A SURVEY OF NATURALLY OCCURRING URANIUM IN GROUNDWATER IN SOUTHWESTERN NORTH DAKOTA

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ABSTRACT

In 1991, following a groundwater monitoring project involving the reclamation of abandoned uraniferous lignite mines, the North Dakota Department of Health, Division of Water Quality carried out a groundwater survey of privately owned water wells in areas geographically and geologically similar to those mines. One hundred fifty-eight (158) water samples were collected from wells ranging from surface springs to 100 foot wells. The geographical area covered extended from Dickinson to Belfield and from Bowman to the Killdeer Mountains. Twenty-six percent (26%) of the water supplies sampled exceeded the USEPA proposed maximum contaminant level (MCL) for uranium of 20 micrograms per liter (ug/l), and 14% exceeded 100 ug/l. Repeat sampling in 1992 confirmed the elevated concentrations.

Previously unpublished uranium prospect data from Dr. Cooper Land revealed that 19% of 2,860 water supplies of varying depth exceeded 20 ug/l uranium and 3% exceeded 100 ug/l. This prospect covered much of the counties of Adams, Bowman, Billings, Dunn, Hettinger, Slope and Stark.

The National Uranium Resource Evaluation (NURE) Project, HSSR report documents 575 well and surface water samples collected from western North Dakota for uranium and select trace metals analyses. The report for the Dickinson 1o x 2o Quadrangle shows that 12% of the samples collected exceed 20 ug/l uranium, and 3% exceed 100 ug/l.

A health risk exists for persons consuming uranium tainted water due to its chemical toxicity. Detrimental effects on the renal system have been documented for several compounds containing uranium. Appropriate water treatment is recommended for water supplies exceeding 100 ug/l uranium.

Most of the water supplies sampled in these surveys are completed in the upper Sentinel Butte and Golden Valley Formations, and the White River Group. The majority of samples were collected from relatively shallow water wells, which supports the hypothesis that natural uranium mineralization generally occurs within 300 vertical feet of the Golden Valley/Sentinel Butte contact. However, archived geophysical logs of uranium test drilling show strong deflections in gamma logs at greater depths. This may indicate that uranium mineralization has a much larger vertical range than was previously expected.

INTRODUCTION

In support of reclamation activities by the North Dakota Public Service Commission, the North Dakota Department of Health, Division of Water Quality, conducted groundwater monitoring at four abandoned uraniferous lignite mines. During the monitoring, it was discovered that water from some shallow aquifers outside the mine boundaries exhibited naturally occurring uranium concentrations as high as 13,000 micrograms per liter (ug/l). The United States Environmental Protection Agency (EPA) recently proposed a maximum contaminant level (MCL) of 20 ug/l for public water supplies, based on the chemical toxicity of processe1d uranium and uraniumbearing compounds encountered in industry. For this reason, the department chose to survey a limited number of private water supplies in geologically similar areas of southwestern North Dakota. The field survey was carried out in 1991 and 1992. A total of 234 water samples were collected from 186 farms and homes in an area extending from Bowman and Adams Counties to the Killdeer Mountains, and from the eastern edge of the Badlands to Richardton in Stark County. Figure 1 shows the areas covered by this survey. Air and water samples for radon analysis were collected from 30 residences during confirmation sampling in 1992.

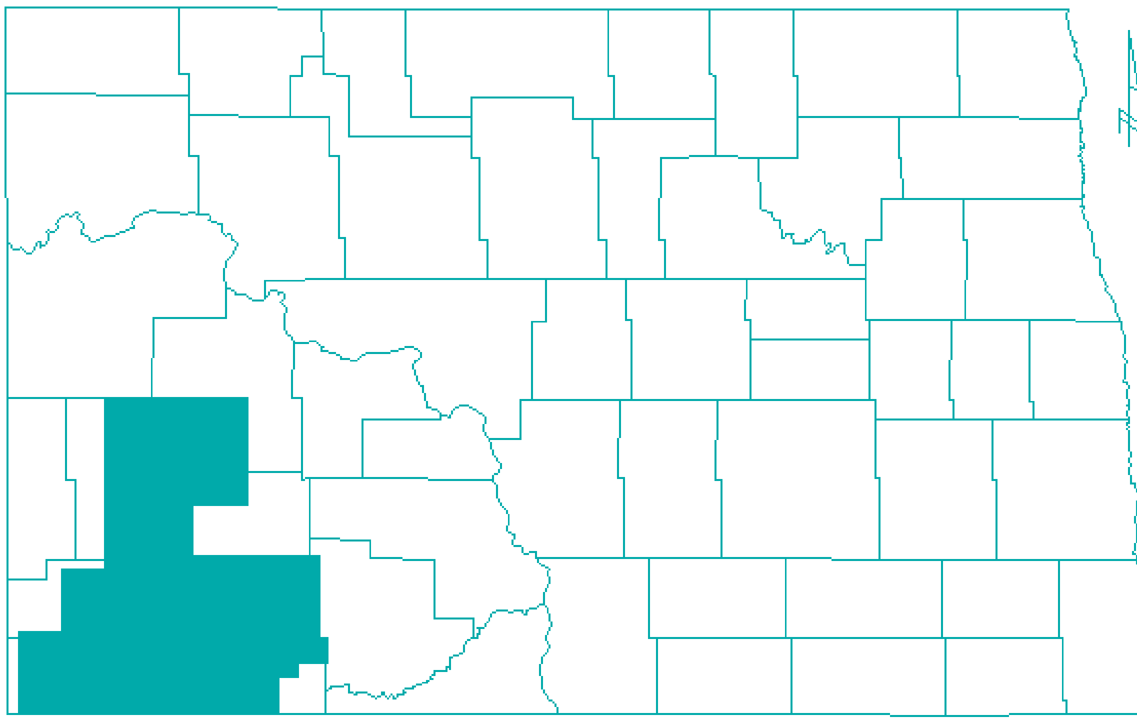

Figure 1 - Southwestern North Dakota uranium survey area.

During the early stages of this project, two resource evaluation studies were encountered and reviewed. One is an unpublished uranium prospect conducted between 1975 and 1977 by Dr. Cooper Land. This project, covering several counties in southwestern North Dakota, in part consisted of collecting 2,864 water supply samples. The second project, that portion of the National Uranium Resource Evaluation (NURE) Project carried out in southwestern North Dakota, consisted in part of collecting 575 water supply samples (Union Carbide Corporation, 1980). Data from these two projects are also discussed in this report. Figures 2 and 3 show the areal extent of these surveys.

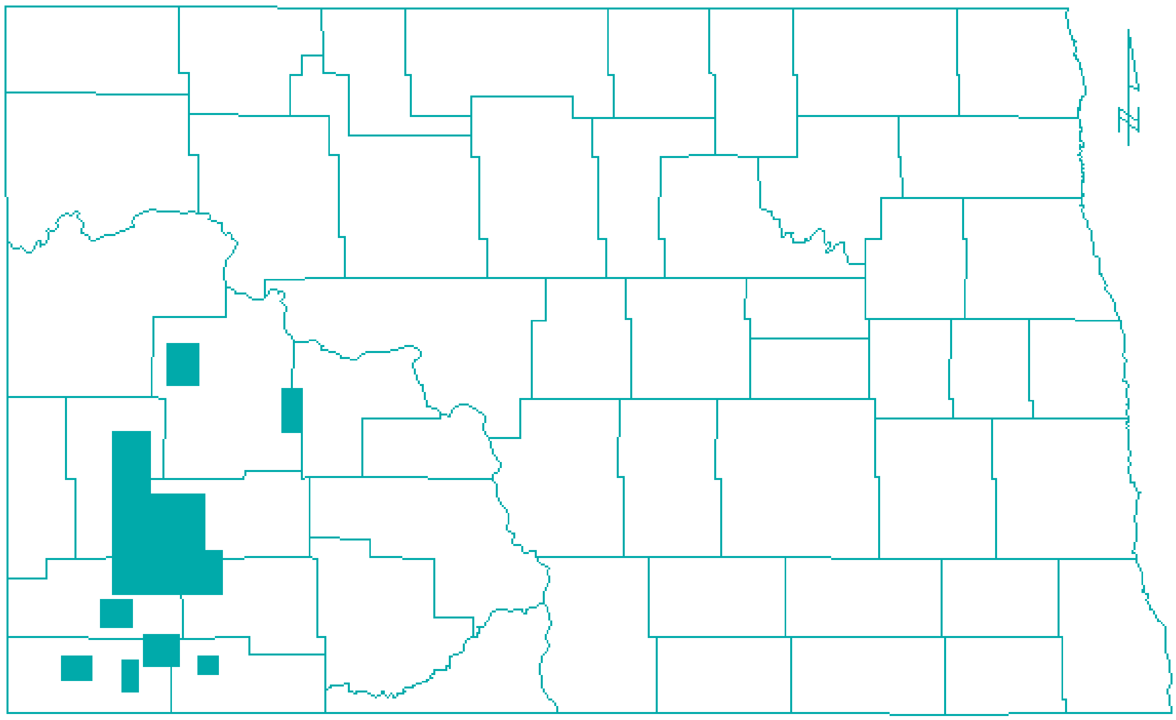

Figure 2- Survey area covered by Dr. Cooper Land.

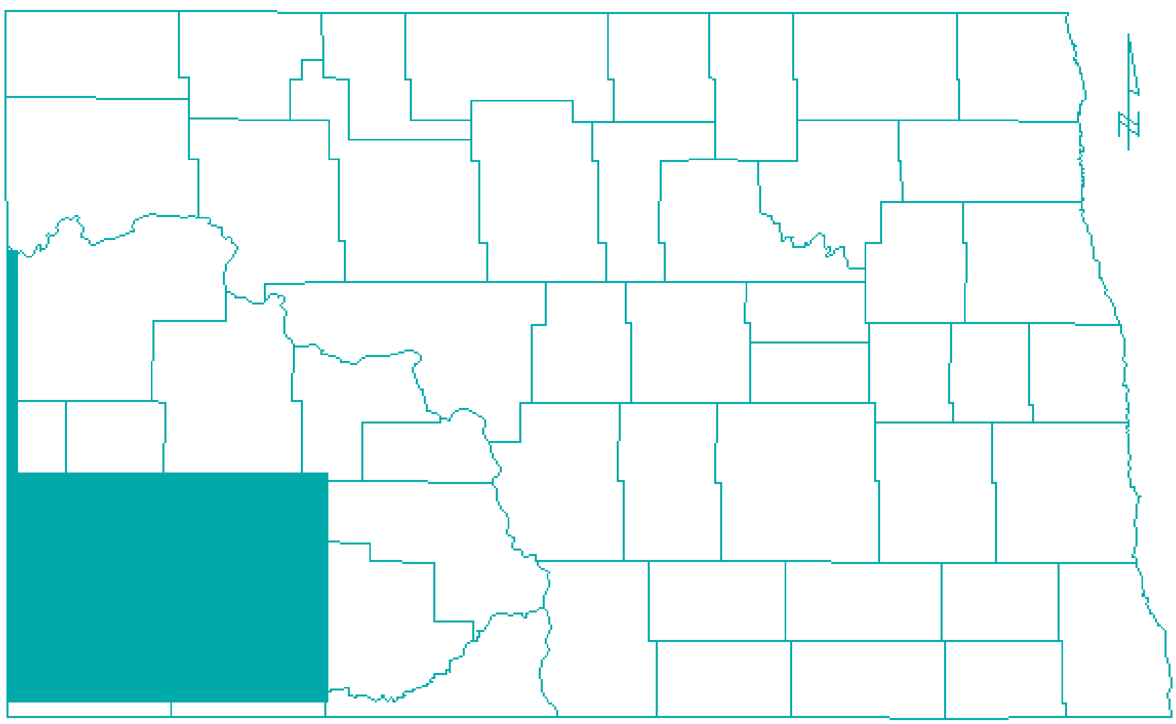

Figure 3- NURE study area in southwest North Dakota.

The area covered by these three studies include the counties of Bowman, Adams, Hettinger, Slope, Billings, Stark, and Dunn Counties in western North Dakota. (Golden Valley, Grant, Sioux, Morton, Oliver, Mercer, and McKenzie Counties are also areas of concern due to similar geologic conditions and a lack of data regarding uranium occurrences).

The area, located on the Missouri Plateau of the Great Plains physiographic province, is found within the Missouri River Basin. The major watersheds of this area are Cedar Creek and BowmanHaley, and the Cannonball, Heart,and Little Missouri Rivers. The terrain consists largely of unglaciated rolling plains, with scattered buttes (Trapp et al., 1975). Along the Little Missouri and Missouri Rivers, Badlands topography dominates in the western portion of the area, giving way to steep bluffs in the eastern portion along the Missouri River.

The study area is characterized by bedrock sediments of Cretaceous and Tertiary age, proceeding stratigraphically from the Cretaceous Pierre Formation to remnants of the White River Formation. The most extensive geologic formations of the area and major focus of this study are the Tertiary Sentinel Butte and Bullion Creek Formations. Also prominent in the study, but of much less areal extent, is the Tertiary Golden Valley Formation which overlies the Sentinel Butte Formation. The geology of this portion of the state is well described by John Bluemle (Bluemle, 1983), Ed Murphy (Murphy et al., 1993), and Art Jacob (Jacob, 1976) of the North Dakota Geological Survey.

Uranium-bearing lignites generally occur less than 350 vertical feet below the unconformity which separates the White River Group sediments from the underlying sediments (Jacob, 1976) of the Golden Valley and Sentinel Butte Formations. Most of the sedimentary rock directly below this unconformity belongs to the Fort Union Group. The uraniumbearing lignites generally occur directly above or below a sandstone aquifer. The widely accepted explanation of mineralization is that percolating groundwater leached uranium from layers high in the stratigraphic section. The most likely source beds seem to be the White River Group and the Arikaree Formation. These sediments are thought to have contained several volcanic ash deposits from which the uranium leached. Rocks of these units reportedly contain uranium concentrations 12 times that of average sedimentary rocks (Denson et al., 1959). The Golden Valley Formation also holds potential as a uranium source (Murphy, personal communication, 1993).

As the uranium-bearing groundwater moved vertically through the underlying strata, it would naturally follow the path of least resistance along permeable sandstone aquifers. This would continue until the uraniumbearing groundwater came into contact with beds rich in organic carbon (i.e., lignites and highly carbonaceous shales). The strong affinity of uranium for organic carbon concentrated the uranium in an amorphous organouranium complex in and near these high carbon beds.

METHODS

North Dakota Health Department Survey. Based on literature and a limited amount of sampling data, it appeared that uranium mineralization was vertically limited. Deep monitoring wells at the abandoned uraniferous lignite mines had significantly lower concentrations of uranium than did the shallow wells. The geology also suggested that deposition of the uranium was limited to the upper portions of the Sentinel Butte Formation along topographic highs. For these reasons, the original plan for the private well survey was to locate water sources associated mainly with topographic highs, stratigraphically high in the Sentinel Butte Formation. With the assistance of the North Dakota Geological Survey, a list of buttes occurring high in this formation was compiled. During this compilation, however, further consideration of the uranium prospecting history and other geologic data caused the department to add the Little Badlands region and areas in Adams, Bowman, and Dunn Counties to the study area. The department targeted the flanks of the buttes in the Sentinel Butte Formation, the flanks of the Killdeer Mountains, and areas of known uranium occurrence. The survey was initially limited to wells with depths of less than 150 feet, although this number was later reduced to 100 feet based on the number of wells encountered. Sampling was begun in July 1991. At each location, the owner or operator was interviewed to determine whether the water supply well met the depth criteria. Information regarding depth, construction, age, and use was collected from the owner. Independent verification through a drilling log search was not attempted for this project. Each sampler carried topographic maps and recorded ground elevation at the wellhead as accurately as possible.

Water samples at each well were collected after flushing the system for at least 5 minutes or until a representative aquifer sample was obtained. Unpreserved samples were collected in 1-liter polypropylene containers for inorganic anion analysis. Samples preserved with 2 milliliters (ml) of concentrated nitric acid were collected in 200-ml polyethylene containers for cation, arsenic, selenium, and uranium analyses. All containers were double rinsed with the source water prior to collection. A goal of 10 percent duplicate samples was maintained during the project. Immediately after collection, all samples were stored in iced coolers for transport to the laboratory. Field-holding time ranged from 2 to 7 days before delivery to the laboratory. The uranium sample containers were delivered to Minnesota Valley Testing Laboratories in Bismarck, where they were repacked and shipped to Energy Labs in Casper, Wyoming for analysis. The other sample containers were delivered to the Health Department's chemistry laboratory for analysis. Analytical data received from the laboratories has been stored in a database management system designed for the purpose.

After preliminary analysis of the accumulated data, it was decided to resample all water supplies which exceeded the EPA-proposed MCL of 20 ug/l. The depth requirement was waived for the confirmation samples, and if possible, all water supplies on the targeted premises were sampled to determine the vertical distribution of uranium occurrence at that location. This second round also provided the opportunity to slightly expand sampling in areas of poor coverage in the first round. The round of confirmation sampling was carried out in April 1992. Analytical results were forwarded to the well owners with a brief explanation of the significance of the findings.

In addition to the sampling described above, air and water sampling for radon was added to the list of confirmation parameters during the follow-up sampling. Radon sample containers and pertinent questionnaires were provided by the Health Department's Division of Environmental Engineering through a contract with Niton Corporation. Roughly half of the collected confirmation samples included duplicate water samples for radon. Due to the very short half life of radon, all water samples for radon were packaged and shipped to Niton Corporation Laboratories by U.S. Mail at the end of each sampling day or the next morning. Water samples were collected for radon analysis in 40-ml, glass, noheadspace bottles. All phases of water sample collection were carried out by field personnel.

Air sampling was initiated at 31 locations. Two samples were collected per household. Sample containers consisted of charcoal traps contained in sealable, 20-ml polyethylene containers. Placement of the containers was discussed with the homeowner and determined by the field personnel. Due to the 48-hour sampling period and the need to minimize transit time to the Niton Corporation Laboratories, homeowners were to start or finish (or both) the tests and mail the sample vials. Department personnel explained all appropriate procedures and filled out all paperwork, except time and date of sample completion.

Water samples delivered to the Health Department's Chemistry Laboratory were logged into the laboratory's system and stored at 4o Celsius until analysis. Major cation analyses were performed on a Perkin Elmer, PII Inductively Coupled, Plazma-Atomic Emission Spectrometer, in accordance with EPA Method 200.7. The analyses for carbonate, bicarbonate, total alkalinity, and hydroxide were performed on a Mettler DL25 autotitrator (EPA Method 310.1). The analyses for chloride and sulfate were performed on a Lachat QuickChem flow injection system (EPA Methods 325.2 and 375.4, respectively). Fluoride determination was accomplished by ion selective electrode (EPA Method 340.2). Specific conductivity was determined on a Wheatstone Bridge (EPA Method 120.1), and laboratory pH was determined by ion selective electrode (EPA Method 150.1). The trace element analyses for arsenic and selenium were performed on a Perkin Elmer, Zeeman 5100 PC, graphite furnace atomic absorption unit (EPA Methods 206.2 and 270.2, respectively). Uranium analyses were performed by Energy Labs on a Jarrell Ash fluorimeter (EPA Method 908.1).

National Uranium Resource Evaluation Survey. The NURE survey was carried out as a resource evaluation and was thus geared toward geochemical prospecting. The objective of the survey was to achieve a uniform sampling of an extremely large area, from which to draw conclusions as to the potential reserves of uranium in the Midwest and West. Due to the emphasis on uniform area coverage, well depth and stratigraphic position were not factors in choice of sampling location. All samples collected in North

Dakota were shipped to and analyzed by Oak Ridge Gaseous Diffusion Laboratories. The reader is referred to the published reports for further information on the methodology of that study.
The data gathered within the Dickinson 1oX2o quadrangle for the NURE study was obtained in second generation digital format from the U.S. Geological Survey. The data was then reformatted into a personal computer-compatible format for analysis. Data required from the Glendive and Miles City, Montana NURE surveys was gleaned from microfiche copies of the reports and added to the data management system.

Dr. Cooper Land Survey. The water sample collection carried out by Dr. Land was also directed toward geochemical prospecting. Dr. Land chose to collect as many samples as possible from potentially leasable properties in southwestern North Dakota. Being one of the first large-scale surveys in that portion of the state, no particular depth limitations were placed on the wells sampled. The samples were collected by two local residents hired by Dr. Land and shipped to Bismarck for reshipment to an out-of-state laboratory. Fluorimetric methods of analysis were used, with an apparent detection limit of 2 ug/l. The data from Dr. Land's survey was stored in hard copy form, and after release to the North Dakota Geological Survey and the Health Department, was entered into a computerized data management system.

RESULTS AND DISCUSSION

1991-1992 North Dakota Health Department Water Quality Survey, Uranium Occurrence. Initial and confirmation samples were combined into one group for analysis. Where confirmation samples were collected, the initial and confirmation samples were averaged. The arithmetic average uranium concentration for all wells sampled was 46.84 ug/l. Forty-eight of the water supplies (25.8 percent) exceeded the proposed MCL of 20 ug/l uranium, and 26 supplies (14 percent) exceeded 100 ug/l. Water supplies sampled in this survey included shallow, developed springs at the ground surface ranging to wells greater than 200 feet in depth; average depth was 79 feet. Water supplies with uranium concentrations above the MCL showed average well depths of significantly less than the overall average. This generally suggests that uranium has been accumulating at shallow depths. Data has been categorized in the same way for each county where samples were collected. A synopsis of the data is shown below.

1991-92 URANIUM CONCENTRATIONS AND WELL DEPTHS BY COUNTY

--------Frequency---------

COUNTY	WELLS SAMPLED	AVERAGE U ug/l	NUMBER >20 ug/l	% >20 ug/l	NUMBER >100 ug/l	% >100 ug/l	AVERAGE DEPTH (ft)
Adams	10	46.2	2	20.0	1	10.0	83
Billings	24	39.1	9	37.5	4	16.7	44
Bowman	24	90.7	10	41.7	8	33.3	142
Dunn	36	3.7	0	0.0	0	0.0	88
Hettinger	10	36.3	2	20.0	1	10.0	87
Slope	29	60.7	12	41.4	6	20.7	63
Stark	53	54.3	13	24.5	6	11.3	70
Total	186	46.84	48	25.8	26	14.0	79

Some of the numbers used here are averages of two or more samples from the same well. In the extreme case, an initial sample contained over 600 ug/l uranium, while a follow-up sample taken nine months later contained only 2 ug/l. The highest concentration of nearly 1,200 ug/l (northeast of Belfield) dropped measurably when averaged with subsequent samples, although the drop was not nearly as radical as the extreme case mentioned. A study of short term variation in uranium concentration was outside the scope of this survey.

Radon Occurrences. Of the 31 air samples initiated for radon analysis, 28 analytical results were received by the department. Sixty-eight percent, or 19 households, exceeded the recommended MCL of 4 picocuries per liter (Pci/l). An additional three households were within one Pci/l of the MCL. Several analyses were questionable due to inappropriate logging of sampling duration by the homeowner; however, adjustments made at the laboratory allow cautious use of those analytical results. Air radon concentrations from the sampled households averaged 11.6 Pci/l, with values ranging from 0.6 Pci/l to 73.4 Pci/l. Minimum and maximum values represent averages of the two vials exposed in each household. Where sampling was carried out on two levels of the home, radon concentrations in the lower level were significantly higher in nearly all cases. A full listing of the analytical results can be found in Appendix B.

Groundwater samples were collected for radon analysis only from wells plumbed directly into the household and used for drinking water purposes. Thirty such groundwater samples were collected, 23 in duplicate. The average radon concentration in groundwater for all 30 sampled households was 2,532 Pci/l, ranging from a minimum of 125 Pci/l to a maximum of 12,474 Pci/l in duplicated samples. Only three of the households exhibited radon concentrations below the proposed MCL of 300 Pci/l for public water supplies. Two more water supplies showed less than 400 Pci/l.

1975-77 Cooper Land Uranium Prospect. The data collected by Dr. Cooper Land was subjected to a similar analysis. A total of 2,864 water supply samples were collected. The arithmetic average uranium concentration was 19.04 ug/l. A total of 530 water supplies (18.5 percent) exceeded the proposed MCL of 20 ug/l uranium, and 81 supplies (2.9 percent) exceeded 100 ug/l.

Water supplies sampled in this survey ranged from shallow, surface springs to wells of more than 2000 feet; average depth was 149 feet. The majority of water supplies exhibiting uranium concentrations greater than 20 ug/l were completed at depths a great deal less than the average. The statistical data has been categorized by county in the same way as the Health Department data. A brief summary of the data is given in the following table.

1975-77 URANIUM CONCENTRATIONS AND WELL DEPTHS BY COUNTY

--------Frequency----------

COUNTY	WELLS SAMPLED	AVERAGE U ug/l	NUMBER >20 ug/l	% >20 ug/l	NUMBER >100 ug/l	% >100 ug/l	AVERAGE DEPTH (ft)
Adams	343	15.4	51	14.9	9	2.6	161
Billings	264	41.4	88	33.3	23	8.7	123
Bowman	469	23.2	95	20.3	23	4.9	202
Dunn	403	10.1	66	16.4	2	0.5	85
Hettinger	602	6.7	43	7.1	0	0.0	148
Slope	316	36.5	82	26.0	14	4.4	184
Stark	467	17.6	106	22.7	11	2.4	113
Total	2864	19.19	531	18.5	82	2.9	149

1979 National Uranium Resource Evaluation (NURE) Project. The data collected during the 1979 NURE Projects in western North Dakota covers an area from northeast of Dickinson to the Montana borders and to within a few miles of the South Dakota border. A total of 575 water samples were collected from water supplies during this survey, with 80 samples showing uranium concentrations in excess of 20 ug/l, and 19 in excess of 100 ug/l. The average concentration of uranium was 15.8 ug/l, and the highest reported concentration of uranium in groundwater was 760 ug/l.

Water supplies sampled in this survey included shallow, surface springs and wells ranging to depths greater than 4,000 feet; average depth was 221 feet. A synopsis of data similar to that performed for the preceding surveys is given below. Data was not categorized by county for this study.

Total number of sample locations: 575

Average total sample U Concentration: 15.80 ug/l**

Average sampled well depth: 221.37 feet

Uranium Concentration	Freq.	Average U ug/l	Average Depth	Well Depth Frequency 0-50	50-100	100-150	150-200	>200
NON-DETECT	134	0.1	343	8	29	17	10	65
0-20.5	361	3.2	202	76	83	55	41	101
20.5-50.5	37	31.5	44	19	11	1	0	1
50.5-100.5	24	70.4	55	9	9	3	0	0
100.5-200.5	10	126.8	69	5	4	0	0	1
200.5-500.5	5	262.3	64	2	3	0	0	0
500.5-1000.5	4	621.7	84	2	0	1	1	0
> 1000.5	0	NA	NA	0	0	0	0	0

** Average total U concentration is the population average including those samples reported below the method detection limit. Below detect values are included using one-half the detection limit.

In addition to groundwater sampling, the NURE teams collected 531 stream sediment samples from drainage basins averaging 10 square miles in area. The average uranium concentration in the stream sediments was 2,820 micrograms per kilogram (ug/kg), with a minimum recorded concentration of 1000 ug/kg and a maximum recorded concentration of 18,000 ug/kg. A total of 171 sediment samples exceeded the average concentration of 2,820 ug/kg. Depth and Geologic Considerations Regarding Uranium. All three regional studies seem to support the mineralization model of Denson and Gill (Denson et al., 1965) described earlier. The most highly concentrated and widespread occurrences of uranium in groundwater appear to be found in aquifers fairly near the land surface. The majority of elevated uranium concentrations occur at depths of less than 150 feet.

As described earlier, the Health Department's survey targeted geologic and topographic areas most likely to show elevated concentrations of uranium. The survey of 186 water supplies sampled only 25 wells which had reported depths of greater than 100 feet. Only three exceeded 20 ug/l uranium.

While the Health Department survey was designed to locate wells meeting a depth criterion of less than 150 feet, Dr. Land's survey and the NURE survey did not have depth limitations. Since the objective of the Land Survey was to locate uranium deposits, all wells encountered within areas of possible mineral leases were sampled. The average well depth was 149 feet. A total of 703 wells of greater than 150 feet in depth were sampled, with 450 of these wells exceeding 200 feet of depth. Of the 703 wells, 34 had water samples exceeding 20 ug/l uranium. Only two samples exceeded 100 ug/l.

One of the criteria of the NURE survey was an approximately uniform coverage of the project area. The average well depth was 221 feet. In the NURE survey of 575 wells, 297 exceeded 100 feet in depth, and 220 exceeded 200 feet. Only eight of the wells greater than 100 feet in depth exceeded 20 ug/l uranium, however.

The relationship of well depth to uranium concentration is clearly shown in Figures 4, 5, and 6, which plot the two parameters for each survey. There is a marked break in uranium concentrations at well depths of about 150 feet. Most of the elevated uranium concentrations in each survey occur at depths of less than 150 feet. For depths over 150 feet, uranium concentrations are generally quite low.

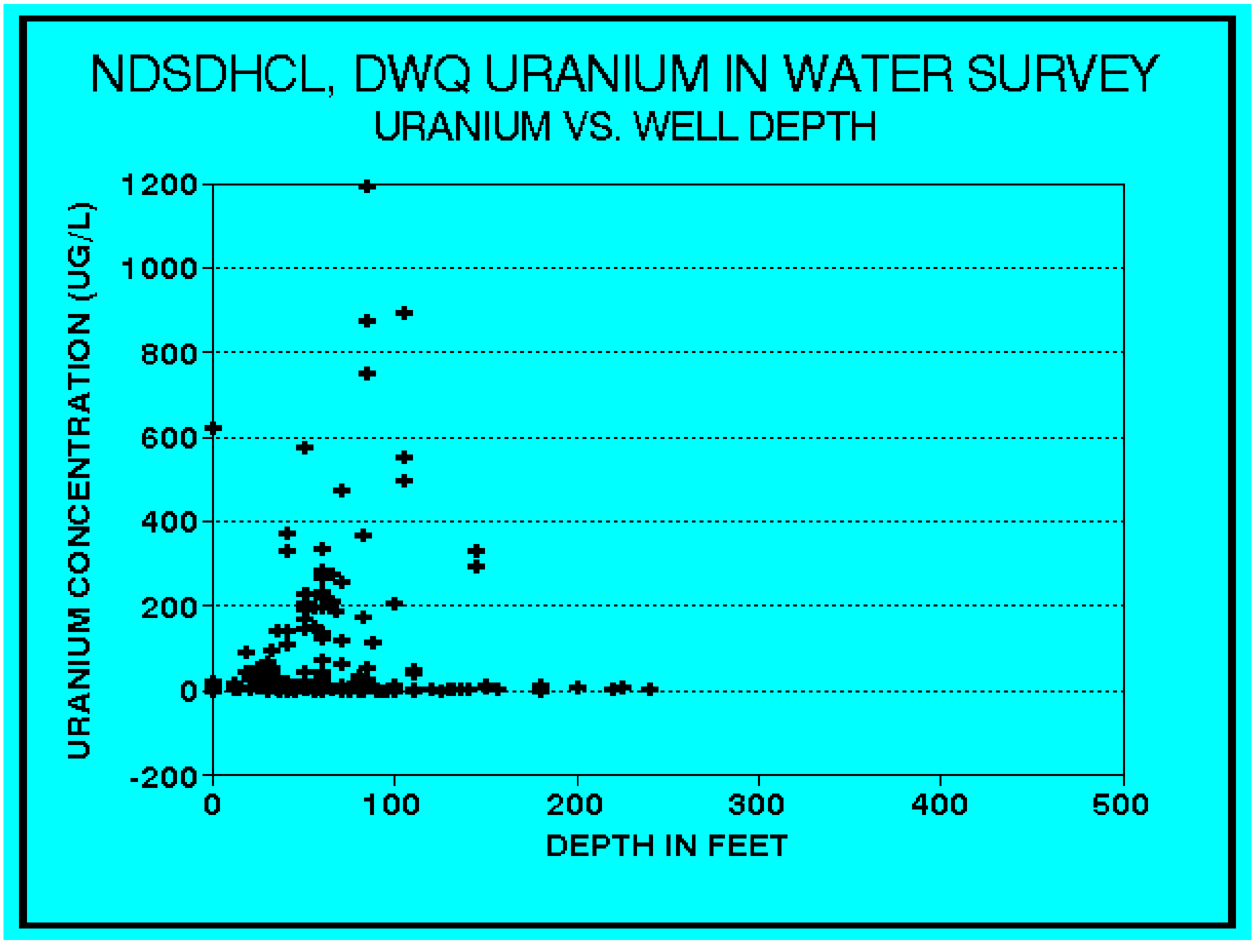

Figure 4 - Uranium concentration as it relates to well depth.

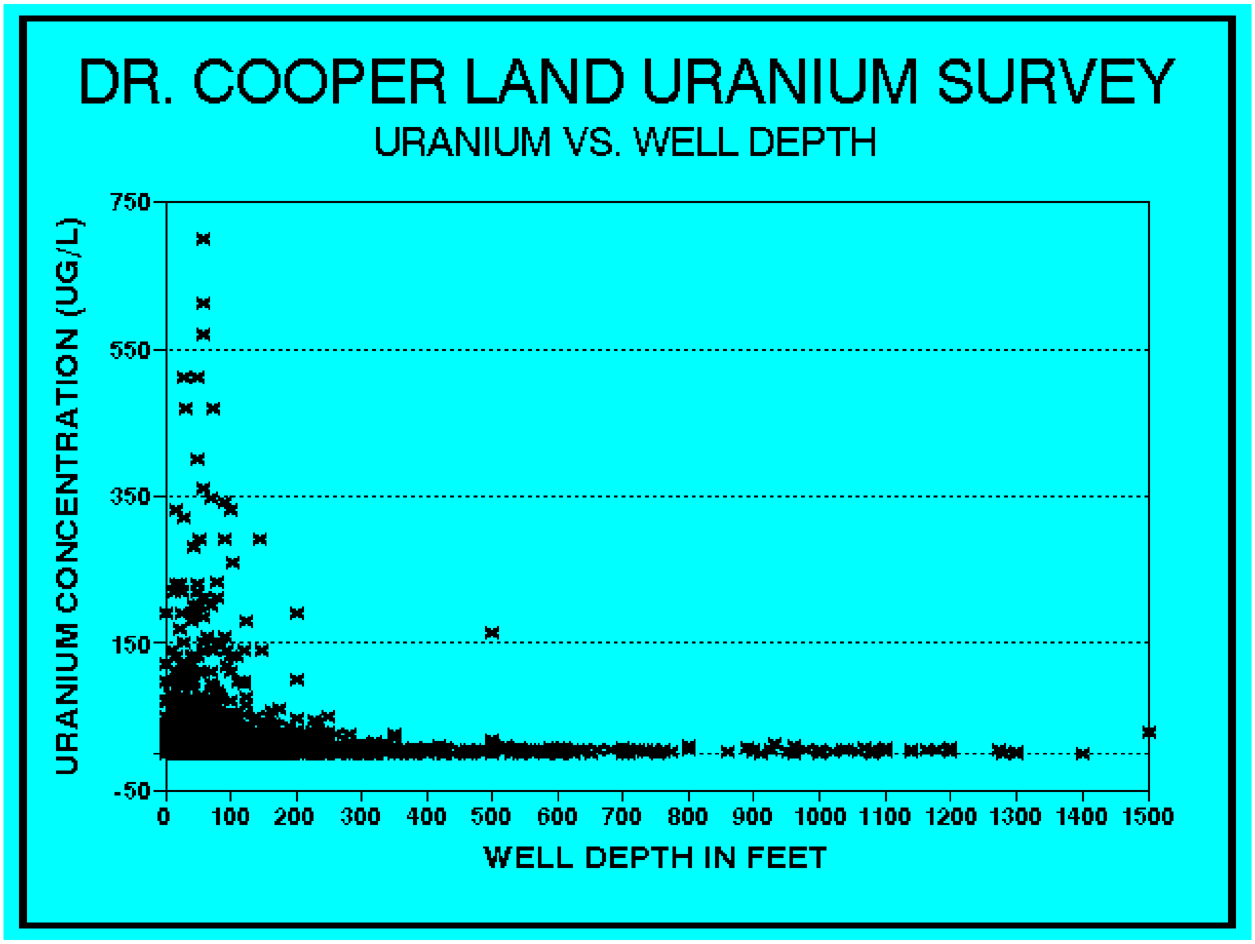

Figure 5- Uranium concentration as it relates to depth, Dr. Land's survey.

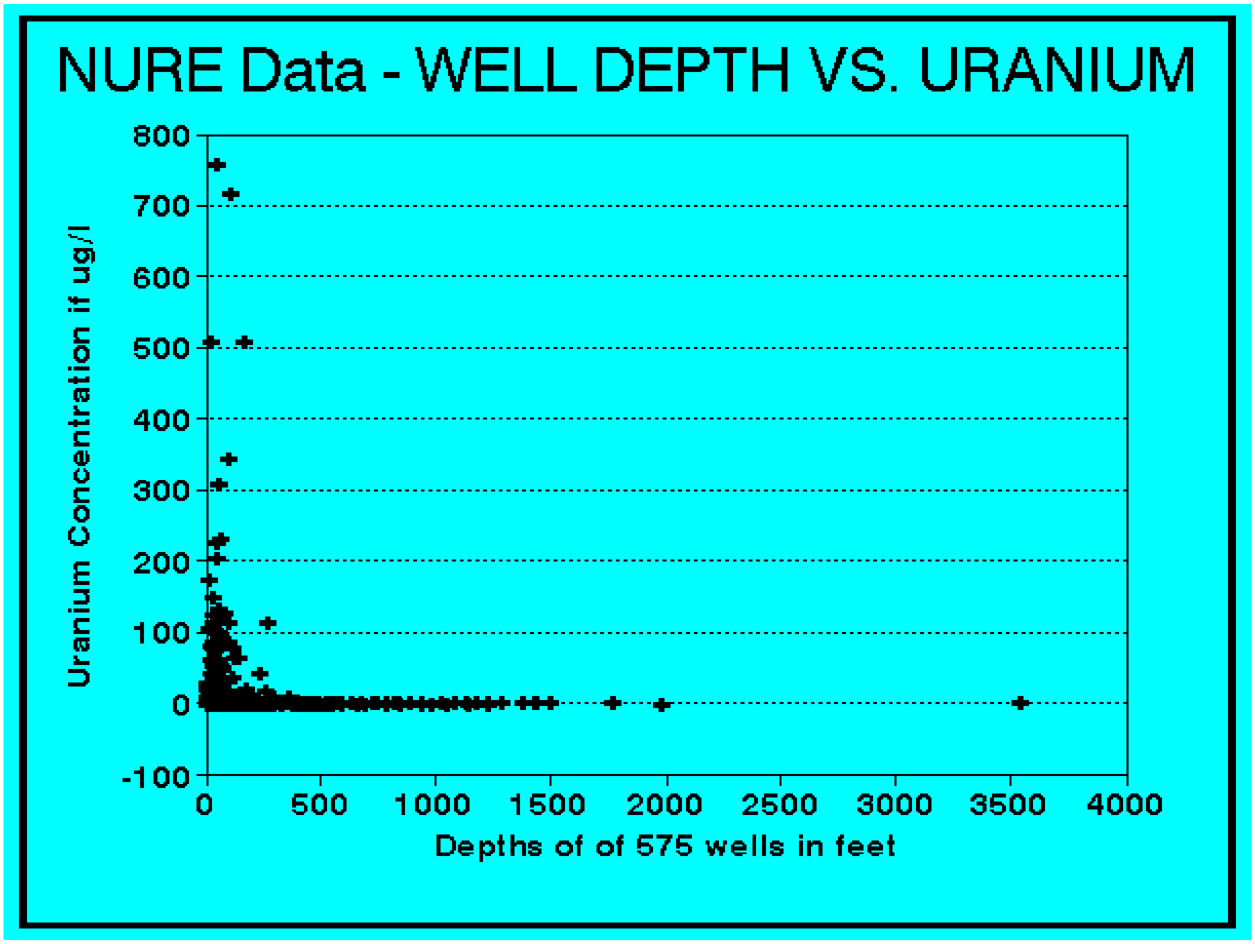

Figure 6 - Uranium concentration as it relates to depth, NURE survey.

Spatially, it appears that well depth increases in the southern portion of the study areas. Figure 7 shows the sampling density of the combined surveys, and Figure 8 shows those locations where well depths exceed 150 feet. Data from the three studies show that well depths average 24 feet deeper in the four southern counties. There also seems to be a slightly higher incidence of elevated uranium concentrations in wells over 150 feet deep in the southern four counties, although most uranium still occurs at depths of less than 100 feet. Figure 9 shows this spatial distribution. There is also data which has come to light through the work of Ed Murphy (Murphy,personal communication, 1993), which supports the theory of a much broader vertical distribution of uranium in this area. Gamma Ray geophysical records from exploration drilling show strong responses to certain strata at greater depths. This same type of response occurs in shallow zones where uranium deposits have been confirmed. If these gamma "kicks" do indeed represent uranium or related radioactive mineralization, then depth generalizations cannot be made without further investigation of the distribution, concentration, and solubility of uranium in these deposits.

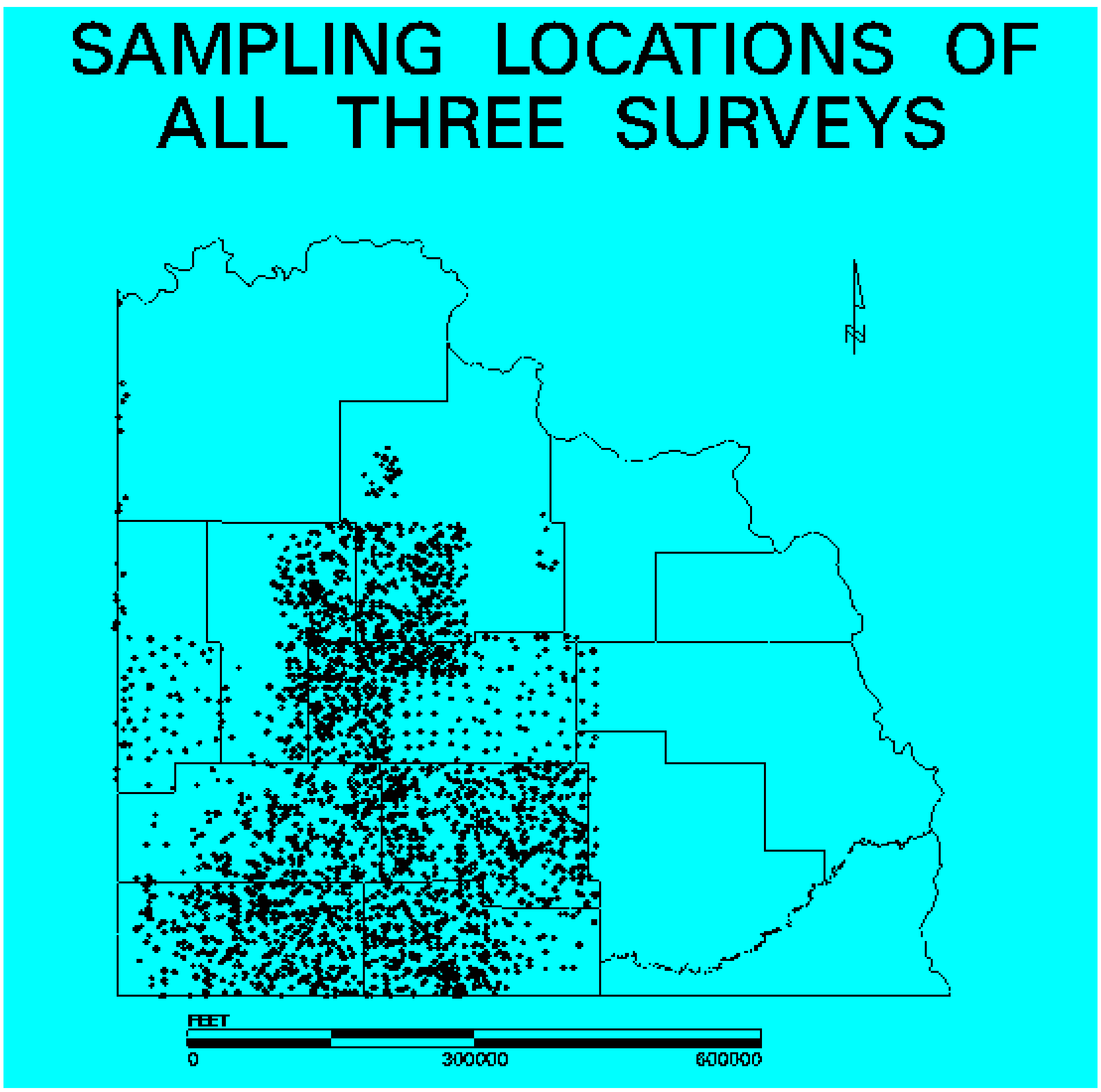

Figure 7- Spacial distribution of sampling locations for the combined surveys.

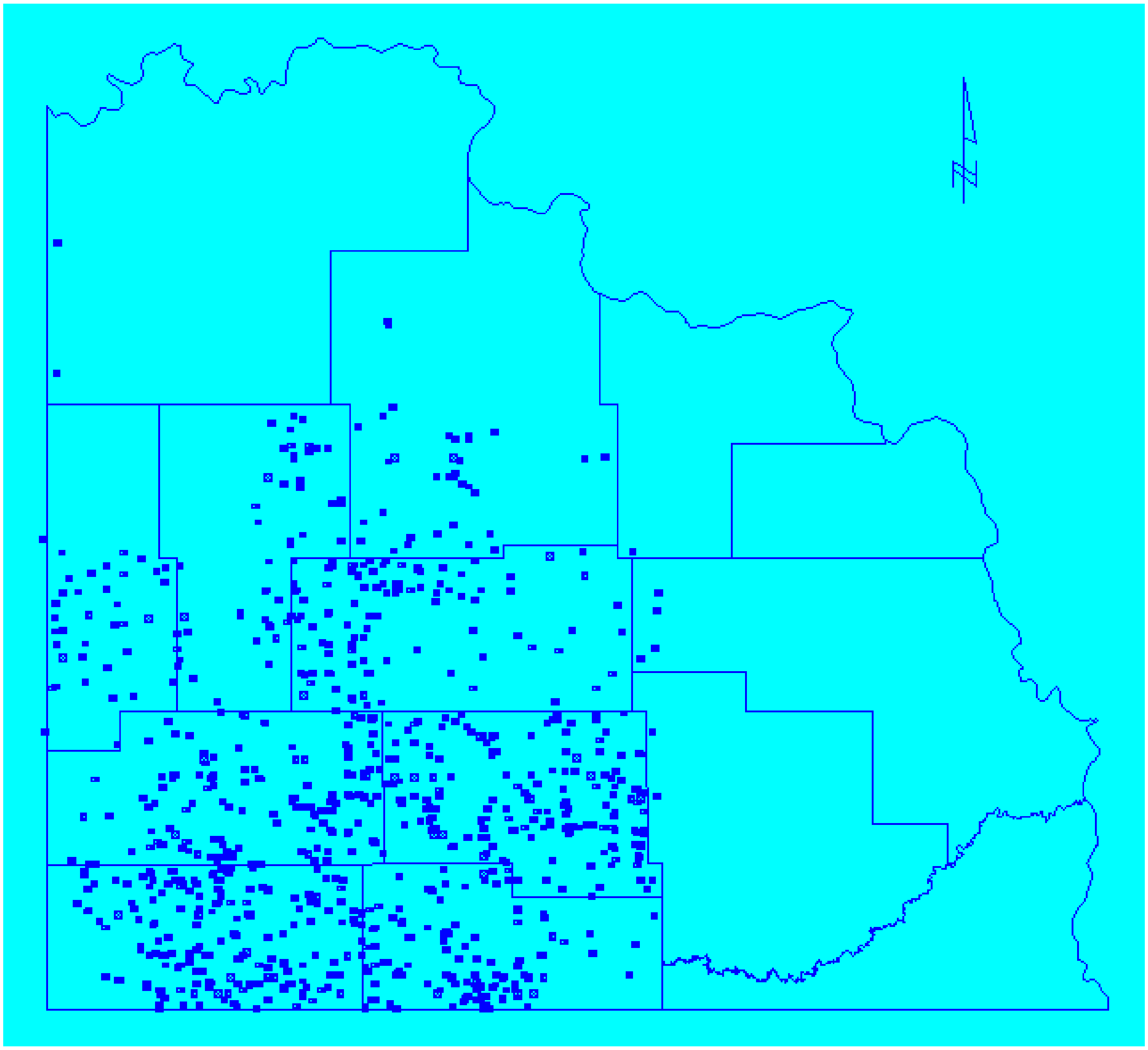

Figure 8 - Spacial distribution of sampling locations with well depth greater than 100 feet.

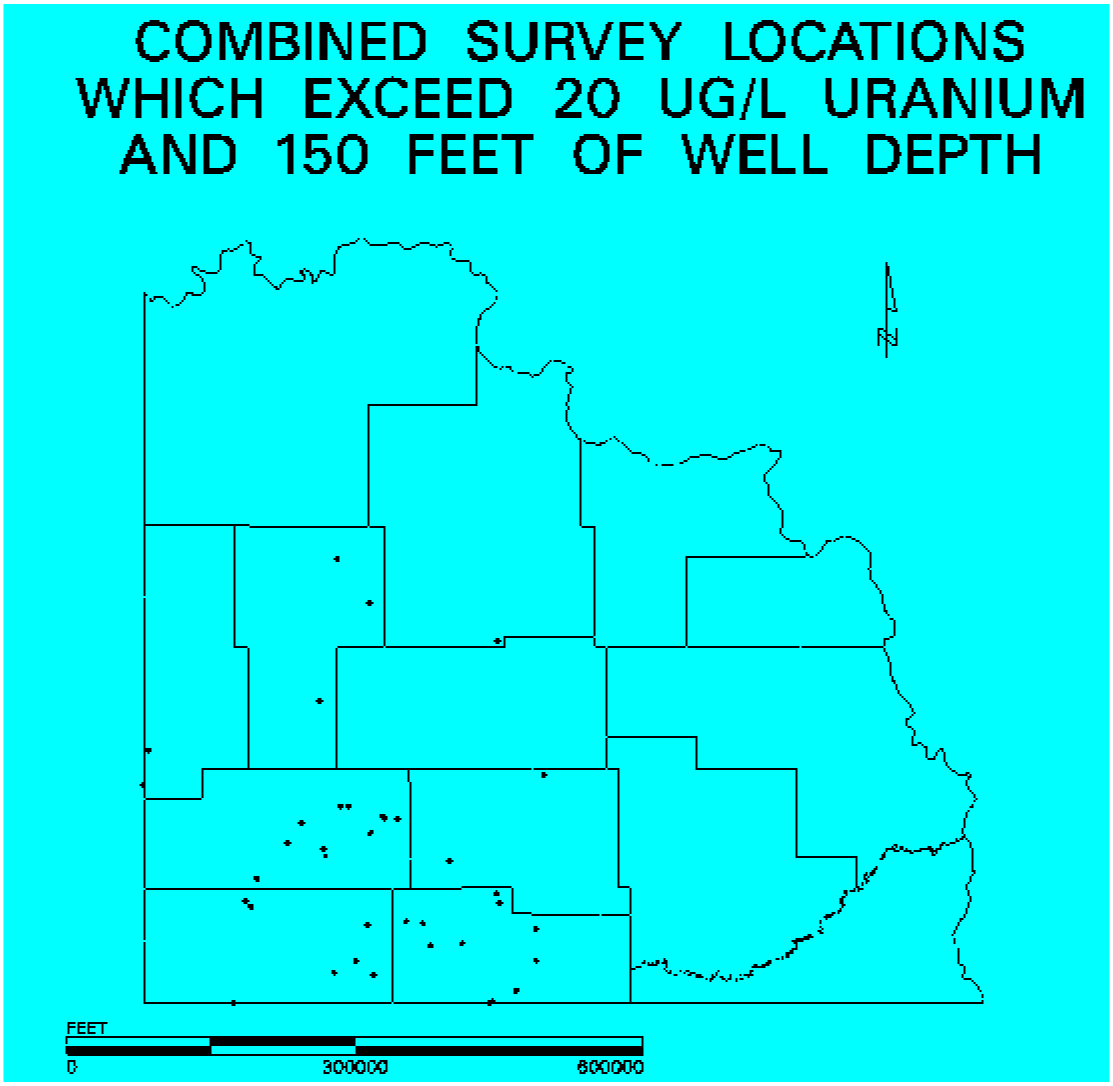

Figure 9- Spacial distribution of sampling locations where well depth exceeds 150 feet and uranium concentration exceeds 20 ug/l.

The integral role of lignite beds or highly carbonaceous strata cannot be confirmed by these studies due to the nature of the sampling methods. Lithologic logs for sampled wells were not available from the owners, and unless their water was organically stained, most did not remember whether lignite beds had been penetrated during drilling. Many of the wells predate the water well construction reporting law, although some information may now be available. It is assumed, however, that the accepted mineralization model applies across the area and at all depths. Review of exploration activity records may verify the presence of highly carbonaceous beds immediately above or below affected sandstone aquifers.

POPULATION AT RISK

In at least one of the surveys, samples have been collected in the counties of Adams, Billings, Bowman, Dunn, Golden Valley, Grant, Hettinger, Mercer, Morton, Slope, and Stark. Few samples were collected from Grant, Morton, and Mercer Counties, and no samples were collected from McKenzie, Oliver, and Sioux Counties. However, since sampling has shown that uranium occurs in most of the stratigraphic units southwest of the Missouri River, all counties will be included in the following analysis. According to the 1990 Census, the populations of the included counties total 90,757. Of that number, 32,644 people reside in rural settings. The Census also estimates that 13,114 rural households (2.5 persons per household) rely on privately owned wells or springs for water supply. These water supplies are not regulated by the Safe Drinking Water Act and, therefore, are not regularly tested for extensive water quality parameters.

In 1992, the Health Department's Municipal Facilities Division conducted a limited survey of public water supplies for the presence of radon and uranium. Two facilities per county were targeted across the state, and at each facility, samples were collected from the shallowest and deepest groundwater supply. For the counties included in this project, the survey revealed that the sampled supplies had levels near or below detection levels for uranium and generally close to or greater than the proposed MCL for radon in water. As shown in the previous discussion, it generally appears that most uranium mineralization occurs at depths of less than 150 feet. Due to the limited number of public facilities sampled, these supplies should be further investigated. Appendix E lists the public water supplies and populations served in southwestern North Dakota, along with the well depths on record with the Health Department. By applying a depth criterion of 150 feet and by eliminating surface water supplies and those systems which have been sampled and found safe, the populations of 12 public water systems have been included in the potential population at risk from uranium intake through drinking water. The total population being served by these 12 systems is 9,813, which averages 817.8 persons per system.

By weighting the averages in the three data sets, the gross possibility of encountering uranium concentrations greater than 20 ug/l in a water supply was calculated at 18.2 percent. Applying this factor to the number of rural and public water supplies shows that 2,386 private supplies and two public supplies have the potential to exhibit uranium concentrations greater than 20 ug/l. Those samples exhibiting concentrations greater than 100 ug/l compose 3.5 percent of the sample sets. By applying this factor in the same manner, it is possible that 459 private water supplies will have levels exceeding 100 ug/l uranium. There is also a 40 percent chance that one public water supply will have a uranium level exceeding 100 ug/l. This translates into a human population of 7,602 potentially consuming water exceeding 20 ug/l uranium, and 1,965 potentially consuming water exceeding 100 ug/l. The above population figures are averages and estimates. A worst case scenario could show significantly higher numbers, particularly in regard to public water supplies not yet tested. The populations served by the public systems range in size from 25 to 3,363. In a worst case, the total population exposed to levels of uranium greater than 20 ug/l could exceed 12,600.

<u>Long-Term Variation of Uranium in Groundwater</u>. Selected data from Dr. Land's and the Health Department's data sets were compared for long-term uranium concentration variations. Although a rigorous analysis was not attempted due to the uncertainty of matching wells in both studies, some wells appearing in both data sets were compared. It does not appear that there has been any significant change over the 17 years separating these two surveys. The uranium concentrations in identified wells were strikingly similar in both studies and well within the ranges which would be expected, given technology and laboratory changes. No attempt was made to compare either of these two data sets with the NURE data set due to differences in data format.

CONCLUSIONS

Three independent surveys were performed between 1975 and 1992 determining the concentration of uranium in drinking water sources in southwestern North Dakota. The largest (in number of samples collected) and earliest of the three was conducted by Dr. Cooper Land from 1975 to 1977. Dr. Land's results showed that nearly 18.5 percent of the samples collected exceeded 20 ug/l uranium, and 3 percent exceeded 100 ug/l. The second survey, conducted on behalf of the U.S. Department of Energy, covered the largest area in the most uniform manner. This NURE survey showed that 13.9 percent of the samples exceeded 20 ug/l uranium, and 3.3 percent exceeded 100 ug/l. The latest survey, completed for this investigation, was the smallest and most focused. While a great deal of geographic area was covered, only regions predicted to have elevated uranium occurrences were considered. This survey found that 25.8 percent of the water supplies sampled exceeded 20 ug/l, and 14 percent exceeded 100 ug/l uranium. A weighted average of all three surveys showed that 18.2 percent of the water supplies in southwestern North Dakota have uranium levels potentially exceeding 20 ug/l uranium, and 3.5 percent have levels potentially exceeding 100 ug/l.

Literature regarding the health risk involved with long-term consumption of naturally occurring uranium in drinking water is sparse. The EPA has proposed an MCL of 20 ug/l in public drinking water supplies, which may be overly protective for private water supplies. According to several pieces of literature and EPA, long-term consumption of up to 100 ug/l would probably pose little or no health risk, except to certain hypersensitive individuals. Therefore, the Health Department is advising all homeowners that they should be aware of the presence of uranium in their drinking water at concentrations between 20 and 100 ug/l, and should consider an alternate water supply or water treatment if their drinking water exceeds 100 ug/l.

Although detailed analysis of the chemical and physical associations of uranium in groundwater was not within the scope of this study, some generalizations may be suggested. The general depth of water wells in southwestern North Dakota is less than 150 feet, and the highest percentage of elevated uranium occurrences seem to be in this range. However, information from the North Dakota Geological Survey has raised some questions regarding deeper formations which may also exhibit high uranium content. The majority of uranium occurrences appear in waters having total dissolved solids (or mineral content) below 2,000 mg/l. This is probably directly related to the relatively shallow depths of withdrawal.

REFERENCES

Bluemle, John, 1983, Bedrock Geologic Map of North Dakota Denson, N. M., and J. R. Gill, Uranium-Bearing Lignite and Carbonaceous Shale in the Southwestern Part of the Williston Basin - A Regional Study, Professional Paper 463, 1965.

Denson, N. M., G.O. Bachman, and H. D. Zeller, "UraniumBearing Lignite in Northwestern South Dakota and Adjacent States," U.S. Geological Survey Bulletin 1055B, Uranium in Coal in the Western United States, U.S. Geological Survey Bulletin 1055, 1959, p36.

Jacob, A.F., Geology of the Upper Part of the Fort Union Group (Paleocene), Williston Basin, With Reference to Uranium, Report of Investigation No. 58, North Dakota Geological Survey, 1976, 49p.

Land, C., "Uranium Deposit Prospect, Southwestern North Dakota," Unpublished, 1977.

Murphy, Ed, Personal Communication, 1993.

Murphy, E.C., J.W. Hoganson, and N.F. Forsman, The Chadron, Brule, and Arikaree Formations in North Dakota, The Buttes of Southwestern North Dakota, Report of Investigation No. 96, North Dakota Geological Survey, 1993, 144p.

Trapp, H., Jr., and M.G. Croft, Geology and GroundWater Resources of Hettinger and Stark Counties, North Dakota, County GroundWater Studies 16 - Part I, North Dakota State Water Commission, 1975, 51p.

Union Carbide Corporation (ORGDP), Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Dickinson NTMS Quadrangle, North Dakota, U.S. Department of Energy, 1980.

------, Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Glendive NTMS Quadrangle, Montana, U.S. Department of Energy, 1980.

------, Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Mile City NTMS Quadrangle, Montana, U.S. Department of Energy, 1980.

U.S. Bureau of Census, 1990