burial in a License Burial Site

Investigations into burial at a licensed burial site indicate that the environmental impacts from such an operation would be greatly increased due to the additional processing, material handling, and transportation required to satisfy current requirements for commercial burial. There is also a great uncertainty as to the availability of commercial burial sites since the moratorium imposed by the states of Washington and Nevada. The overall increase in energy consumption and the economic burden of over 300 million dollars over the remaining life of the facility add to the negative prospects of commercial burial.

TABLE 1

CHEMICAL CONSTITUENTS OF WET SLUDGE

(per cent)

Al	0.15%
As	0.012
B	<0.013
Ca	0.10
Cl (incl. Br and I)	0.005
C (from CO_2)	0.02
Fe	0.25
F	0.001
K	0.005
Mg (incl. Mn, Ni, Pb)	0.06
Mo	0.03
Na	0.12
N	0.73
P	0.04
Si	0.24
S	0.33
V	0.02
Zr	<0.10
H_2O	60.0

RADIONUCLIDES IN WET SLUDGE

(pCi/gm)

Ra	22.	pCi/gm
Th-230	5,060.	
Th-234	<640.	
Th-228 + 232	<450.	
Other		
Pb-210, Po-210, Ac-227, Ra-228, Pa-231, U-235	<750.	pCi/gm
U-238 + U-234	<270.	

TABLE 2

SEQUOYAH RAFFINATE DISPOSAL PIT

ANALYSIS OF WATER QUALITY IN MONITOR WELLS*

Analysis	S-4	S-5	S-6	S-8	S-9	S-10C	S-11C	S-12C
Cu, mg/ℓ	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Mo, mg/ℓ	<0.001	0.001	<0.001	0.002	0.001	<0.001	0.003	0.004
Ni, mg/ℓ	<0.001	0.003	0.005	0.007	0.002	0.004	<0.001	0.001
U, mg/ ℓ	0.022	0.018	0.018	0.10	0.045	0.011	0.018	0.027
Th-230, pCi/ℓ	0.011	0.015	0.003	0.031	0.015	<0.004	0.004	0.013
Gross Alpha, pCi/ℓ	<10.	<10.	<10.	58.	23.	<10.	<10.	22.
Gross Beta, pCi/ℓ	<19.	<19.	<19.	<19.	<19.	<19.	<19.	<19.
Specific Conductance, μmhos/ℓ	354.	622.	386.	3080.	1680.	387.	323.	597.
TDS, mg/ℓ	260.	450.	260.	2170.	670.	250.	260.	420.
TSS, mg/ℓ	210.	304.	78.	110.	87.	25.	279.	230.
Ra-226,								
Sol., pCi/ℓ	.07	.26	.30	.06	.17	.17	.13	.18
Ins., pCi/ℓ	.60	.49	.43	.34	.42	.27	.49	.19

*Analysis performed by Kerr-McGee Technical Center on samples taken 5/18/79.

EXHIBIT A

KERR-McGEE NUCLEAR CORPORATION
SEQUOYAH FACILITY

SPECIFICATION NO. K-M 55-901-60E
For Raffinate Sludge Burial

1.0 SCOPE

This specification covers construction of a sludge burial pit at the Kerr-McGee Sequoyah Facility near Gore, Oklahoma.

2.0 GENERAL

2.1 The work is subject to Kerr-McGee's "General Conditions for Construction" and drawings 290-C-1013 and 290-C-1014 attached.

2.2 Contractor will furnish all labor, equipment, supplies and materials to perform required operations in connection with the work shown on the drawings and as specified herein.

3.0 WORK INCLUDED

3.1 All earthwork.

3.2 Fence.

4.0 WORK NOT INCLUDED

4.1 Establishment of pit location, base lines and bench marks.

4.2 Plastic liner.

5.0 CLIMATOLOGICAL DATA - MUSKOGEE, OKLAHOMA

Average annual precipitation - 42". Average summer temperature - 81^{o}F. Highest temperature recorded - 118^{o}F. Average humidity varies from 50% in the afternoons to 85% at night.

6.0 LINES AND GRADES

All work under this specification shall be done to the lines and grades as shown on drawings and as directed by the owner. Base lines and bench marks, which in the opinion of the owner are necessary for contractor's purposes in carrying out the work, will be established by the owner. If, during the course of work, the contractor or its subcontractors, or their representatives or employees move, destroy or render inaccurate control points or other reference marks, they will be replaced by the owner and the cost of such replacement shall be charged to the contractor. The accuracy of all work, other than control established by owner, shall be the responsibility of contractor.

7.0 EARTHWORK

7.1 Soils Engineer: The soils engineer shall act as the owner's representative and shall make observations and tests as necessary to assure contractor is complying with this specification. Placement of soils in the various areas of the project and suitability of soils will be determined by the soils engineer. The soils engineer's interpretation of this specification shall be final and binding on the contractor.

7.2 Soil Classifications

7.2.1 Topsoil: Friable residual surface soils, containing humus and naturally deposited organic matter, capable of supporting a satisfactory turf as demonstrated by suitable growth in its undisturbed location, and free of harmful quantities of clay, sand or graval.

7.2.2 Rock: Rock consists of igneous, metamorphic and sedimentary rock which cannot be excavated by normal ripping procedures or without blasting and all boulders or detached rock each having a volume of (1/2) one-half cubic yard or more.

7.2.3 Suitable Clay: Impervious clay materials suitable for embankment liner, meeting soil classification and compaction requirements.

7.2.4 Suitable Common Soils: Common soils suitable for particular application in embankment structure for strength, meeting soil classification and compaction requirements.

7.2.5 Waste Soils: All soils unsuitable for embankment structures such as rock or silt.

7.2.6 Sand: Includes coarse to fine but must be free of rocks and organic materials.

7.3 Excavation and Placement

7.3.1 Topsoil: Excavation and stockpiling of topsoil shall be done prior to any other excavation. Upon completion of pit structure, a portion of the topsoil shall be placed on the outer slopes of dikes as indicated on the drawings or as directed by owner and the remainder shall be placed for use in reclamation of the pit phases.

7.3.2 Unsuitable Soils: Excavations shall be disposed of as waste in an area designated by owner.

7.3.3 Suitable Clay and Suitable Common Soils: These soils shall make up the embankments and may be stockpiled as deemed necessary or placed directly on appropriate part of embankment, in accordance with the drawings or at the direction of the soils engineer.

7.3.4 Sand: Place according to drawing.

7.4 Pit Lining Construction

7.4.1 Subgrade Preparation: Subgrade preparation shall consist of scarifying, blading and compaction of all foundation areas upon which clay lining is to be placed. Scarifying shall be carried to a uniform depth of 8 inches. In the event that unsuitable soils exist at subgrade, they shall be over excavated to suitable materials, and prepared as stated. Compaction shall be as defined in paragraph 7.4.3.

7.4.2 Lifts: No lifts may be thicker than eight inches.

7.4.3 Compaction: All clay fill shall be compacted to a density at least 95 per cent of standard Proctor density, and at a moisture content that is $\pm$ 2 per cent of optimum.

7.4.4 Moisture Content: The contractor shall add water to the clay to bring it within moisture content requirements if the natural moisture content is too dry; and he shall windrow, turn and otherwise work clay that is too moist, so that at all times the clay is within the proper moisture limits.

7.4.5 Tests: A field density test shall be made for each 200 linear feet of lining and for each lift. Additional field tests may be made by the soils engineer from time to time.

EXHIBIT B

STANDARD SPECIFICATIONS
for
REINFORCED HYPALON MEMBRANE LININGS

Specification No. KM 55-901-50L

01. GENERAL REQUIREMENTS.

The work covered by this specification consists of installing a reinforced Hypalon membrane lining in the disposal pit where shown on the attached drawings or directed by the Kerr-McGee project engineer. All work shall be done in strict accordance with the drawing and this specification, and subject to the terms and conditions of the contract.

02. REINFORCED HYPALON LINING MATERIALS

A. General.

The materials supplied under this specification shall be first quality products designed and manufactured specifically for the purposes of this work, and which have been satisfactorily demonstrated by prior use to be suitable and durable for such purposes. The manufacturer of the calendered rolls shall show where a minimum of 500,000 sq. ft. (46,000 sq. m) of its 58-inch (147-cm) wide material has been installed for lining hydraulic structures.

B. Description of Hypalon Material.

The Hypalon membrane lining shall consist of 58-inch widths of calendered Hypalon sheeting fabricated into large sections by means of .75-inch (19-mm) wide dielectrically bonded seams into a single panel, or into the minimum number of large panels required to fit the jobsite.

1. Physical Characteristics.

The Hypalon materials shall have the reinforcing fabric completely encapsulated by the Hypalon lamination, which shall extend a minimum 1/4 inch (6 mm) beyond the selvedge edge of the fabric reinforcement. The Hypalon shall have the physical properties as shown on the attached "Physical Properties for Reinforced Hypalon."

Hypalon materials shall be manufactured from domestic Hypalon resin and specifically compounded for use in hydraulic facilities. Reprocessed materials shall not be used. Certification test results showing that the sheeting meets the specifications shall be supplied by the manufacturer of the calender rolls on request.

03. FACTORY FABRICATION.

Individual calender widths of Hypalon materials shall be fabricated into large sections by dielectric sealing into a single piece, or into a minimum number of panels as required to fit the facility. The fabricator shall have previously fabricated a minimum of 500,000 sq. ft. of Hypalon material for hydraulic linings. Lap joint with a minimum of .75 inch (19 mm) lap of the reinforced portion of the film shall be used. After fabrication, the lining shall be accordion folded in both directions and packaged for minimum handling in the field. Shipping boxes shall be substantial enough to prevent damage to contents. When factory splices run parallel to the waterline all encapsulated edges shall lap down the slope.

NOTE: On side slopes greater than 2:1, all splices shall be a 1-1/2-inch (38-mm) wide dielectric lap joint.

04. INSTALLATION OF HYPALON LINING.

A. General.

Installation shall be performed by a contractor that has previously installed a minimum of 500,000 sq. ft. (46,000 sq. m) of this material and an experienced fabricator field representative in attendance. The surface (substrate) to receive the liner shall be smooth and free of sharp objects that could puncture the lining. All vegetation must be removed. The Hypalon lining shall be placed over the prepared surfaces to be lined in such a manner as to assure minimum handling. The lining shall be closely fitted and sealed around inlets, outlets, and other projections through the lining using prefabricated fittings wherever possible.

1. Field Joints.

Lap joints shall be used to seal factory fabricated panels of Hypalon together in the field. Lap joints shall be formed by lapping 4 inches (10 cm) minimum of the reinforced portion of the film. The contact surfaces of the panels shall be wiped clean to remove all dirt, dust or other foreign materials. Scrub mating surfaces at splices with Trichloroethane. Apply splice cement liberally to mating surfaces with brush and join surfaces immediately. Roll splices smooth using rollers and remove wrinkles at that time. A plank or board can be used for back up. If atmospheric conditions are marginal, the use of hot air guns or other acceptable heating apparatus may be required.

2. Joints to Structures.

All curing compounds and coatings shall be completely removed from the joint area. Joining the Hypalon to concrete shall be made with Hypalon to concrete adhesive, #WE-400, and mechanically fastened. Unless otherwise shown on the drawing, the minimum width of the adhered area to the concrete will be 8 inches (20 cm).

3. Repairs to Hypalon.

Any necessary repairs to the Hypalon shall be patched with the lining material itself. Use a patch large enough to extend 6 inches (15 cm) in all directions from the puncture. Use field joint procedure.

4. Quality of Workmanship.

All joints, on completion of the work, shall be tightly bonded. Any lining surface showing injury due to scuffing, penetration by foreign objects, or distress from rough sub-grade shall be replaced or covered and sealed with an additional layer of Hypalon of the proper size.

05. QUALITY ASSURANCE.

Unless this requirement is waived, the contractor shall, at his expense, provide a field representative of the liner fabricator at the jobsite to insure compliance with the manufacturer's directions. The field representative must be present when the liner installation is started and may make periodic check-backs. As required, he shall instruct the contractor and observe the work, reporting unsatisfactory conditions and making recommendations for improvement in procedures to the contractor and the project engineer. The field representative shall not be directly responsible for the quality of the work involved; such responsibility shall be solely that of the contractor.

PHYSICAL PROPERTIES
for
REINFORCED HYPALON

PROPERTY	VALUE	TEST METHOD
Thickness nominal*	.036 inches	
Scrim	10x10 1000D Polyester	
Strength, lbf, minimum		
Warp	200	ASTM D 751
Fill	200	Grab Method
Tongue Tear, lbf, minimum		
Warp	80	ASTM D 751
Fill	80	
Mullens Burst, psi, minimum	375	ASTM D 751
Puncture Resistance, lbf, minimum	200	FTMS 101-B Method 2031
Low Temp. Resistance		
Cold Bend, no cracks	-45F	ASTM D 2136
Brittleness, no failure	-45F	ASTM D 746 Procedure B
Dimensional Stability, %, Maximum	-3	ASTM D1204-54 2h 160F 2h 212F
Ozone Resistance	No cracks visible under 7x magnification	ASTM D 1149 (3ppm @ 30% strain @ 104° F/70 hrs.)
Chemical Resistance	Highly resistant to aqueous solutions of nitric acid and other inorganic acids. Excellent compatibility with ammonium nitrate** and other ammoniacal solutions	

* The Hypalon covering the scrim is to be a minimum of .014 in. thick in conformance with DuPont recommendations. Factory dielectric splice 5/8-inch wide minimum is certified to exceed parent strength of material.

**The Kerr-McGee Nuclear Corporation has a Hypalon-lined pond at its Cimarron facility near Crescent, Oklahoma. This pond has contained ammonium nitrate solutions and withstood weather conditions for a period of seven years without observable deterioration.

EXHIBIT C

HYDROLOGIC ASSESSMENT

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