ANALYSIS OF NATURALLY OCCURING RADIOACTIVE MATERIALS IN DRILL CUTTINGS, GREATER WATTENBERG FIELD, WELD COUNTY COLORADO

COGCC Special Project 2136

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COLORADO
Oil & Gas Conservation Commission
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LIST OF ACRONYMS

ALS	ALS Laboratory Group
ASTM	ASTM International (formerly known as American Society for Testing and Materials)
CCR	Code of Colorado Regulations
CDPHE	Colorado Department of Public Health and Environment
COGCC	Colorado Oil & Gas Conservation Commission
DOT	Department of Transportation
E&P	Exploration & Production
keV	kiloelectron volts
MDA	minimum detection activity
NORM	Naturally Occurring Radioactive Materials
pCi/g	picoCuries per gram
STRONGER	State Review of Oil & Natural Gas Environmental Regulations
TENORM	Technically Enhanced Naturally Occurring Radioactive Material
USEPA	U.S. Environmental Protection Agency

INTRODUCTION

In October 2011, the State Review of Oil & Natural Gas Environmental Regulations (STRONGER) team recommended that the Colorado Oil & Gas Conservation Commission (COGCC) gather information on the occurrence and level of Naturally Occurring Radioactive Materials (NORM) in Exploration & Production related (E&P) wastes in Colorado.

COGCC Special Project 2136 (NORM Study) was initiated in 2014. COGCC staff undertook a sampling program to collect representative samples of selected E&P waste for analytical laboratory evaluation for NORM. Because of the widespread practice of beneficial reuse of drill cuttings as an agricultural soils amendment, staff determined that evaluation of NORM levels in drill cuttings was an appropriate focus for this information gathering study. This study focused on drill cuttings from recent well drilling in the Greater Wattenberg Field in Weld County.

A total of 36 samples were collected during the months of May and June 2014 and submitted for analyses. The samples included 12 samples of drill cuttings, 12 samples of soils with drill cuttings incorporated, and 12 samples of native soils collected as background samples. The analytical results for these samples have been uploaded to the COGCC database and are available for public review. Discussions of the results are presented below.

BACKGROUND

Naturally Occurring Radioactive Material (NORM) is any radioactive material that occurs naturally and is not byproduct, source or special nuclear material (6 Code of Colorado Regulations [CCR] 1007-1 Part 01). NORM is sometimes defined as primordial radionuclides, or natural radioactivity in the form of uranium and thorium and their progeny such as radium, present in water, soils, rocks, and materials undisturbed as a result of human activity.

Technically Enhanced Naturally Occurring Radioactive Material (TENORM) is naturally occurring radioactive material where the natural radionuclide concentrations are increased by or as a result of human practices (6 CCR 1007-1 Part 01). TENORM does not include background radiation or natural radioactivity of rocks or soils. Typical TENORM materials include materials such as gas plant pipe scaling, some drinking water purification and treatment wastes, mining/refining wastes, scrap metal, industrial sludges, and other industrial process wastes and materials.

The Radiation Program of the Colorado Department of Public Health and Environment (CDPHE) Hazardous Materials and Waste Division provides some regulatory oversight and guidance regarding TENORM materials (http://www.colorado.gov/cs/Satellite/CDPHE-HM/CBON/1251617273613).

NORM is everywhere. It is a part of our daily lives, as the natural environment has many sources of radiation. Radiation continually bombards us from space. The earth's rocks and soils, the air we breathe, the food we eat, the water we drink, even our bodies are radioactive. In most cases the level of NORM is below any regulatory definition of radioactive material and the health risks from these low levels of radiation are considered low. In some cases, however, the level of NORM may be equal to materials governed under TENORM regulatory programs, or the handling of NORM materials can create issues which may increase potential for health exposures.

The primary radionuclides of concern in NORM are radium-226 (^{226}Ra) of the uranium-238 (^{238}U) decay series, and radium-228 (^{228}Ra) of the thorium-232 (^{232}Th) decay series. Figures 1 and 2 depict the decay chains of ^{238}U and ^{232}Th, respectively.

SAMPLE RESULTS

COGCC staff collected 12 samples of drill cuttings, 12 samples of soils with incorporated drill cuttings, and 12 background soil samples at location shown on Figures 3 through 9**.** Where samples were collected post-incorporation, an appropriate background location was selected and sampled. Where cuttings were still in storage piles prior to incorporation, a site-specific background sample was not collected. All sampling and laboratory analyses were conducted according to procedures described in the *Sampling and Analysis Plan for Naturally Occurring Radioactive Material in Oil and Gas Well Drill Cuttings* (COGCC 2014).

FIELD SCREENING

A Ludlum Model 19A Micro-R Meter, a direct reading gamma ray meter, was used for field screening to identify the possible presence and degree of NORM in cuttings. No instrument readings above ambient background were recorded for any of the samples collected. Additionally, radiological screening (sample acceptance protocol) conducted by the laboratory showed no instrument readings exceeding background for samples received.

ANALYTICAL LABORATORY SAMPLE RESULTS

Laboratory analyses for the NORM Study were conducted by ALS Laboratory Group (ALS) in Fort Collins, Colorado. Samples were either hand-delivered to the laboratory or shipped via commercial transporter. Table 1 summarizes the analytical parameters, analyses methods, sample quantities, and holding times for this study. Table 2 summarizes the detection limits for the laboratory analyses for this study. Tables 3 through 6 summarize sample results for the NORM Study and include both radionuclides detected and those that were analyzed but were not detected.

The following description of radiochemical analysis is summarized and excerpted from Consolvo and Sukpsky's *Radiological Lab Results Don't Have to Be Confusing* (2011).

> For radiochemical parameters the amount of energy released through radioactive decay is measured in units of activity as alpha, beta, or gamma radiation. The decay rate (disintegrations per minute) is converted to activity based on the Curie (Ci) unit of activity. Because of the very small radioactivity of environmental samples, the unit of measure is reported in picoCuries (10^{-12} Ci) per gram (pCi/g) for solid samples (this study) or in pCi per liter (pCi/l) for water samples. Unlike most general analytical chemistry results, which are typically reported down to a minimum reporting level, radiochemistry results are reported raw and flagged with a "U" when the activity is less than the requested Method Detectable Concentration (MDC).
>
> There are two detection-capabilities associated with radionuclide analyses; the Requested MDC , and the Achieved MDC (reported in the analytical reports for this study as MDC).
>
> **The Requested MDC** are *a prior* calculations that determine, prior to actual sample analysis, whether a particular measurement system can detect activity to a specific level, and are used to determine the counting time required to meet a predetermined minimum detection limit. Lower Limit of Detection (LLD) is the smallest activity level in a sample that will yield a net count (above system background) that can be detected with a 95 percent probability. LLD is a calculation that represents the measurement capabilities of a system. Required Detection Limit (RDL) is the

minimum level to which an analytical method must be able to report to measure radionuclides. RDL is the concentration that can be counted with a precision of ± 100 percent at the 95 percent confidence level (that is, 1.96 σ, where σ is the standard deviation in the net counting rate of the sample)

Achieved MDC are *a posteriori* calculations that, following an actual sample analysis, determine the minimum detection limit specifically for that analysis. Minimum Detectable Activity (MDA) is the smallest activity of radioactive material in a sample that will yield a net count (above sample background) that can be detected with 95 percent probability.

Uncertainty Report
Along with a result (activity level) and detection limit, each sample result's uncertainty level is reported. A sample's uncertainty level is a combination of counting error of the analytical instrument and uncertainty due to statistical effects in the emission of radiation, and statistical effects in the detection process. In this report, uncertainty is reported as "±" a value.

Negative Radioactivity
Reported sample results are sometimes negative values. When a sample has little radioactivity, the analytical results should have a normal distribution of positive and negative results around zero. When a sample result is subtracted from that of the system's background and the sample value is less than that background, the result is a negative value. A negative result indicates that the radionuclide activity in the sample is low.

Gross Alpha Results

Table 3 provides a summary of the gross alpha analytical results. Gross alpha activities in drill cuttings ranged between 1.48 ± 0.80 and 10 ± 3.5 picoCuries per gram (pCi/g). The highest gross alpha activity detected, 10 ± 3.5 pCi/g, occurred in unincorporated cuttings at the BBC-436067 beneficial reuse area. Gross alpha activities in background samples ranged between 1.28 ± 0.39 pCi/g and 6.6 ± 1.4 pCi/g. The highest gross alpha activities occurred in sample GREELEY AIRPORT-436890-BKG.

The gross alpha activity detected is related to naturally occurring alpha-emitting radionuclides, primarily Uranium-238 (^{238}U), Thorium-232 (^{232}Th), and their daughter products present in surface soils and subsurface rocks.

Gross Beta Results

Table 3 presents a summary of the gross beta analytical results. Gross beta activities in drill cuttings ranged between 1.81 ± 0.79 and 6.3 ± 1.9 pCi/g. The highest gross beta activity detected occurred in incorporated cuttings at the KRIER-436891 beneficial reuse area. Gross beta activities in background samples ranged between 1.98 ± 0.57 pCi/g and 5.2 ± 1.4 pCi/g. The highest gross beta activities occurred in background sample SPANDAU-431953-BKG.

The gross beta activity detected is related to naturally occurring potassium-40 (^{40}K) in surface soils and subsurface rocks. ^{40}K is one of the most abundant naturally occurring radionuclides and primarily occurs in clay and mica minerals that compose both the surface soils and shales found in the subsurface.

Gamma-Emitting Radionuclide Results

Table 4 provides a summary of the gamma-emitting radionuclide results. Naturally occurring radionuclides detected include actinium-228 (^{228}Ac), bismuth-212 (^{212}Bi), bismuth-214 (^{214}Bi), potassium-40 (^{40}K), lead-212 (^{212}Pb), lead-214 (^{214}Pb), thallium-208 (^{208}Tl), radium-226 (^{226}Ra), and radium-228 (^{228}Ra). Gamma-emitting radionuclides not detected include protactinium-234m (^{234m}Pa), thorium-227 (^{227}Th), thorium-234 (^{234}Th), and uranium-235 (^{235}U).

Actinium-228 (^{228}Ac)

Actinium-228 activities in cuttings ranged from not detected to 1.92 ± 0.62 pCi/g with the highest activities occurring in sample SUN-NIX-425797. ^{228}Ac activities in background sample ranged from not detected to 2.08 ± 0.62 pCi/g, with the highest activities occurring in sample KMG-422067-BKG (duplicate analysis).

Bismuth-212 (^{212}Bi)

Bismuth-212 activities in cuttings ranged from not detected to 3.5 ± 1.9 pCi/g, with the highest activities occurring in sample LUDWIG-430649. ^{212}Bi was not detected in any of the background samples.

Bismuth-214(^{214}Bi)

Bismuth-214 activities in cuttings ranged from not detected to 2.12 ± 0.46 pCi/g with the highest activities occurring in sample MILLER-425667 (duplicate analysis). ^{214}Bi activities in background samples ranged from not detected to 1.82 ± 0.52 with the highest activities occurring in sample KMG-422067-BKG.

Potassium-40 (^{40}K)

Potassium-40 activities in cuttings ranged from 8.9 ± 2.7 to 26 ± 4.9 pCi/g, with the highest activities occurring in sample LUDWIG-431183. ^{40}K activities in background samples ranged from 16.9 ± 3.8 to 30.1 ± 5.6, with the highest activities occurring in sample LUDWIG-431183-BKG.

Lead-212 (^{212}Pb)

Lead-212 activities in cuttings ranged from 0.52 ± 0.23 to 2.12 ± 0.44 pCi/g, with the highest activities occurring in sample KMG-422067. ^{212}Pb activities in background samples ranged from 0.68 ± 0.23 to 2.35 ± 0.52 pCi/g, with the highest activities occurring in sample KMG-422067-BKG.

Lead-214 (^{214}Pb)

Lead-214 activities in cuttings ranged from 0.83 ± 0.27 to 2.31 ± 0.48 pCi/g, with the highest activities occurring in sample MILLER-425667. ^{214}Pb activities in background samples ranged from 0.46 ± 0.18 to 1.77 ± 0.44 pCi/g, with the highest activities occurring in sample KMG-422067-BKG.

Thallium-208 (^{208}Tl)

Thallium-208 activities in cuttings ranged from not detected to 0.55 ± 0.20 pCi/g, with the highest activities occurring in sample SUN-NIX-425797. ^{208}Tl activities in background samples ranged from not detected to 0.81 ± 0.27 pCi/g, with the highest activities occurring in sample KMG-422067-BKG.

Radium-226 (^{226}Ra)

Radium-226 activities in cuttings ranged from 0.83 ± 0.24 to 2.80 ± 0.52 pCi/g, with the highest activities occurring in sample Miller-425667. ^{226}Ra activities in background samples ranged from 0.53 ± 0.2 to 2.29 ± 0.47 pCi/g, with the highest activities occurring in sample KMG-422067-BKG.

Radium-228 (^{228}Ra)

Radium-228 activities in cuttings ranged from not detected to 1.68 ± 0.63 pCi/g, with the highest activities occurring in sample SYNRGY-DECHANT-BRA. ^{228}Ra activities in background samples ranged from not detected to 2.08 ± 0.62 pCi/g, with the highest activities occurring in sample KMG-422067-BKG (duplicate analysis).

Uranium Isotopic Radionuclide Results

Table 5 provides a summary of the alpha spectroscopy uranium isotopic radionuclide results.

Uranium-234 (^{234}U)

Uranium-234 activities in cuttings ranged from 0.61 ± 0.13 to 1.94 ± 0.39 pCi/g, with the highest activities occurring in sample MILLER-425667. ^{234}U activities in background samples ranged from 0.34 ± 0.11 to 1.43 ± 0.28 pCi/g, with the highest activities occurring in sample SPANDAU-431953-BKG.

Uranium-235 (^{235}U)

Uranium-235 activities in cuttings ranged from not detected to 0.076 ± 0.043 pCi/g, with the highest activities occurring in sample NOBLE-425666. ^{235}U activities in background samples ranged from not detected to 0.059 ± 0.038 pCi/g, with the highest activities occurring in sample KMG-422060-BKG.

Uranium-238 (^{238}U)

Uranium-238 activities in cuttings ranged from 0.58 ± 0.14 to 2.09 ± 0.42 pCi/g, with the highest activities occurring in sample MILLER-425667. ^{238}U activities in background samples ranged from 0.46 ± 0.12 to 1.34 ± 0.26 pCi/g, with the highest activities occurring in sample SPANDAU-431953-BKG.

Thorium Isotopic Radionuclide Results

Table 6 provides a summary of the alpha spectroscopy thorium isotopic radionuclide results.

Thorium-228 (^{228}Th)

Thorium-228 activities in cuttings ranged from 0.51± 0.22 to 1.60 ± 0.28 pCi/g, with the highest activities occurring in sample KMG-422067. ^{238}Th activities in background samples ranged from 0.82 ± 0.15 to 2.12 ± 0.36 pCi/g, with the highest activities occurring in sample KMG-422067-BKG.

Thorium-230 (^{230}Th)

Thorium-230 activities in cuttings ranged from 0.80 ± 0.21 to 3.03 ± 0.50 pCi/g, with the highest activities occurring in sample NOBLE-425666. ^{230}Th activities in background samples ranged from 0.54 ± 0.12 to 1.92 ± 0.35 pCi/g, with the highest activities occurring in sample GOBBLER-2N66W23-BKG.

Thorium-232 (^{232}Th)

Thorium-232 activities in cuttings ranged from 0.64 ± 0.13 to 1.65 ± 0.29 pCi/g, with the highest activities occurring in sample KMG-422067. ^{232}Th activities in background samples ranged from 0.81±0.15 to 2.17 ± 0.37 pCi/g, with the highest activities occurring in sample KMG-422067-BKG.

DISCUSSION

The data collected and reviewed for this study shows that NORM activities in cuttings are at very low activities. No trends are observed in the presence of naturally occurring radionuclides when comparing drill cuttings, either pre- or post-incorporation, with background samples. None of the observed radionuclide activity levels from the cuttings or background samples were at any levels which would indicate elevated or enriched conditions.

Although NORM has no regulatory limits, comparison of the NORM Study radiological results to CDPHE TENORM Policy and Guidance (Table 7) show that no radiological activity levels in the NORM Study samples exceeded the administrative release limits and would be considered exempted from radiological control by that policy.

CONCLUSION AND RECOMMENDATIONS

The COGCC NORM Study was implemented in response to the October 2011 STRONGER recommendation that the COGCC gather information on the occurrence and level of NORM in E&P wastes in Colorado. The initial project involving the evaluation of the concentrations of NORM in drill cuttings from newly drilled wells in the Greater Wattenberg Area of Weld County has been completed. The COGCC staff observed no radionuclide activity levels in this E&P waste that indicate that NORM in drilling cuttings exceed radionuclide activity levels observed in background samples. In many cases, radionuclide activity levels in background samples were found to be higher than levels from drill cuttings.

The data available at present indicate that the beneficial reuse of drill cuttings as an agricultural soils amendment does not create conditions that pose impacts to human health or the environment from radiation. Although NORM has no regulatory limits, comparison of the NORM Study radiological results to CDPHE TENORM regulations show that no radiological activity levels in the NORM Study samples exceeded the unrestricted use limits.

RECOMMENDATIONS

1. The COGCC has additional limited radiological sampling data from earlier sampling, such as the Project Rulison (Project 1991) sampling required by order in the Rulison blast area, which should be incorporated into a follow-on data review/report in FY 2015.
2. COGCC should proceed to analyze E&P wastes generated in Colorado for the presence of NORM and continue to develop a database of radiological information for the following E&P wastes:
   - Produced water at all stages of water handing activities including surface evaporation pits.
   - Cuttings from other formations and other areas of the State, as available (this is envisioned as opportunistic sampling as drilling operations make cuttings available in other areas).
   - Other E&P wastes such as tank bottoms, drilling mud, pit sludges, and well completion flow-back, among others (again, this will be opportunistic and may be associated with other environmental investigations).

REFERENCES

Argonne National Laboratories, Environmental Science Division. 2005. Human Health Fact Sheet, Natural Decay Series: Uranium, Radium, and Thorium.

6 Colorado Code of Regulations [CCR] 1007-1 Part 01.

Colorado Department of Public Health and Environment (CDPHE). Radiation Control Program. https://www.colorado.gov/cdphe/radiation Accessed on November 8, 2014.

Colorado Oil & Gas Conservation Commission (COGCC). April 2014. Sampling and Analysis Plan for Naturally Occurring Radioactive Material in Oil and Gas Well Drill Cuttings.

Consolvo, John and Sukosky, John M., July 2011, Radiological Lab Results Don't Have to Be Confusing: OpFlow, American Water Works Association. http://www.awwa.org/opflow.

FIGURES

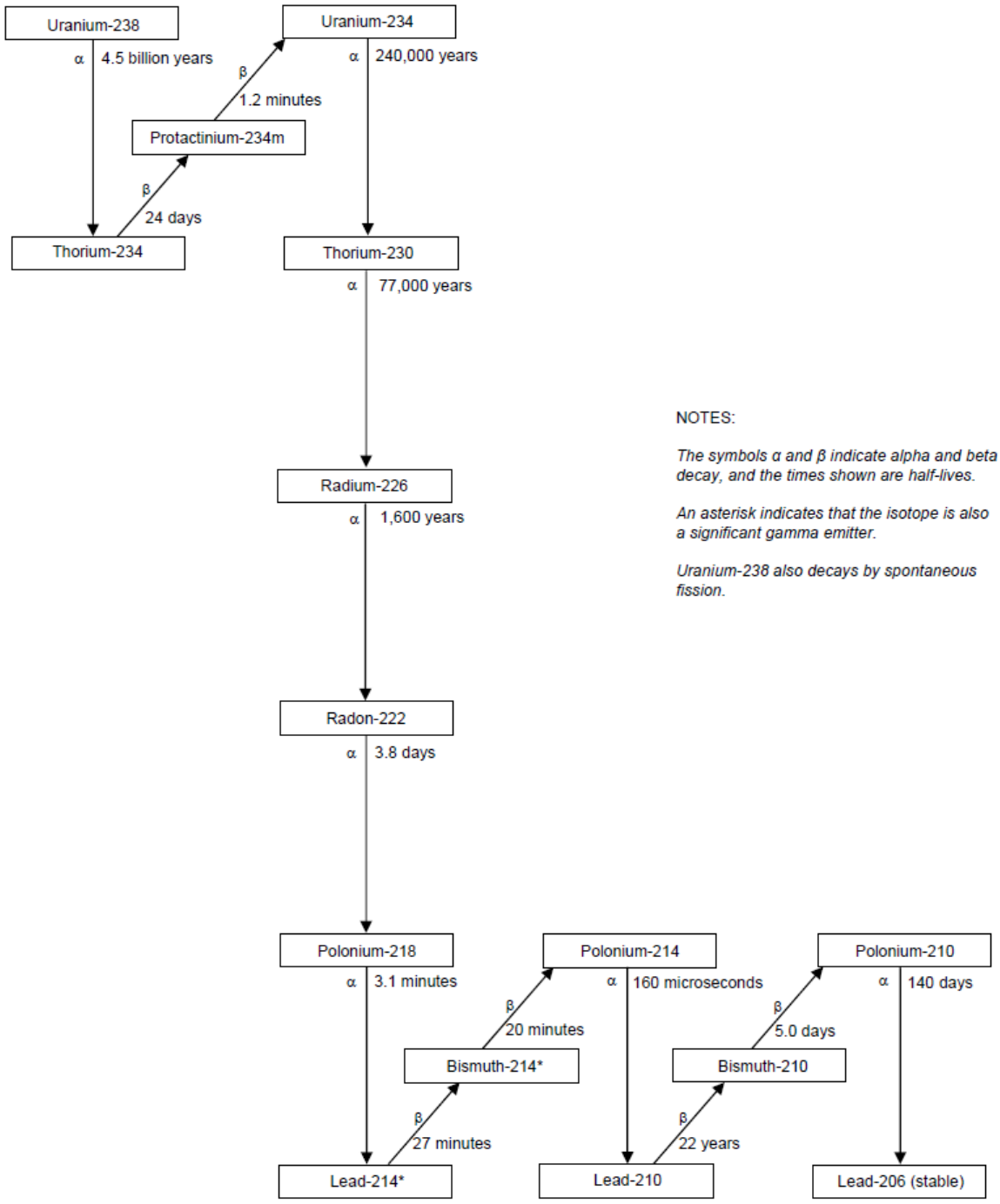


Figure 1. Natural Decay Series: Uranium-238

Source: Argonne National Laboratory, 2005

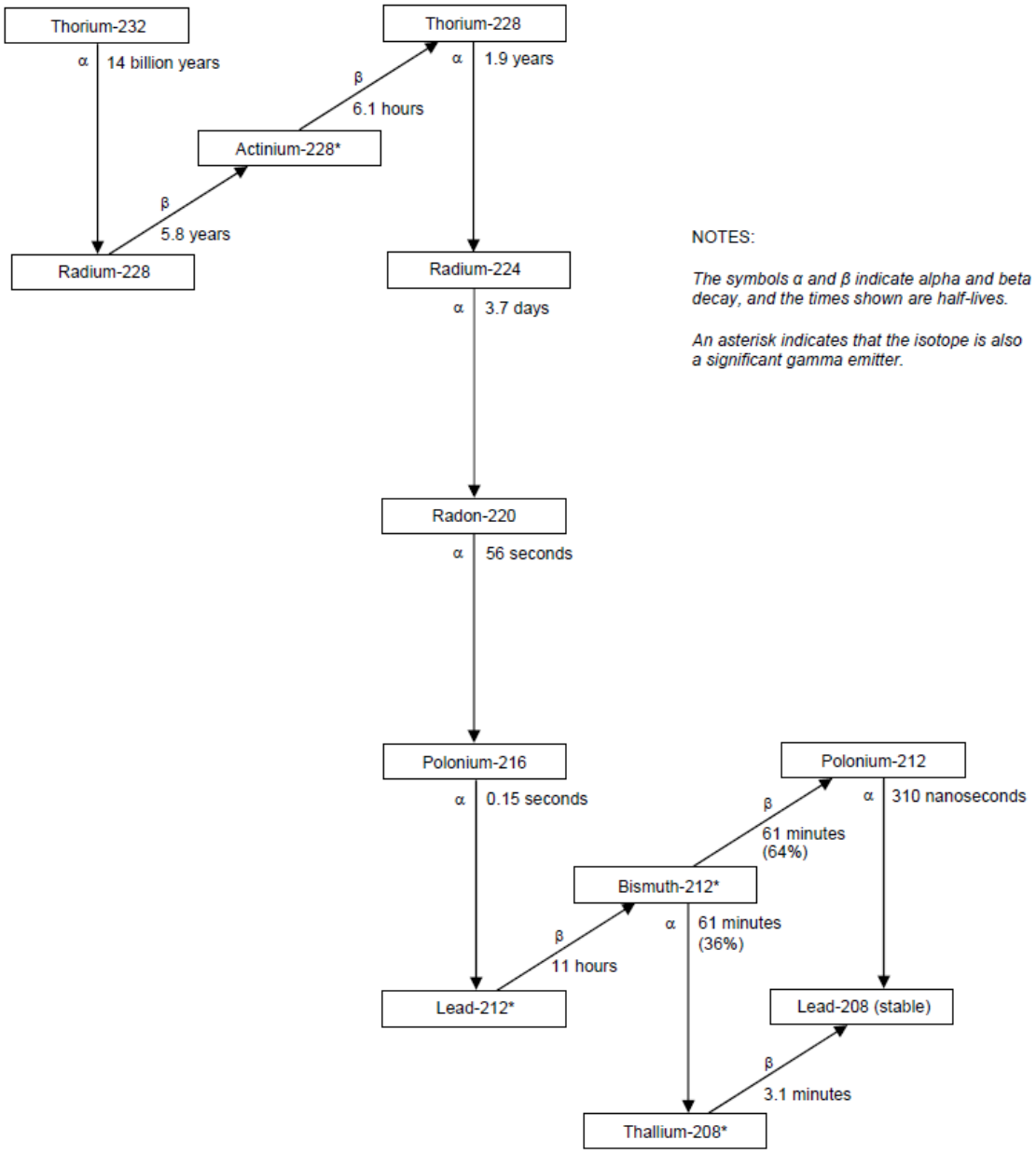
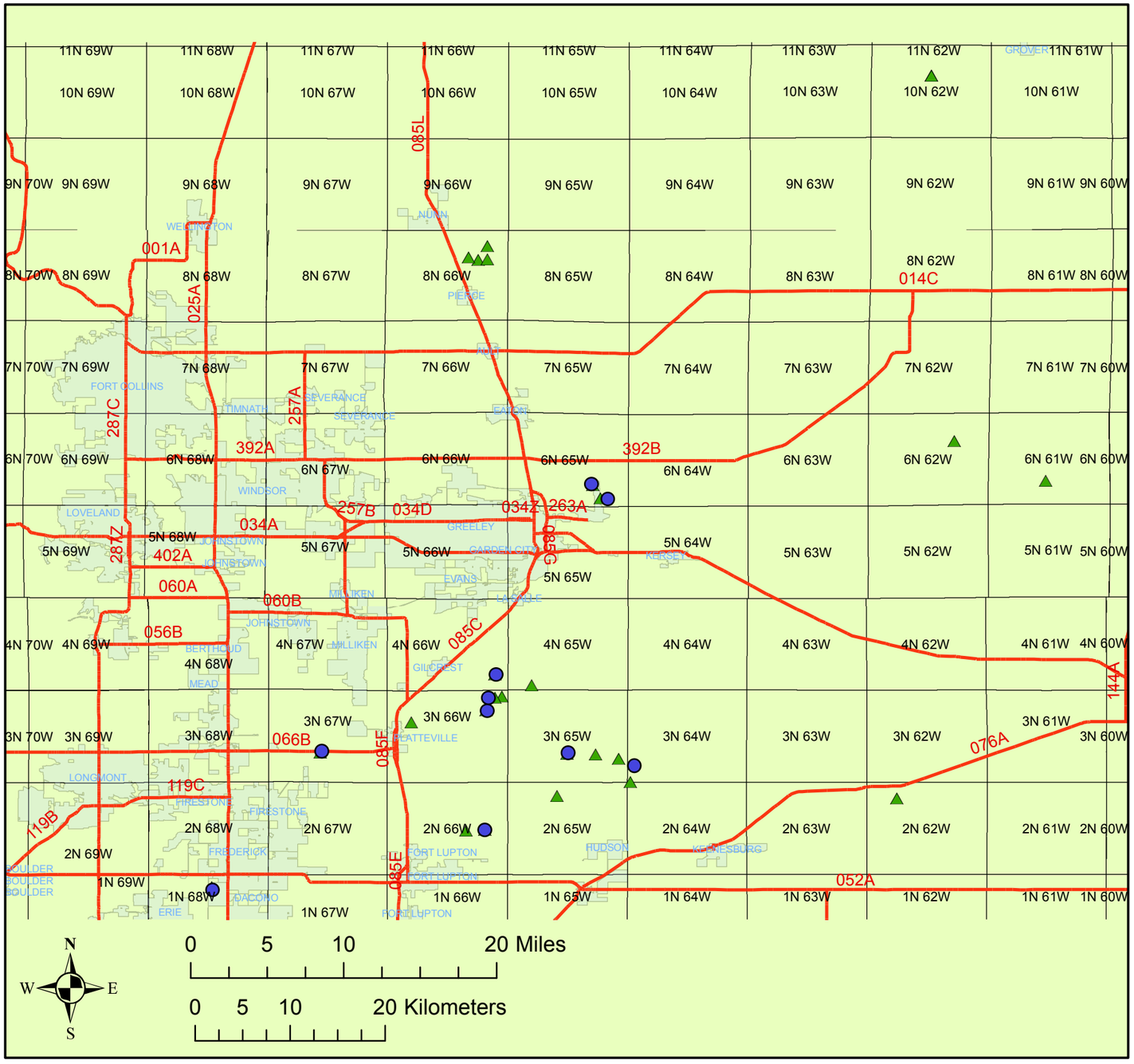


Figure 2. Natural Decay Series: Thorium-232

Source: Argonne National Laboratory, 2005

Figure 3 NORM Sample Locations



NORM Sample Locations

SampleType

- Background
- Cuttings
- Highway
- Cities
- Township and Range

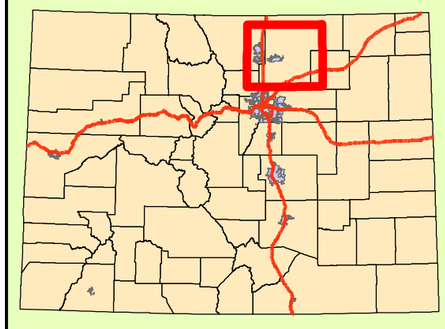
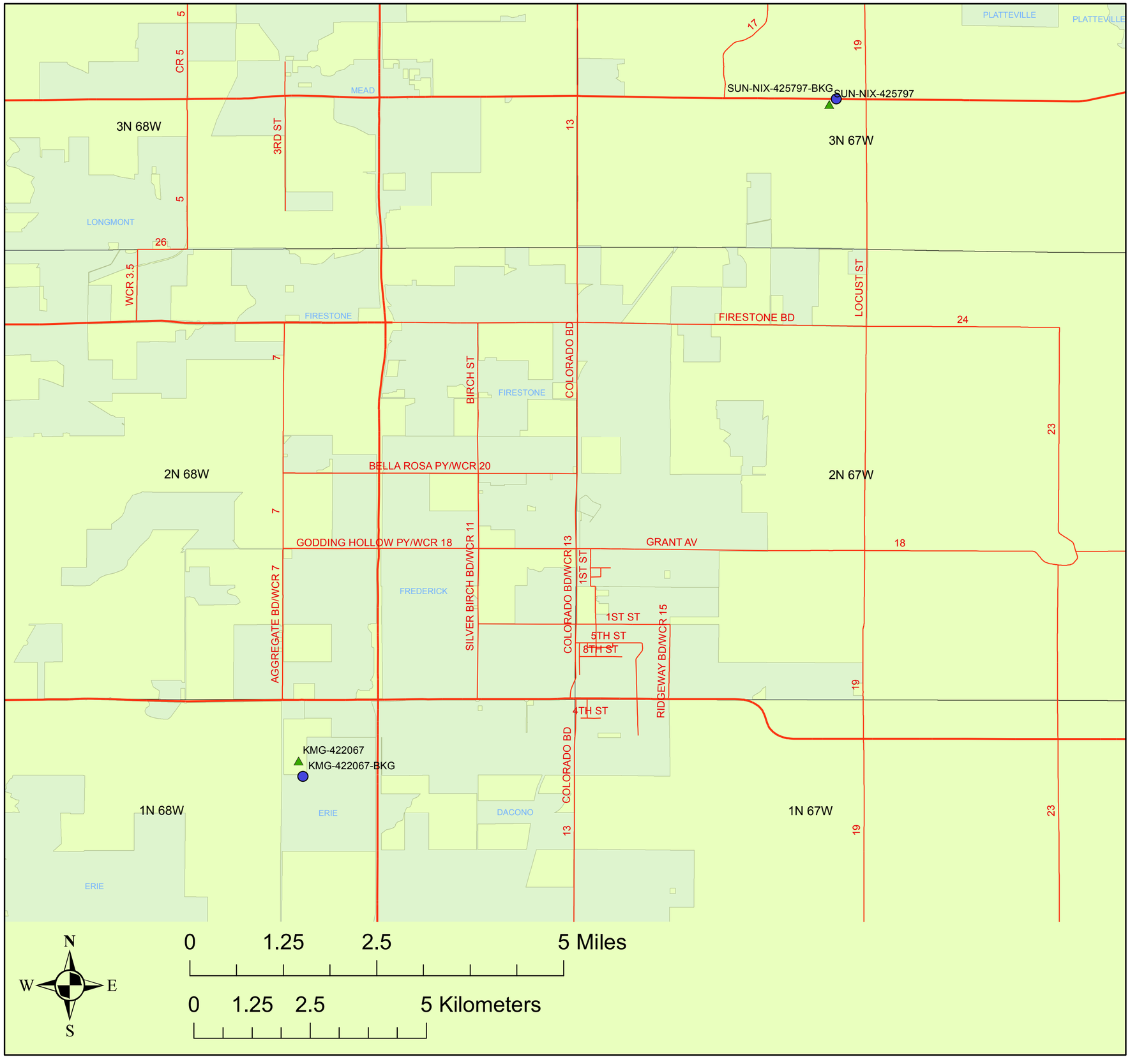


Figure 4 NORM Sample Locations Near Fredrick



NORM Sample Locations

SampleType

- Background
- Cuttings
- Major Rds
- Highway
- Cities
- Township and Range

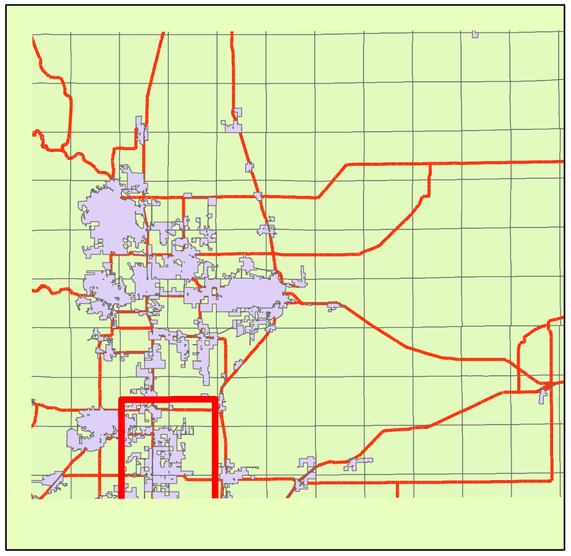
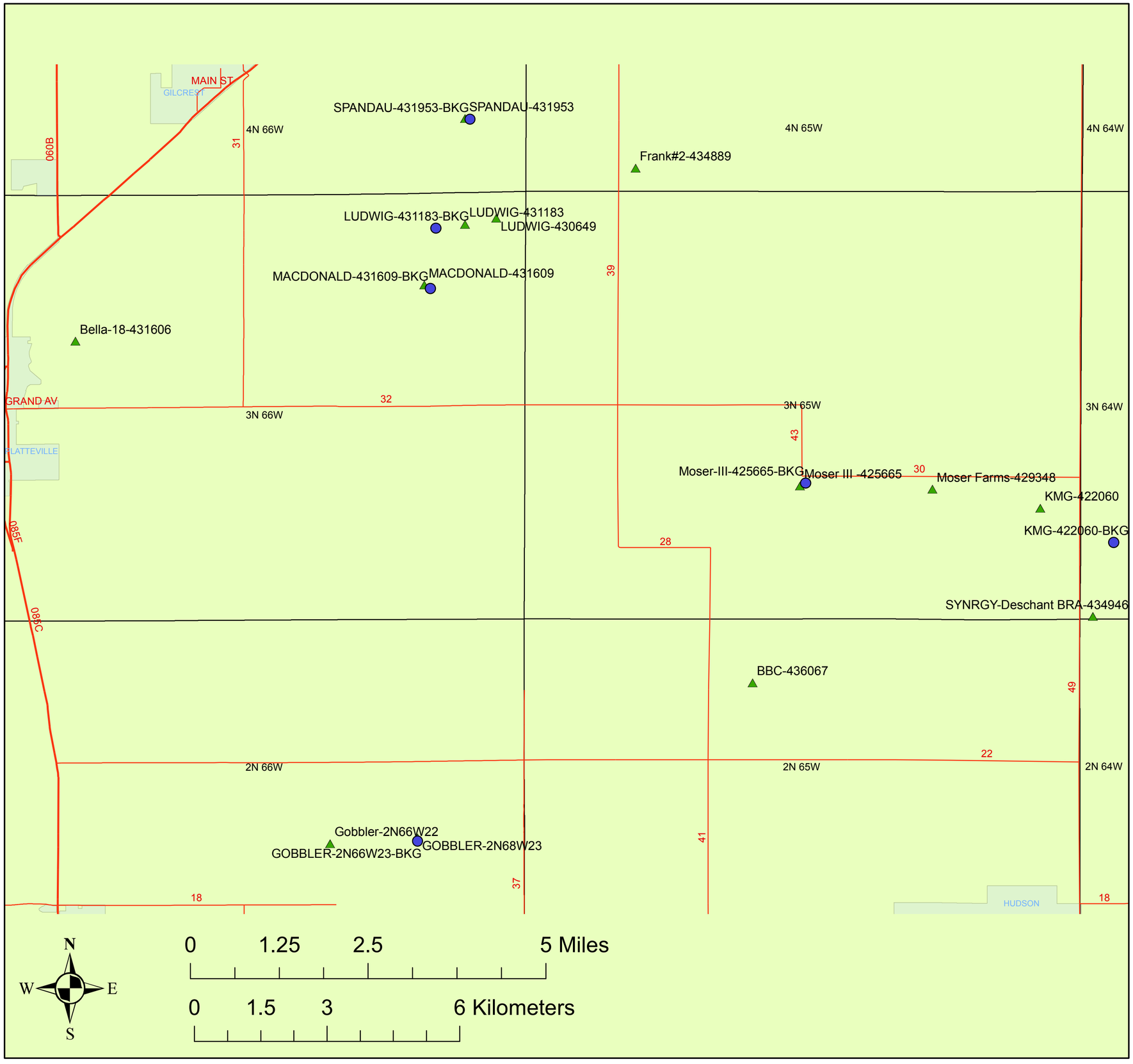


Figure 5 NORM Sample Locations Near Platteville



NORM Sample Locations

SampleType

- Background
- Cuttings
- Major Rds.
- Highway
- Cities
- Township & Range

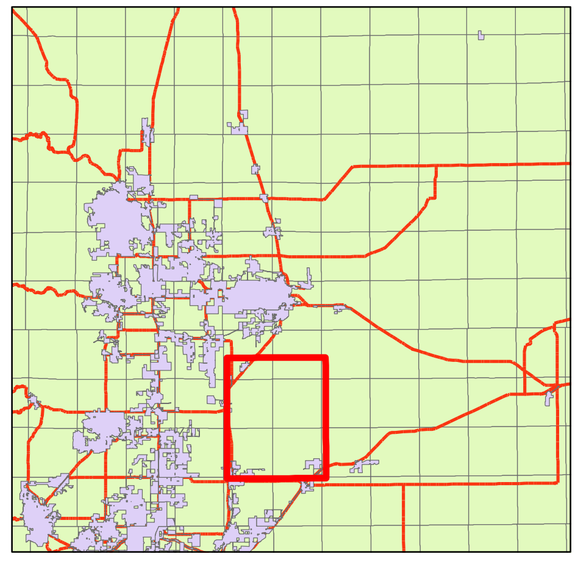
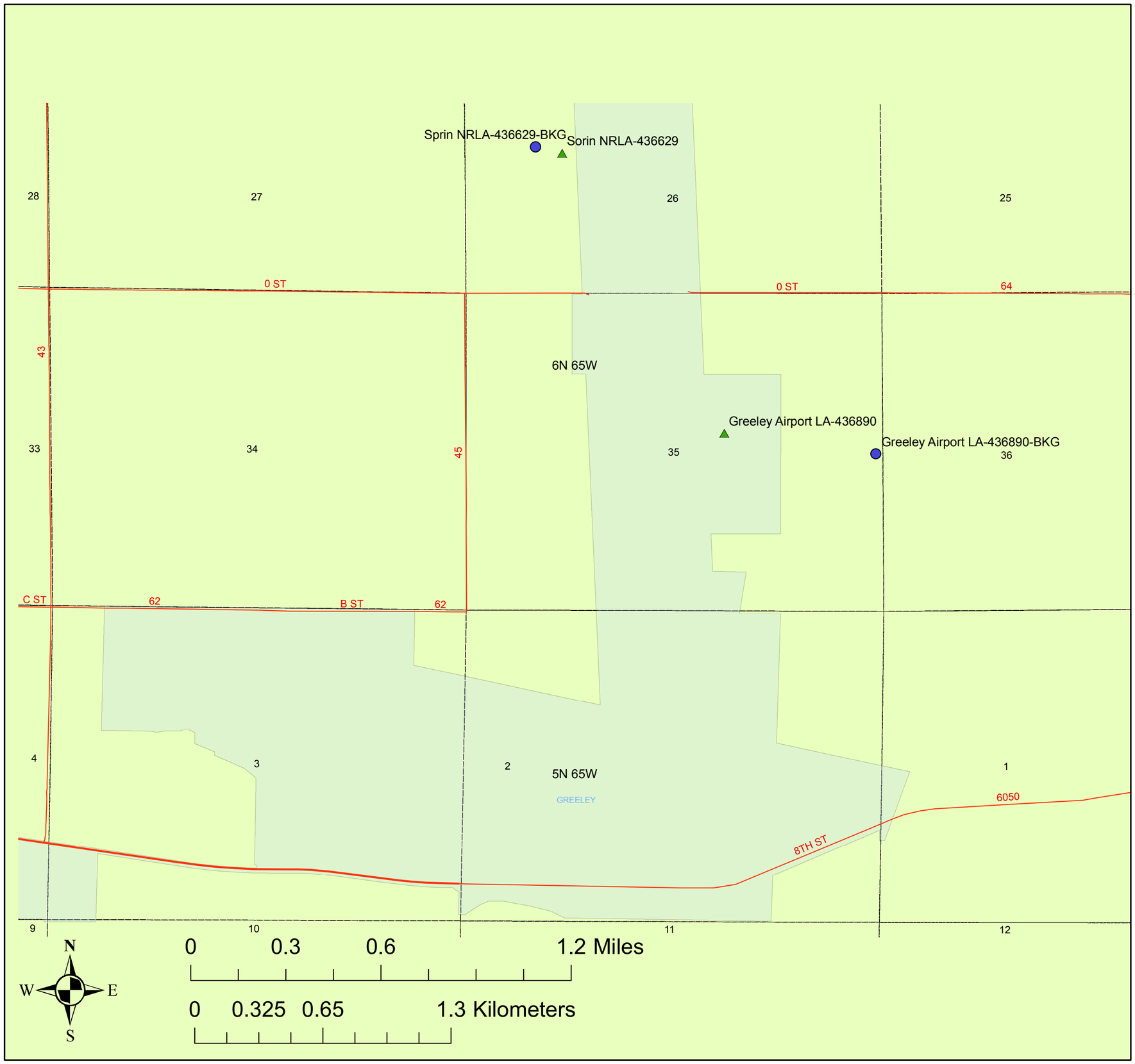


Figure 6 NORM Sample Locations Near the Greeley Airport



NORM Sample Locations

SampleType

- Background
- Cuttings
- Major Rds
- Highway
- Cities
- Township & Range
- sections

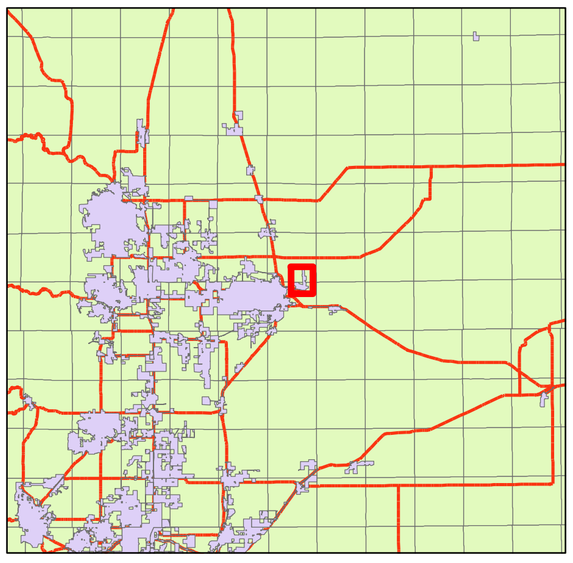
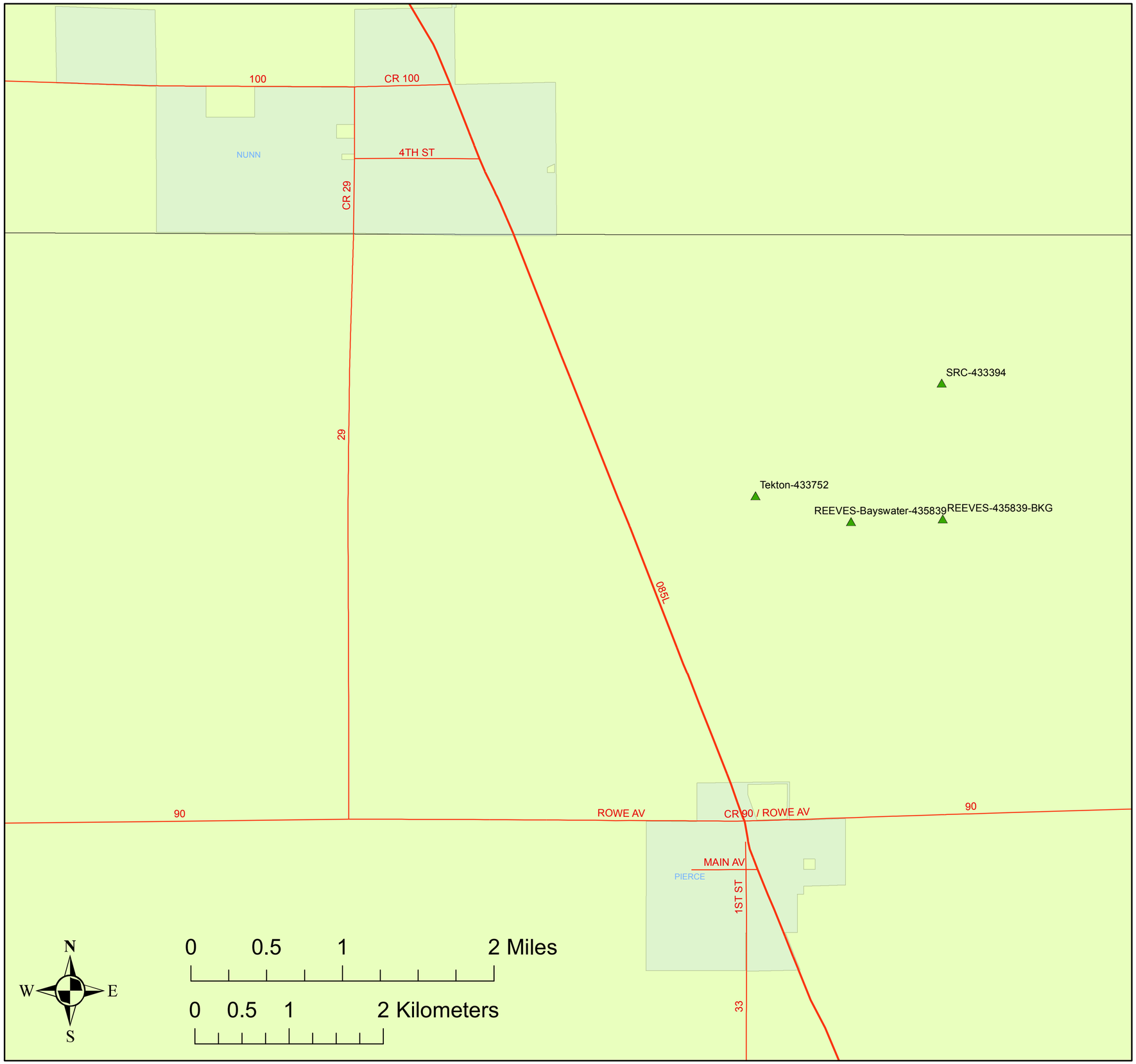


Figure 7 NORM Sample Locations Near Nunn



NORM Sample Locations

SampleType

- Background
- Cuttings
- Major Rds
- Highway
- RadCities
- RadTR

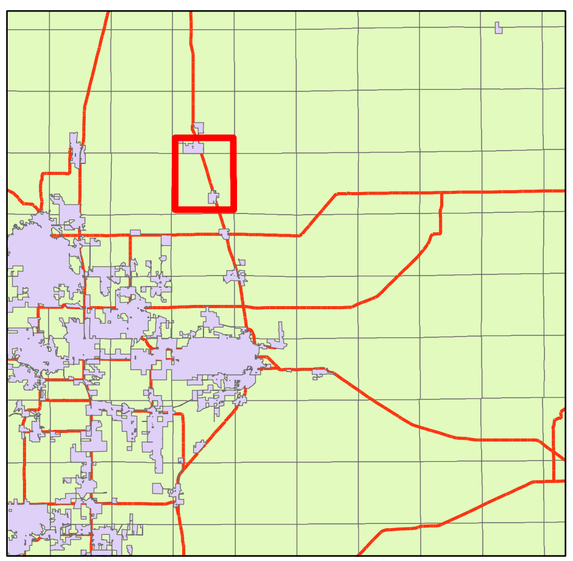
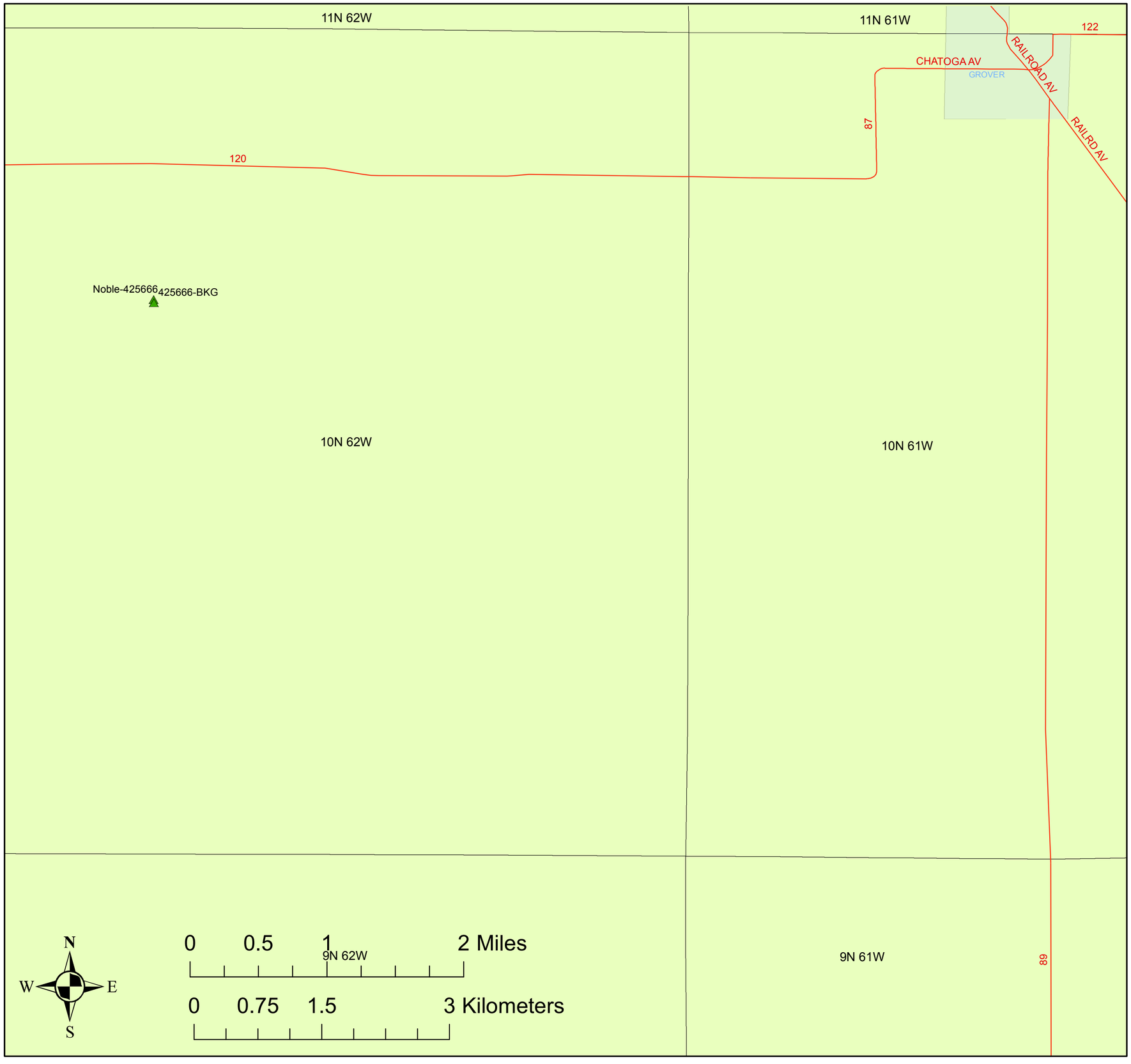


Figure 8 NORM Sample Locations Near Grover



NORM Sample Locations

SampleType

- Background
- Cuttings
- Major Rds
- Highways
- Cities
- Township & Range

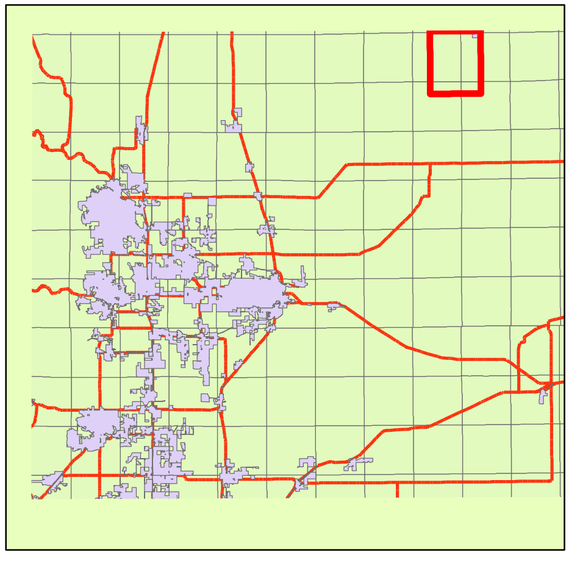
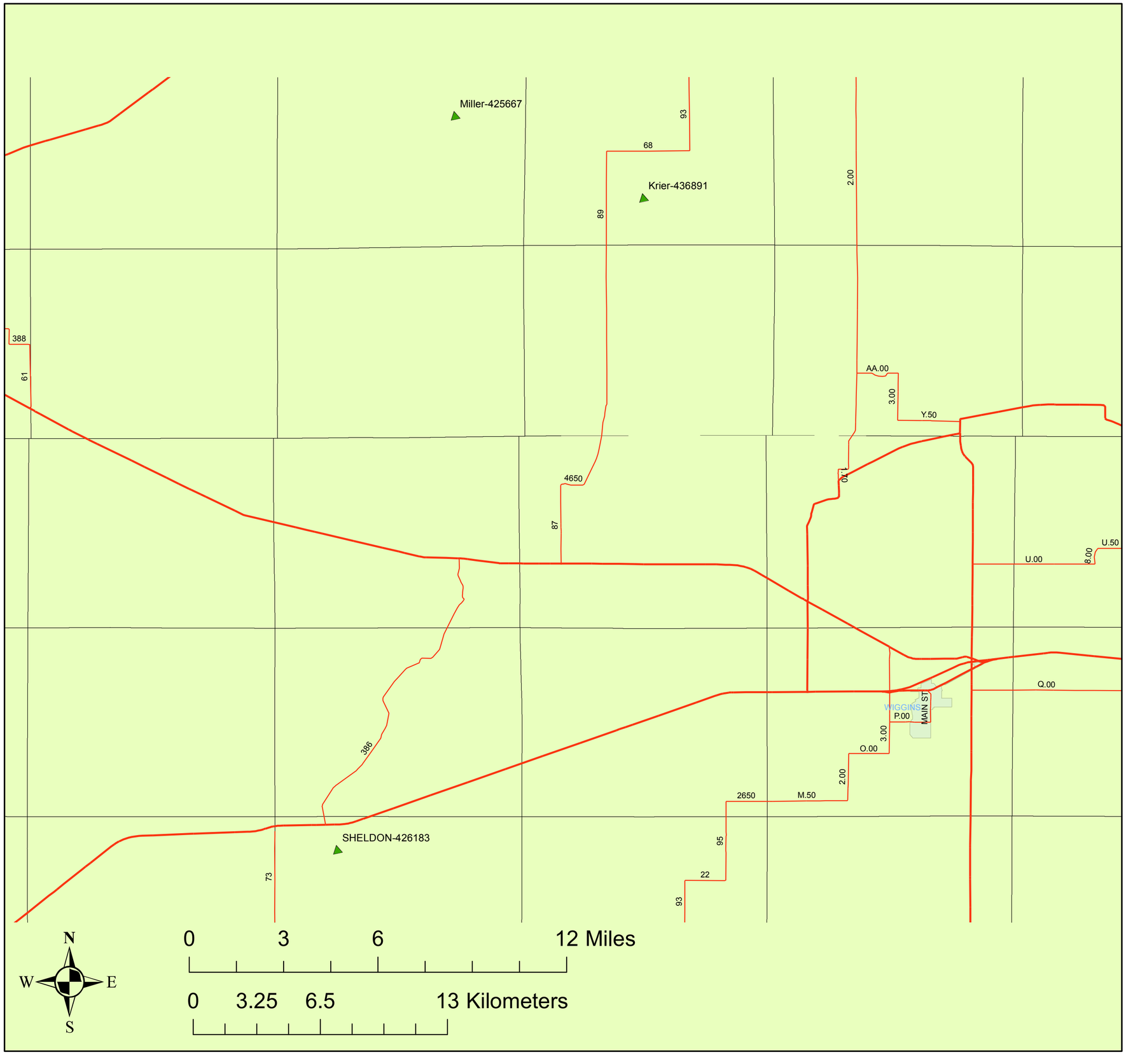


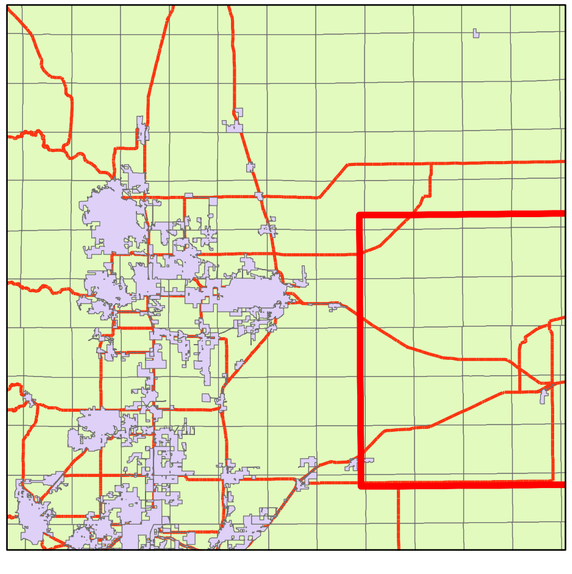
Figure 9 NORM Sample Locations Near Wiggins



NORM Sample Locations

SampleType

- Background
- Cuttings
- Major Rds
- Highway
- Cities
- Township & Range



TABLES

Table 1. Analytical Parameters, Media, Analytical Methods, Quantity, Container Type, Preservation, and Holding Times

Parameter	Media	Analysis Method	Sample Quantity	Container Type	Preservative	Holding Time
Gross Alpha and Gross Beta	Solid	USEPA 900.0	20 grams	Plastic	None	None
Lab Specific Natural Products Library (13 radionuclides) by gamma spectroscopy	Solid	USEPA 901.1 or similar	300 grams	Plastic	None	None
Thorium and Uranium Isotopes	Solid	alpha spectroscopy (ASTM D3972)	50 grams	Plastic	None	None

USEPA – U.S. Environmental Protection Agency

ASTM – ASTM International (formerly known as American Society for Testing and Materials)

Table 2. Approximate Minimum Detectable Activity Using Spectroscopic Gamma Analysis for Radiological Elements of Interest

Element of Interest	Direct or Inferred	Inferred Nuclide	Photon Energy (keV)	Yield (Percent)	Sample MDA (a) Using HPGE (pCi/g)
Ra-228	Inferred	Ac-228	911.2	25.8	1
Th-230	Direct	NA	67.6	0.38	~25 to 125
Ra-226	Direct	NA	186.2	3.59	1 to 5
Ra-226	Inferred	Bi-214	1764.5	46.3	0.1-0.5
Ra-226	Inferred	Pb-214	295.2 and 351.9	15.8	0.1-0.5
U-238 **(b)**	Inferred	Th-234	63.3	4.8	1.9 to 3.5
U-238 **(b)**	Inferred	Pa-234m	1001.0	0.84	~50

(a) The nuclide minimum detection activity (MDA) values stated in the table are from samples analyzed by the HPGe spectrometer in a shielded 1 L Marinelli beaker which is counted for 15 minutes.

(b) XRF may be used for solid matrix uranium determination and ICP-MS used for liquid samples.

pCi/g – picoCuries per gram.

keV – kiloelectron volts.

TABLE 3. GROSS ALPHA AND GROSS BETA SAMPLE RESULTS

SAMPLE ID	SAMPLE DATE	GROSS ALPHA	±	LAB QUALIFIERS	GROSS BETA	±	LAB QUALIFIERS
SYNRGY-DECHANT BRA	05/01/14	2.4	1.0	LT	2.48	0.87	LT
Duplicate Analysis		1.48	0.80	LT	1.81	0.79	LT
KMG-422067	05/16/14	6.8	2.5		7	2.2	
KMG-422067-BKG	05/16/14	6.6	2.1		5.6	1.4	
GOBBLER-2N66W22	05/16/14	5.2	2.4		4.6	1.8	
SUN-NIX-425797	05/16/14	4.7	2.1		3.4	1.6	LT
SUN-NIX-425797-BKG	05/16/14	5.9	1.6		4	1	LT
GOBBLER-2N66W23	05/16/14	9.3	3.3		4.5	1.8	
GOBBLER-2N66W23-BKG	05/16/14	2.75	0.83	LT	3.22	0.78	LT
FRANK#2-434889	05/16/14	5.8	2.5		3.1	1.6	LT
SHELDON-426183	05/21/14	6.7	2.7		5.7	2.0	
Duplicate Analysis		5.2	2.4		5.8	2.0	
BBC-436067	05/21/14	10.0	3.5		3.6	1.7	LT
MACDONALD-431609	05/21/14	4.4	1.4		4.0	1.0	
MACDONALD-431609-BKG	05/21/14	1.74	0.55	LT	2.01	0.51	LT
LUDWIG-431183	05/21/14	3.14	0.83		2.86	0.65	LT
LUDWIG-431183-BKG	05/21/14	5.0	1.2		3.34	0.74	LT
LUDWIG-430649	05/21/14	5.0	2.2		4.8	1.6	
MOSER III -425665	06/04/14	6.8	2.0		4.6	1.3	
MOSER III -425665-BKG	06/04/14	1.28	0.39	LT	2.08	0.47	LT
MOSER FARMS-429348	06/04/14	6.0	2.1		4.8	1.4	
KMG-422060	06/04/14	4.5	1.4		4.0	1.2	
KMG-422060-BKG	06/04/14	4.4	1.4		6.0	1.5	
GREELEY AIRPORT-436890	06/10/14	4.8	1.7		4.3	1.4	
GREELEY AIRPORT-436890-BKG	06/10/14	6.6	1.4		3.99	0.79	LT
TES-436629	06/10/14	5.0	1.6		4.5	1.4	
TES-436629-BKG	06/10/14	6.1	1.8		4.9	1.4	
MILLER-425667	06/10/14	3.3	1.2		5.1	1.8	
KRIER-436891	06/10/14	5.7	1.5		6.3	1.9	
BELLA-18-431606	06/12/14	3.0	1.3	LT	3.4	1.2	LT
SPANDAU-431953	06/12/14	3.0	1.5	LT	4.8	1.4	LT

TABLE 3. GROSS ALPHA AND GROSS BETA SAMPLE RESULTS

SAMPLE ID	SAMPLE DATE	GROSS ALPHA	±	LAB QUALIFIERS	GROSS BETA	±	LAB QUALIFIERS
SPANDAU-431953-BKG	06/12/14	6.0	1.7		5.2	1.4	
REEVES-435839	06/30/14	3.4	1.7		2.5	1.4	LT
TEKTON-433752	06/30/14	4.3	2.0		3.5	1.6	LT
SRC-433394	06/30/14	6.0	2.6		4.7	1.8	
REEVES-435839-BKG	06/30/14	3.05	0.88		3.36	0.80	LT
NOBLE-425666	06/30/14	5.8	2.7		4.1	1.7	
415666-BKG	06/30/14	1.84	0.65	LT	1.98	0.67	LT
Duplicate Analysis		2.02	0.67	LT	1.72	0.53	LT

Note: All concentrations in picoCuries per gram (pCi/g)
LT - Result is less than requested Minimum Detectable Concentration (MDC), greater than sample specific MDC.

Table 4. Gamma Spectroscopy Sample Results

SAMPLE ID	SAMPLE DATE	^{228}Ac	±	LAB QUAILFIERS	^{212}Bi	±	LAB QUALIFIERS	^{214}Bi	±	LAB QUALIFIERS
SYNRGY-DECHANT BRA	05/01/14	1.68	0.63	LT,G,Tl	1.7	1.8	U,G	1.00	0.38	G,J
Duplicate Analysis		1.15	0.45	LT,G,Tl	2.1	1.4	G	1.14	0.36	G,J
KMG-422067	05/16/14	1.65	0.71	LT,G	0.7	1,6	U,G	1.68	0.50	G,J
KMG-422067-BKG	05/16/14	1.91	0.73	LT,G,Tl	2.1	2.3	U,G	1.82	0.52	G,J
Duplicate Analysis		2.08	0.62	G,Tl	1.7	1.9	U,G	1.82	0.47	G,J
GOBBLER-2N66W22	05/16/14	1.66	0.61	LT,G,Tl	2.8	1.8	G,NQ	1.09	0.42	G,J
SUN-NIX-425797	05/16/14	1.92	0.62	LT,G,Tl	2.3	2.2	U,G	0.81	0.38	G,J
SUN-NIX-425797-BKG	05/16/14	1.84	0.58	LT,G	2.5	1.8	U,G	1.01	0.40	G,J
GOBBLER-2N66W23	05/16/14	1.28	0.49	LT,G	1.4	1.7	U,G	0.82	0.43	G,J
GOBBLER-2N66W23-BKG	05/16/14	1.03	0.60	LT,G,Tl	2.1	1.8	U,G	0.98	0.34	G,J
FRANK#2-434889	05/16/14	1.23	0.50	LT,G,Tl	1.7	1.7	U,G	0.95	0.37	G,J
SHELDON-426183	05/21/14	1.20	0.45	LT,G	0.3	1.8	U,G	1.03	0.38	G,J
BBC-436067	05/21/14	1.22	0.59	LT,G,Tl	1.4	2.3	U,G	1.50	0.53	G,J
MACDONALD-431609	05/21/14	0.93	0.43	LT,G	1.7	1.7	U,G	0.97	0.41	G,J
MACDONALD-431609-BKG	05/21/14	1.13	0.50	LT,Tl	2.3	1.8	U	0.56	0.27	J
Duplicate Analysis		0.84	0.37	LT,LI	1.7	1.3	U	0.40	0.27	U,J
LUDWIG-431183	05/21/14	0.98	0.47	LT	0.6	1.4	U	0.28	0.24	U,J
LUDWIG-431183-BKG	05/21/14	1.31	0.47	LT	1.9	1.5	U	0.83	0.33	J
LUDWIG-430649	05/21/14	0.86	0.60	U,G	3.5	1.9	G,NQ	1.49	0.44	G,J
MOSER III -425665	06/04/14	1.10	0.45	LT,G	0.2	2.0	U,G	0.89	0.41	G,J
MOSER III -425665-BKG	06/04/14	0.85	0.37	LT	0.5	1.3	U	0.25	0.27	U,J
MOSER FARMS-429348	06/04/14	1.27	0.62	G,NQ	1.1	1.9	U,G	1.20	0.45	G,J

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{228}Ac	±	LAB QUAILFIERS	^{212}Bi	±	LAB QUALIFIERS	^{214}Bi	±	LAB QUALIFIERS
KMG-422060	06/04/14	0.79	0.36	LT,G,Tl	1.9	1.5	U,G	0.84	0.29	G,J
KMG-422060-BKG	06/04/14	1.60	0.51	LT,G	2.7	2.1	U,G	0.91	0.36	G,J
GREELEY AIRPORT-436890	06/10/14	0.94	0.60	LT,G,Tl	1.0	1.9	U,G	0.84	0.43	G,J
GREELEY AIRPORT-436890-BKG	06/10/14	1.16	0.51	LT,G,Tl	0.4	1.6	U,G	1.14	0.40	G,J
TES-436629	06/10/14	0.69	0.43	U,G	1.3	1.5	U,G	1.08	0.35	G,J
TES-436629-BKG	06/10/14	1.00	0.61	LT,G,Tl	1.6	1.4	U,G	1.21	0.35	G,J
MILLER-425667	06/10/14	0.65	0.53	U,G	0.2	2.0	U,G	1.91	0.54	G,J
Duplicate Analysis		0.44	0.56	U,G	0.6	1.5	U,G	2.12	0.46	G,J
KRIER-436891	06/10/14	1.5	1.0	LT,G,Tl	2.1	2.6	U,G	1.64	0.55	G,J
BELLA-18-431606	06/12/14	0.84	0.62	U,G	-1.9	2.1	U,G	1.09	0.38	G,J
Duplicate Analysis		0.97	0.42	LT,G	0.5	1.9	U,G	1.11	0.35	G,J
SPANDAU-431953	06/12/14	1.22	0.68	G,NQ	0.9	2.2	U,G	1.31	0.45	G
SPANDAU-431953-BKG	06/12/14	1.63	0.57	LT,G,Tl	1.9	1.7	U,G	1.20	0.41	G,J
REEVES-435839	06/30/14	0.63	0.51	U,G	1.3	1.9	U,G	0.90	0.36	G,J
TEKTON-433752	06/30/14	1.19	0.66	LT,G,Tl	0.6	1.6	U,G	0.83	0.36	G,J
SRC-433394	06/30/14	1.41	0.68	G,NQ	2.0	2.1	U,G	1.40	0.48	G,J
REEVES-435839-BKG	06/30/14	0.70	0.44	LT,G,Tl	0.9	1.4	U,G	0.88	0.36	G,J
Duplicate Analysis		0.73	0.57	U,G	0.7	1.8	U,G	0.95	0.40	G,J
NOBLE-425666	06/30/14	0.79	0.58	U,G	0.9	1.6	U,G	1.69	0.47	G,J
415666-BKG	06/30/14	0.85	0.51	LT,Tl	-1.0	1.5	U	0.57	0.30	J

Notes: All concentrations in picoCuries per gram (pCi/g) (2 Sigma Total Propagated Uncertainty [TPU])

LT - Result is less than requested Minimum Detectable Concentration (MDC), greater than sample specific MDC.

U – Analyte was analyzed but result is less than the sample specific MDC (**not detected**).

M3 – The requested MDC was not met, but the reported activity is greater than the reported MDC.

Y2 – Chemical yield outside default limits.

Table 4. Gamma Spectroscopy Sample Results, Continued.

J – Activity value estimated.
NQ – Nuclide is not detected or supported at any level above the reported MDC.
Tl – Nuclide identification is tentative.
G – Sample density differs by more than 15 % of LCS density.

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{40}K	±	LAB QUALIFIERS	^{234m}Pa	±	LAB QUALIFIERS	^{212}Pb	±	LAB QUALIFIERS
SYNRGY-DECHANT BRA	05/01/14	15.8	4.0	G	23	22	U,G	1.32	0.35	G
Duplicate Analysis		14.3	3.3	G	13	16	U,G	1.54	0.34	G
KMG-422067	05/16/14	18.2	4.5	G	-27	26	U,G	2.12	0.44	G
KMG-422067-BKG	05/16/14	19.0	5.0	G	11	25	U,G	2.35	0.52	G
Duplicate Analysis		17.7	4.2	G	15	19	U,G	2.51	0.50	G
GOBBLER-2N66W22	05/16/14	19.0	4.4	G	16	20	U,G	1.26	0.34	G
SUN-NIX-425797	05/16/14	24.4	5.5	G	1	30	U,G	1.55	0.36	G
SUN-NIX-425797-BKG	05/16/14	25.9	5.2	G	10	21	U,G	1.78	0.39	G
GOBBLER-2N66W23	05/16/14	20.4	4.8	G	13	23	U,G	1.32	0.34	G
GOBBLER-2N66W23-BKG	05/16/14	27.5	5.3	G	-6	18	U,G	1.24	0.31	G
FRANK#2-434889	05/16/14	16.0	3.9	G	6	21	U,G	1.04	0.28	G
SHELDON-426183	05/21/14	18.3	4.2	G	0	20	U,G	1.31	0.33	G
BBC-436067	05/21/14	13.8	4.3	G	14	23	U,G	1.05	0.38	G
MACDONALD-431609	05/21/14	21.0	4.9	G	0	21	U,G	1.16	0.32	G
MACDONALD-431609-BKG	05/21/14	29.1	5.2		0	15	U	0.92	0.25	
Duplicate Analysis		29.1	4.9		4	17	U	0.91	0.24	
LUDWIG-431183	05/21/14	26.0	4.9		-5	17	U	1.09	0.30	
LUDWIG-431183-BKG	05/21/14	30.1	5.6		6	21	U	1.19	0.30	
LUDWIG-430649	05/21/14	13.5	3.4	G	-2	18	U,G	1.05	0.27	G
MOSER III -425665	06/04/14	23.2	5.2	G	-10	21	U,G	1.11	0.34	G
MOSER III -425665-BKG	06/04/14	26.6	4.7		10	17	U	0.68	0.23	
MOSER FARMS-429348	06/04/14	15.4	4.1	G	21	24	U,G	0.63	0.28	G

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{40}K	±	LAB QUAILFIERS	^{234m}Pa	±	LAB QUALIFIERS	^{212}Pb	±	LAB QUALIFIERS
KMG-422060	06/04/14	21.5	4.2	G	9	16	U,G	0.83	0.25	G
KMG-422060-BKG	06/04/14	20.1	4.4	G	-11	20	U,G	1.57	0.34	G
GREELEY AIRPORT-436890	06/10/14	18.7	4.9	G	20	22	U,G	0.81	0.30	G
GREELEY AIRPORT-436890-BKG	06/10/14	19.3	4.2	G	6	19	U,G	1.34	0.33	G
TES-436629	06/10/14	15.4	3.6	G	12	20	U,G	0.89	0.27	G
TES-436629-BKG	06/10/14	16.9	3.8	G	3	16	U,G	0.99	0.27	G
MILLER-425667	06/10/14	9.7	3.4	LT,G	13	29	U,G	0.52	0.23	G
Duplicate Analysis		8.9	2.7	LT,G	-2	19	U,G	0.60	0.21	G
KRIER-436891	06/10/14	15.1	4.6	G	3	26	U,G	1.09	0.38	G
BELLA-18-431606	06/12/14	16.3	4.4	G	-13	25	U,G	0.96	0.31	G
Duplicate Analysis		15.8	3.7	G	3	17	U,G	1.25	0.28	G
SPANDAU-431953	06/12/14	15.5	4.5	G	3	21	U,G	1.20	0.34	G
SPANDAU-431953-BKG	06/12/14	24.4	4.8	G	2	18	U,G	1.74	0.40	G
REEVES-435839	06/30/14	17.7	4.5	G	0	24	U,G	1.32	0.35	G
TEKTON-433752	06/30/14	18.7	4.2	G	20	20	U,G	1.06	0.33	G
SRC-433394	06/30/14	10.7	3.4	G	2	24	U,G	0.73	0.27	G
REEVES-435839-BKG	06/30/14	19.9	4.2	G	14	17	U,G	0.93	0.27	G
Duplicate Analysis		21.2	4.5	G	12	22	U,G	0.92	0.27	G
NOBLE-425666	06/30/14	13.8	3.7	G	-6	19	U,G	0.41	0.38	U,G
415666-BKG	06/30/14	20.5	4.3		16	21	U	0.74	0.25	

Note: All concentrations in picoCuries per gram (pCi/g) (2 Sigma Total Propagated Uncertainty [TPU])

LT - Result is less than requested Minimum Detectable Concentration (MDC), greater than sample specific MDC.

U – Analyte was analyzed but result is less than the sample specific MDC (**not detected**).

M3 – The requested MDC was not met, but the reported activity is greater than the reported MDC.

Y2 – Chemical yield outside default limits.

J – Activity value estimated.

Table 4. Gamma Spectroscopy Sample Results, Continued.

NQ – Nuclide is not detected or supported at any level above the reported MDC.

Tl – Nuclide identification is tentative.

G – Sample density differs by more than 15 % of LCS density.

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{214}Pb	±	LAB QUAILIFIERS	^{227}Th	±	LAB QUALIFIERS	^{234}Th	±	LAB QUALIFIERS
SYNRGY-DECHANT BRA	05/01/14	1.21	0.32	G,J	0.3	1.0	U,G	-0.2	2.1	U,G
Duplicate Analysis		1.59	0.31	G,J	-0.88	0.72	U,G	-0.7	1.9	U,G
KMG-422067	05/16/14	1.47	0.39	G,J	-2.4	1.4	U,G	1.8	2.2	U,G
KMG-422067-BKG	05/16/14	1.77	0.44	G,J	0.4	1.2	U,G	-2.9	2.8	U,G
Duplicate Analysis		1.41	0.37	G,J	-0.32	0.97	U,G	2.5	2.9	U,G
GOBBLER-2N66W22	05/16/14	1.26	0.33	G,J	-0.12	0.59	U,G	2.7	2.8	U,G
SUN-NIX-425797	05/16/14	1.03	0.30	G,J	-0.9	1.0	U,G	-0.2	1.9	U,G
SUN-NIX-425797-BKG	05/16/14	0.88	0.29	G,J	-0.33	0.90	U,G	2.7	2.6	U,G
GOBBLER-2N66W23	05/16/14	1.27	0.35	G,J	-0.01	0.57	U,G	0.8	1.9	U,G
GOBBLER-2N66W23-BKG	05/16/14	0.82	0.28	G,J	-0.23	0.47	U,G	0.7	1.6	U,G
FRANK#2-434889	05/16/14	1.03	0.31	G,J	-0.04	0.58	U,G	0.7	2.2	U,G
SHELDON-426183	05/21/14	1.14	0.32	G,J	-0.39	0.85	U,G	-0.5	2.1	U,G
BBC-436067	05/21/14	1.74	0.43	G,J	0.32	0.96	U,G	1.4	3.5	U,G
MACDONALD-431609	05/21/14	0.94	0.31	G,J	0.16	0.54	U,G	0.8	1.4	U,G
MACDONALD-431609-BKG	05/21/14	0.53	0.23	J	-0.58	0.45	U	0.1	1.4	U
Duplicate Analysis		0.57	0.19	J	0.31	0.47	U	0.1	1.6	U
LUDWIG-431183	05/21/14	0.95	0.26	J	0.56	0.69	U	1.3	1.4	U
LUDWIG-431183-BKG	05/21/14	0.98	0.27	J	-0.07	0.45	U	1.1	1.2	U
LUDWIG-430649	05/21/14	1.87	0.39	G,J	-0.06	0.50	U,G	1.6	1.8	U,G
MOSER III -425665	06/04/14	1.06	0.34	G,J	-0.55	0.85	U,G	2.6	2.4	U,G
MOSER III -425665-BKG	06/04/14	0.46	0.18	J	0.03	0.69	U	-1.0	1.6	U
MOSER FARMS-429348	06/04/14	1.04	0.34	G,J	-0.45	0.98	U,G	-0.9	1.9	U,G

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{214}Pb	±	LAB QUAIFLIERS	^{227}Th	±	LAB QUALIFIERS	^{234}Th	±	LAB QUALIFIERS
KMG-422060	06/04/14	0.73	0.22	G,J	0.26	0.73	U,G	0.8	1.7	U,G
KMG-422060-BKG	06/04/14	1.21	0.32	G,J	-0.15	0.49	U,G	1.5	1.3	U,G
GREELEY AIRPORT-436890	06/10/14	1.03	0.34	G,J	-0.24	0.69	U,G	3.3	3.1	U,G
GREELEY AIRPORT-436890-BKG	06/10/14	0.97	0.26	G,J	-0.38	0.82	U,G	0.7	2.1	U,G
TES-436629	06/10/14	1.22	0.31	G,J	0.08	0.83	U,G	1.1	2.1	U,G
TES-436629-BKG	06/10/14	1.62	0.34	G,J	0.13	0.54	U,G	-0.1	2.1	U,G
MILLER-425667	06/10/14	2.31	0.48	G,J	0.46	0.60	U,G	0.7	1.6	U,G
Duplicate Analysis		2.02	0.39	G,J	-0.03	0.46	U,G	1.0	1.3	U,G
KRIER-436891	06/10/14	1.76	0.46	G,J	-0.21	0.80	U,G	1.2	2.3	U,G
BELLA-18-431606	06/12/14	1.07	0.32	G,J	0.13	0.51	U,G	1.2	1.5	U,G
Duplicate Analysis		1.02	0.27	G,J	-0.18	0.42	U,G	1.9	1.4	U,G
SPANDAU-431953	06/12/14	1.45	0.39	G,J	-0.28	0.99	U,G	1.6	2.2	U,G
SPANDAU-431953-BKG	06/12/14	1.17	0.31	G,J	0.40	0.92	U,G	-0.2	2.2	U,G
REEVES-435839	06/30/14	1.21	0.35	G,J	0.12	0.87	U,G	1.4	2.3	U,G
TEKTON-433752	06/30/14	0.83	0.27	G,J	0.14	0.89	U,G	2.0	2.5	U,G
SRC-433394	06/30/14	1.20	0.35	G,J	-1.0	1.1	U,G	1.4	2.2	U,G
REEVES-435839-BKG	06/30/14	0.88	0.26	G,J	0.12	0.49	U,G	-0.9	1.9	U,G
Duplicate Analysis		1.12	0.30	G,J	0.25	0.74	U,G	0.9	1.4	U,G
NOBLE-425666	06/30/14	1.70	0.37	G,J	-0.76	0.86	U,G	1.7	2.4	U,G
415666-BKG	06/30/14	0.73	0.24	J	-0.63	0.79	U	-0.5	1.6	U

Note: All concentrations in picoCuries per gram (pCi/g) (2 Sigma Total Propagated Uncertainty [TPU])

LT - Result is less than requested Minimum Detectable Concentration (MDC), greater than sample specific MDC.

U – Analyte was analyzed but result is less than the sample specific MDC (**not detected**).

M3 – The requested MDC was not met, but the reported activity is greater than the reported MDC.

Y2 – Chemical yield outside default limits.

J – Activity value estimated.

Table 4. Gamma Spectroscopy Sample Results, Continued.

NQ – Nuclide is not detected or supported at any level above the reported MDC.

Tl – Nuclide identification is tentative.

G – Sample density differs by more than 15 % of LCS density.

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{208}Tl	±	LAB QUALIFIERS	^{235}U	±	LAB QUALIFIERS	^{226}Ra	±	LAB QUALIFIERS	^{228}Ra	±	LAB QUALIFIERS
SYNRGY-DECHANT BRA	05/01/14	0.33	0.17	G	0.63	0.66	U,G	1.45	0.33	G	1.68	0.63	G,Tl
Duplicate Analysis		0.31	0.15	G	0.66	0.56	U,G	1.89	0.35	G	1.15	0.45	G,Tl
KMG-422067	05/16/14	0.46	0.22	G	-0.29	0.63	U,G	1.91	0.41	G	1.65	0.71	M3,G
KMG-422067-BKG	05/16/14	0.81	0.27	G	0.12	0.82	U,G	2.29	0.47	G	1.91	0.73	M3,G,Tl
Duplicate Analysis		0.71	0.21	G	0.09	0.71	U,G	2.07	0.42	G	2.08	0.62	G,Tl
GOBBLER-2N66W22	05/16/14	0.32	0.18	G	-0.09	0.57	U,G	1.65	0.38	G	1.66	0.61	G,Tl
SUN-NIX-425797	05/16/14	0.55	0.20	G	-0.17	0.58	U,G	1.27	0.33	G	1.92	0.62	G,Tl
SUN-NIX-425797-BKG	05/16/14	0.68	0.22	G	-0.06	0.61	U,G	1.19	0.32	G	1.84	0.58	G
GOBBLER-2N66W23	05/16/14	0.50	0.20	G	0.17	0.54	U,G	1.43	0.36	G	1.28	0.49	G
GOBBLER-2N66W23-BKG	05/16/14	0.38	0.16	G	0.13	0.40	U,G	1.09	0.29	G	1.03	0.60	G,Tl
FRANK#2-434889	05/16/14	0.25	0.14	G	0.14	0.58	U,G	1.38	0.35	G	1.23	0.50	G,Tl
SHELDON-426183	05/21/14	0.54	0.20	G	-0.08	0.54	U,G	1.51	0.36	G	1.20	0.45	G
BBC-436067	05/21/14	0.43	0.25	G	0.45	0.67	U,G	2.14	0.47	G	1.22	0.59	G,Tl
MACDONALD-431609	05/21/14	0.29	0.17	G	0.16	0.55	U,G	1.22	0.33	G	0.93	0.43	LT,G
MACDONALD-431609-BKG	05/21/14	0.29	0.12		0.29	0.42	U	0.67	0.22	LT	1.13	0.50	Tl
Duplicate Analysis		0.27	0.12		0.07	0.40	U	0.71	0.21	LT	0.84	0.37	LT,Tl
LUDWIG-431183	05/21/14	0.28	0.13		-0.04	0.46	U	0.83	0.24	LT	0.98	0.47	LT

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{208}Tl	±	LAB QUALIFIERS	^{235}U	±	LAB QUALIFIERS	^{226}Ra	±	LAB QUALIFIERS	^{228}Ra	±	LAB QUALIFIERS
LUDWIG-431183-BKG	05/21/14	0.34	0.16		-0.35	0.41	U	1.0	0.28		1.31	0.47	
LUDWIG-430649	05/21/14	0.24	0.17	U,G	-0.08	0.48	U,G	2.14	0.40	G	0.86	0.60	U,G
MOSER III - 425665	06/04/14	0.26	0.17	G	0.55	0.67	U,G	1.28	0.35	G	1.10	0.45	G
MOSER III - 425665-BKG	06/04/14	0.28	0.15		-0.07	0.48	U	0.53	0.20	LT	0.85	0.37	LT
MOSER FARMS-429348	06/04/14	0.17	0.15	U,G	-0.34	0.63	U,G	1.36	0.35	G	1.27	0.72	G,NQ
KMG-422060	06/04/14	0.30	0.13	G	0.14	0.45	U,G	1.05	0.26	G	0.79	0.36	LT,G,Tl
KMG-422060-BKG	06/04/14	0.49	0.18	G	0.09	0.51	U,G	1.41	0.33	G	1.60	0.51	G
GREELEY AIRPORT-436890	06/10/14	0.39	0.18	G	0.29	0.74	U,G	1.23	0.36	G	0.94	0.60	LT,G,Tl
GREELEY AIRPORT-436890-BKG	06/10/14	0.32	0.17	G	0.06	0.65	U,G	1.35	0.31	G	1.16	0.51	G,Tl
TES-436629	06/10/14	0.37	0.19	G	0.11	0.47	U,G	1.45	0.31	G	0.69	0.43	U,G
TES-436629-BKG	06/10/14	0.29	0.15	G	0.43	0.45	U,G	2.00	0.37	G	1.00	0.61	LT,G,Tl
MILLER-425667	06/10/14	0.21	0.17	U,G	0.71	0.66	U,G	2.80	0.52	G	0.65	0.53	U,G
Duplicate Analysis		0.23	0.14	G	0.34	0.44	U,G	2.64	0.44	G	0.44	0.56	U,G
KRIER-436891	06/10/14	0.23	0.19	U,G	0.72	0.73	U,G	2.20	0.48	G	1.5	1.0	M3,G,Tl
BELLA-18-431606	06/12/14	0.30	0.18	G	0.14	0.53	U,G	1.39	0.33	G	0.84	0.62	U,G
Duplicate Analysis		0.38	0.16	G	0.12	0.42	U,G	1.36	0.29	G	0.97	0.42	LT,G

Table 4. Gamma Spectroscopy Sample Results, Continued.

SAMPLE ID	SAMPLE DATE	^{208}Tl	±	LAB QUALIFIERS	^{235}U	±	LAB QUALIFIERS	^{226}Ra	±	LAB QUALIFIERS	^{228}Ra	±	LAB QUALIFIERS
SPANDAU-431953	06/12/14	0.23	0.18	U,G	0	0.63	U,G	1.78	0.41	G	1.22	0.68	G,NQ
SPANDAU-431953-BKG	06/12/14	0.49	0.18	G	-0.12	0.70	U,G	1.57	0.35	G	1.63	0.57	G,Tl
REEVES-435839	06/30/14	0.45	0.20	G	-0.21	0.63	U,G	1.38	0.34	G	0.63	0.51	U
TEKTON-433752	06/30/14	0.31	0.14	G	-0.30	0.69	U,G	1.09	0.30	G	1.19	0.66	G,Tl
SRC-433394	06/30/14	0.21	0.17	U,G	0.48	0.50	U,G	1.57	0.37	G	1.41	0.68	G,NQ
REEVES-435839-BKG	06/30/14	0.28	0.12	G	-0.17	0.53	U,G	1.21	0.30	G	0.70	0.44	LT,G,Tl
Duplicate Analysis		0.35	0.16	G	0.10	0.50	U,G	1.38	0.33	G	0.73	0.57	U,G
NOBLE-425666	06/30/14	0.34	0.20	G	0.38	0.65	U,G	2.25	0.43	G	0.79	0.58	U,G
415666-BKG	06/30/14	0.32	0.14		0.16	0.47	U	0.83	0.24	LT	0.85	0.51	LT,Tl

Notes: All concentrations in picoCuries per gram (pCi/g) (2 Sigma Total Propagated Uncertainty [TPU])

LT - Result is less than requested Minimum Detectable Concentration (MDC), greater than sample specific MDC.

U – Analyte was analyzed but result is less than the sample specific MDC (**not detected**).

M3 – The requested MDC was not met, but the reported activity is greater than the reported MDC.

Y2 – Chemical yield outside default limits.

J – Activity value estimated.

NQ – Nuclide is not detected or supported at any level above the reported MDC.

Tl – Nuclide identification is tentative.

G – Sample density differs by more than 15 % of LCS density.

TABLE 5. ISOTOPIC URANIUM SAMPLE RESULTS

SAMPLE ID	SAMPLE DATE	^{234}U	±	LAB QUALIFIERS	^{235}U	±	LAB QUALIFIERS	^{238}U	±	LAB QUALIFIERS
SYNRGY-DECHANT BRA	05/01/14	1.07	0.21		0.070	0.035	LT	1.24	0.23	
Duplicate Analysis		1.05	0.20		0.054	0.030	LT	0.98	0.19	
KMG-422067	05/16/14	1.05	0.21		0.050	0.031	LT	0.87	0.18	
KMG-422067-BKG	05/16/14	0.93	0.19		0.037	0.027	LT	0.86	0.18	
GOBBLER-2N66W22	05/16/14	0.85	0.18		0.023	0.021	LT	0.72	0.16	
SUN-NIX-425797	05/16/14	0.72	0.16		0.038	0.030	LT	0.58	0.14	
SUN-NIX-425797-BKG	05/16/14	0.54	0.14		0.013	0.022	U	0.72	0.17	
GOBBLER-2N66W23	05/16/14	1.15	0.23		0.054	0.033	LT	1.18	0.23	
GOBBLER-2N66W23-BKG	05/16/14	0.53	0.13		0.010	0.019	U	0.53	0.13	
FRANK#2-434889	05/16/14	0.80	0.16		0.061	0.034	LT	0.75	0.16	
SHELDON-426183	05/21/14	1.01	0.19		0.032	0.022	LT	1.07	0.20	
BBC-436067	05/21/14	1.35	0.25		0.058	0.031	LT	1.25	0.23	
MACDONALD-431609	05/21/14	0.83	0.16		0.059	0.031	LT	0.79	0.16	
MACDONALD-431609-BKG	05/21/14	0.60	0.13		0.026	0.019	LT	0.61	0.13	
LUDWIG-431183	05/21/14	0.61	0.13		0.043	0.028	LT	0.65	0.14	
LUDWIG-431183-BKG	05/21/14	0.62	0.13		0.037	0.025	LT	0.73	0.15	
LUDWIG-430649	05/21/14	1.38	0.25		0.075	0.037	LT	1.41	0.26	
MOSER III -425665	06/04/14	1.06	0.24		0.040	0.033	LT	0.89	0.21	
MOSER III -425665-BKG	06/04/14	0.34	0.11		0.020	0.028	U	0.48	0.14	
Duplicate Analysis		0.43	0.11		0.016	0.019	LT	0.46	0.12	

TABLE 5. ISOTOPIC URANIUM SAMPLE RESULTS

SAMPLE ID	SAMPLE DATE	^{234}U	±	LAB QUALIFIERS	^{235}U	±	LAB QUALIFIERS	^{238}U	±	LAB QUALIFIERS
MOSER FARMS-429348	06/04/14	1.30	0.27		0.071	0.044	LT	1.35	0.27	
KMG-422060	06/04/14	0.90	0.21		0.020	0.028	U	0.85	0.20	
KMG-422060-BKG	06/04/14	1.37	0.27		0.059	0.038	LT	1.22	0.25	
GREELEY AIRPORT-436890	06/10/14	0.98	0.21		0.042	0.032	LT	0.92	0.20	
GREELEY AIRPORT-436890-BKG	06/10/14	0.97	0.21		0.035	0.031	LT	1.07	0.23	
TES-436629	06/10/14	0.86	0.20		0.026	0.026	LT	0.73	0.18	
TES-436629-BKG	06/10/14	1.04	0.23		0.043	0.037	U	0.82	0.19	
MILLER-425667	06/10/14	1.94	0.39		0.123	0.065		2.09	0.42	
KRIER-436891	06/10/14	1.39	0.29		0.080	0.048	LT	1.75	0.35	
BELLA-18-431606	06/12/14	0.90	0.19		0.041	0.032	LT	0.93	0.20	
SPANDAU-431953	06/12/14	1.27	0.26		0.038	0.031	LT	1.24	0.25	
SPANDAU-431953-BKG	06/12/14	1.43	0.28		0.033	0.027	LT	1.34	0.26	
REEVES-435839	06/30/14	0.86	0.19		0.057	0.035	LT	0.91	0.19	
TEKTON-433752	06/30/14	0.94	0.20		0.027	0.028	U	1.02	0.22	
Duplicate Analysis		1.06	0.22		0.056	0.036	LT	1.03	0.21	
SRC-433394	06/30/14	1.15	0.24		0.049	0.033	LT	1.12	0.23	
REEVES-435839-BKG	06/30/14	0.57	0.14		0.024	0.024	U	0.64	0.15	
NOBLE-425666	06/30/14	1.56	0.31		0.076	0.043	LT	1.54	0.30	
415666-BKG	06/30/14	0.74	0.19		0.030	0.030	LT	0.70	0.18	

Note: All concentrations in picoCuries per grams (pCi/g).
LT - Result is less than requested Minimum Detectable Concentration (MDC), greater than sample specific MDC.
U – Result is less than the sample specific MDC (**not detected**).

TABLE 6. ISOTOPIC THORIUM SAMPLE RESULTS

SAMPLE ID	SAMPLE DATE	^{228}Th	±	LAB QUALIFIERS	^{230}Th	±	LAB QUALIFIERS	^{232}Th	±	LAB QUALIFIERS
SYNRGY-DECHANT BRA	05/01/14	1.06	0.20		1.34	0.25	M3	1.15	0.21	
KMG-422067	05/16/14	1.60	0.28		1.81	0.32	M3	1.65	0.29	
Duplicate Analysis		1.47	0.26		1.95	0.34	M3	1.56	0.28	
KMG-422067-BKG	05/16/14	2.12	0.36		1.64	0.29	M3	2.17	0.37	
GOBBLER-2N66W22	05/16/14	1.07	0.20		1.59	0.29	M3	1.15	0.21	
SUN-NIX-425797	05/16/14	1.36	0.26	M3	1.53	0.29	M3	1.27	0.24	
SUN-NIX-425797-BKG	05/16/14	1.64	0.31	M3	1.79	0.33	M3	1.73	0.31	
GOBBLER-2N66W23	05/16/14	1.23	0.23		1.50	0.27	M3	1.28	0.23	
GOBBLER-2N66W23-BKG	05/16/14	1.04	0.21	M3	1.92	0.35	M3	1.15	0.22	
FRANK#2-434889	05/16/14	0.92	0.20	M3	0.81	0.19	M3	0.94	0.19	
SHELDON-426183	05/21/14	1.12	0.30	M3	1.16	0.31	M3	1.24	0.31	
BBC-436067	05/21/14	0.82	0.20	M3	1.48	0.30	M3	0.81	0.18	
MACDONALD-431609	05/21/14	1.11	0.26	M3	0.82	0.21	M3	1.08	0.24	
MACDONALD-431609-BKG	05/21/14	1.04	0.23	M3	0.68	0.18	M3	1.13	0.24	
LUDWIG-431183	05/21/14	1.12	0.26	M3	0.80	0.21	M3	1.20	0.26	
LUDWIG-431183-BKG	05/21/14	1.64	0.34	M3	0.76	0.20	M3	1.48	0.31	
LUDWIG-430649	05/21/14	0.83	0.16		1.50	0.27		0.80	0.15	
MOSER III -425665	06/04/14	1.17	0.20		1.18	0.21		1.12	0.19	
MOSER III -425665-BKG	06/04/14	0.93	0.17		0.54	0.12		0.95	0.17	
MOSER FARMS-429348	06/04/14	0.70	0.15	M3	1.25	0.23		0.66	0.13	
KMG-422060	06/04/14	1.10	0.19		0.96	0.17		1.07	0.18	
KMG-422060-BKG	06/04/14	1.59	0.27		1.42	0.24		1.55	0.26	

TABLE 6. ISOTOPIC THORIUM SAMPLE RESULTS

SAMPLE ID	SAMPLE DATE	^{228}Th	±	LAB QUALIFIERS	^{230}Th	±	LAB QUALIFIERS	^{232}Th	±	LAB QUALIFIERS
GREELEY AIRPORT-436890	06/10/14	0.99	0.19		1.05	0.20		0.91	0.17	
GREELEY AIRPORT-436890-BKG	06/10/14	0.92	0.17		0.90	0.17		0.93	0.17	
TES-436629	06/10/14	1.16	0.22		1.14	0.22		1.03	0.19	
TES-436629-BKG	06/10/14	0.95	0.18		1.29	0.23		0.85	0.16	
MILLER-425667	06/10/14	0.53	0.13	M3	2.17	0.38	M3	0.64	0.13	
Duplicate Analysis		0.51	0.22	Y2,M3	2.21	0.48	Y2,M3	0.70	0.20	Y2
KRIER-436891	06/10/14	0.86	0.18	M3	1.72	0.30		0.84	0.16	
BELLA-18-431606	06/12/14	1.10	0.19		1.35	0.24	M3	1.01	0.18	
SPANDAU-431953	06/12/14	0.94	0.17		2.43	0.40	M3	0.91	0.17	
SPANDAU-431953-BKG	06/12/14	1.53	0.26		1.58	0.27	M3	1.35	0.23	
REEVES-435839	06/30/14	1.03	0.18		1.18	0.21	M3	1.09	0.19	
TEKTON-433752	06/30/14	1.11	0.19		1.26	0.22	M3	1.10	0.19	
SRC-433394	06/30/14	1.00	0.18		1.82	0.30	M3	0.91	0.16	
REEVES-435839-BKG	06/30/14	1.02	0.18		1.46	0.25	M3	0.99	0.17	
NOBLE-425666	06/30/14	0.83	0.16		3.03	0.50	M3	0.94	0.17	
415666-BKG	06/30/14	0.82	0.15		1.06	0.20	M3	0.81	0.15	

Note: All concentrations in picoCuries per gram (pCi/g)

LT - Result is less than requested Minimum Detectable Concentration (MDC), greater than sample specific MDC.

U – Result is less than the sample specific MDC (**not detected**).

M3 – The requested MDC was not met, but the reported activity is greater than the reported MDC.

Y2 – Chemical yield outside default limits.

Table 7. Unrestricted Use TENORM

Materials that do not exceed the following limits may be managed without consideration of the radioactive constituents**:**

Combined $^{226}Ra/^{228}Ra$	**3 pCi/g above background**
Natural Uranium	**30 pCi/g above background**
Natural Thorium	**3 pCi/g above background**

pCi/g – picocuries per gram

^{226}Ra – radium-226

^{228}Ra – radium-228