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Jack  
Pearce



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# **Project Rulison**

**1970**

## **Environmental Surveillance Summary Report**

◀ **Colorado Department of Health**

DIVISION OF OCCUPATIONAL AND RADIOLOGICAL HEALTH

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STATE OF COLORADO

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PROJECT RULISON

1 9 7 0

Environmental Surveillance

Summary Report

Colorado Department of Health

Division of Occupational and Radiological Health

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## FOREWORD

Project Rulison is an experimental Plowshare project undertaken cooperatively by the Atomic Energy Commission (AEC) and the Department of Interior for the government, and Austral Oil Company and CER Geonuclear Corporation for private industry. As required by law, the AEC has had complete custody and control of the nuclear explosive device used in the experiment. This statutory responsibility is provided under Section 31 of the Federal Atomic Energy Act of 1954 as amended. After the underground detonation on September 10, 1969, the AEC continued to exercise supervisory control of all project activities.

Other participants in the project include:

Eberline Instrument Company (EIC), Santa Fe, New Mexico, charged with on-site health and safety control.

Southwestern Radiological Health Laboratory (SWRHL), Las Vegas, Nevada, charged with off-site safety and environmental monitoring and surveillance activities.

Lawrence Radiation Laboratory (LRL), Livermore, California, which is conducting environmental sampling for an ecological study.

The United States Geological Survey and United States Bureau of Mines are concerned with special portions of the project.

During the detonation phase of the experiment, the Occupational and Radiological Health Division (O & RHD) of the Colorado Department of Health participated cooperatively with SWRHL in their off-site activities and also conducted an independent environmental surveillance program. These activities have been discussed in the periodic Rulison Progress Reports.

The Department is authorized by state statute (Chapter 66, Article 26, Section 3 CRS 1963, amended 1965) "to develop and conduct programs for evaluation and control of hazards associated with the use of any and all radioactive materials and other sources of ionizing radiation." In accord with this philosophy, our effort has been directed toward the collection of air, air moisture, water and milk samples in or near populated areas around the Rulison site and the analysis of these samples within the Department's laboratory capabilities. The resulting data show environmental levels of radioactivity for an extensive area of Western Colorado. It has not been the Department's intent, nor would it have been possible to provide a complete environmental surveillance and monitoring service for this particular project.

This summary is for the 1970 calendar year.

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## SUMMARY

The monitoring and sampling networks maintained by the Colorado Department of Health during the detonation phase of the Project Rulison Experiment have been continued in 1970 throughout the reentry and flaring activities. In addition, tritium analysis capabilities and air moisture sampling techniques have been developed to expand the Department's environmental surveillance program.

A total of 2,432 radiochemical analyses have been done on 954 environmental samples pertaining to Project Rulison by the Department during 1970. These include:

- 644 air particulate filter samples
- 49 air moisture samples
- 209 precipitation and water samples
- 52 composite milk samples

Schedules for the flaring of natural gas from the Rulison chimney are outlined in the Narrative to establish the periods of time involved and to give the approximate amounts of gas released in this manner. Sample collection and monitoring activities were correlated with these flaring phases whenever possible.

~~The data discussed in this report indicate no radioactive contribution from the Rulison flaring that would increase radiation dose to the human population in the area.~~ There has been no buildup of radioactivity in any of the sampled media, with the exception of sporadic increases in tritium ( $^3\text{H}$ ) concentrations at the exclusion area boundary and immediately off site. These levels were many times less than the maximum permissible concentration (MPC) for the general public. Continued surveillance and studies of the effect and behavior of these amounts in the environment is considered essential.

Applicable standards are listed and the Department's procedures for the various radiochemical analyses are provided in this summary report. The complete analytical results are also tabulated in the Appendix.

## NARRATIVE

In January, 1970, Civil Actions to prevent the flaring of the natural gas produced by the Project Rulison detonation were heard in Denver by Chief Judge Alfred A. Arraj in the United States District Court. The plaintiffs included the Colorado Open Space Coordinating Council, Martin G. Dumont, District Attorney for Colorado's Ninth Judicial District, and individuals situated near the site. A text of Judge Arraj's decision, rendered in March, 1970, stated in part: "The proposed flaring of gas from the Rulison cavity has not been shown to present a danger to life, health or property of the plaintiffs, or any others similarly situated." This decision also prescribed procedures for the public dissemination of all on-site and off-site monitoring and surveillance data. An open file for these data was established at the Colorado Department of Health and also at Federal offices in Denver, Bartlesville, Oklahoma and Las Vegas, Nevada.

Drilling to reestablish down-hole contact with the Rulison chimney started on April 28, 1970. This operation was conducted through the exploratory well (REX) and progressed vertically for about 6500 feet. Angular or "whipstock" drilling then proceeded toward the emplacement hole (REM). Drilling ceased on July 28, 1970, at a vertical depth of 8243 feet after loss of drilling mud indicated that the chimney had been encountered.

CALIBRATION FLARING

Projected schedules initially called for calibration flaring to begin as soon as possible after reentry, followed by three production testing periods of 6, 16, and 90 days' duration, with each period preceded by a 21-day shut-in interval. Actually, on-site calibration systems were first tested briefly on August 1, followed by other calibration flarings on August 18 and 22. Each of the latter tests was terminated after about 30 minutes because of mud and debris plugging the system. An interim delay during September was utilized to clean out the production hole and recheck the monitoring and calibration equipment. Austral Oil Company estimated that 850,000 standard cubic feet of natural gas was released during the August activities.

Calibration flaring was resumed at 7:05 a.m. Sunday, October 4, but was shut down at 8:47 a.m. the same day. The first sustained flaring occurred from 9:15 p.m., October 4, to 5:00 p.m., October 5, during which a rate of 15 million standard cubic feet ( $M^2SCF$ ) per day was reached. The next sustained release occurred from 4:00 p.m. October 6 to about 1:00 p.m. on October 7 at a steady rate of 5  $M^2SCF$  per day. An approximate volume of 12  $M^2SCF$  of natural gas from the chimney was flared during this period.<sup>(1)</sup>

PRODUCTION FLARING

The first production flaring started at 2:30 p.m. on October 26 and reached a rate of about 17.5  $M^2SCF$  per day at 9:00 p.m. The rate then declined slowly until the well was shut in about 2:00 p.m. November 3. An estimated 109  $M^2SCF$  was flared during this 8-day period.<sup>(2)</sup>

A special flaring interval was substituted for the second production test. This phase started on Tuesday, December 1, at an initial rate of 5.2 M<sup>2</sup>SCF per day. Continuous flaring followed for 20 days at an average rate of about 5 M<sup>2</sup>SCF per day. The well was shut in at 2:03 p.m. on December 20 after yielding approximately 100 M<sup>2</sup>SCF of natural gas. This completed production from the Rulison chimney for 1970. The total volume of natural gas was somewhat less than that predicted for the end of the second production period.

The third production phase began in February, 1971, and is expected to run for 90 days. Capacity of the chimney will determine the flaring rate which should stabilize during this extended period.

Radionuclides of chief interest contained in the Rulison natural gas are tritium (<sup>3</sup>H) and krypton 85 (<sup>85</sup>Kr). Other radioactive components are carbon 14, argon 37, argon 39, radon 222, and mercury 203. Concentrations of these are almost below detectable limits. Concentrations of <sup>3</sup>H and <sup>85</sup>Kr in wellhead gas samples have occurred in almost a one-to-one ratio. December, 1970 flaring data revealed concentrations of about 104 picocuries per cubic centimeter (pCi/cc) of gas for each. By contrast, the August, 1970 concentrations for <sup>3</sup>H and <sup>85</sup>Kr approximated 175 pCi/CC.<sup>(3)</sup> The August samples were collected when the well was first opened.

#### COLORADO DEPARTMENT OF HEALTH ACTIVITIES

Staff members of the Department's Occupational and Radiological Health Division (O & RHD) have done environmental sampling in correlation with the above flaring schedule. As many as three teams have been in the field simultaneously, conducting monitoring and sampling procedures. Department laboratory capabilities were expanded during the year to include tritium (<sup>3</sup>H) analysis. The laboratory is not yet equipped to perform krypton 85 (<sup>85</sup>Kr) analysis.

The discussions which follow examine and interpret the data obtained from our surveillance systems.

- (1) Project Rulison Off-Site Surveillance For The Flaring Operation of October 4-7, 1970.  
SWRHL Preliminary Report, January 22, 1971
- (2) Project Rulison Interim Radioactivity Report - High-Rate Flaring  
Nevada Operations Office, USAEC, January, 1971
- (3) AEC News NV-71-4  
Nevada Operations Office, USAEC, January 13, 1971

DISCUSSION

AIR PARTICULATE SAMPLES

A total of 644 filters, each representing over 2,000 cubic meters (m<sup>3</sup>) of sampled ambient air, were collected from a network of eight high-volume sampling stations. Their location is designated on Map A which follows. The Grand Valley station (R10) is supervised by the Division of Occupational and Radiological Health. The other stations are in the Department's Air Pollution Control Network.

The bar graph of Figure 1 represents the average long-lived total beta activity from each station. Figure 2 shows the monthly variation of beta activity with the stations grouped in three geographical and meteorological areas.

Alpha determinations were run on 521 filter samples. Figure 3 shows the average long-lived alpha activity per sampling station. The higher concentrations shown for R10, R12 and R13 stations are due to polonium 210 which was identified by alpha spectrometry. Polonium 210 is a naturally occurring radioactive material of the Uranium Series. The Figure 4 graph shows the monthly alpha activity variations and also reflects the higher concentrations at R10, R12 and R13.

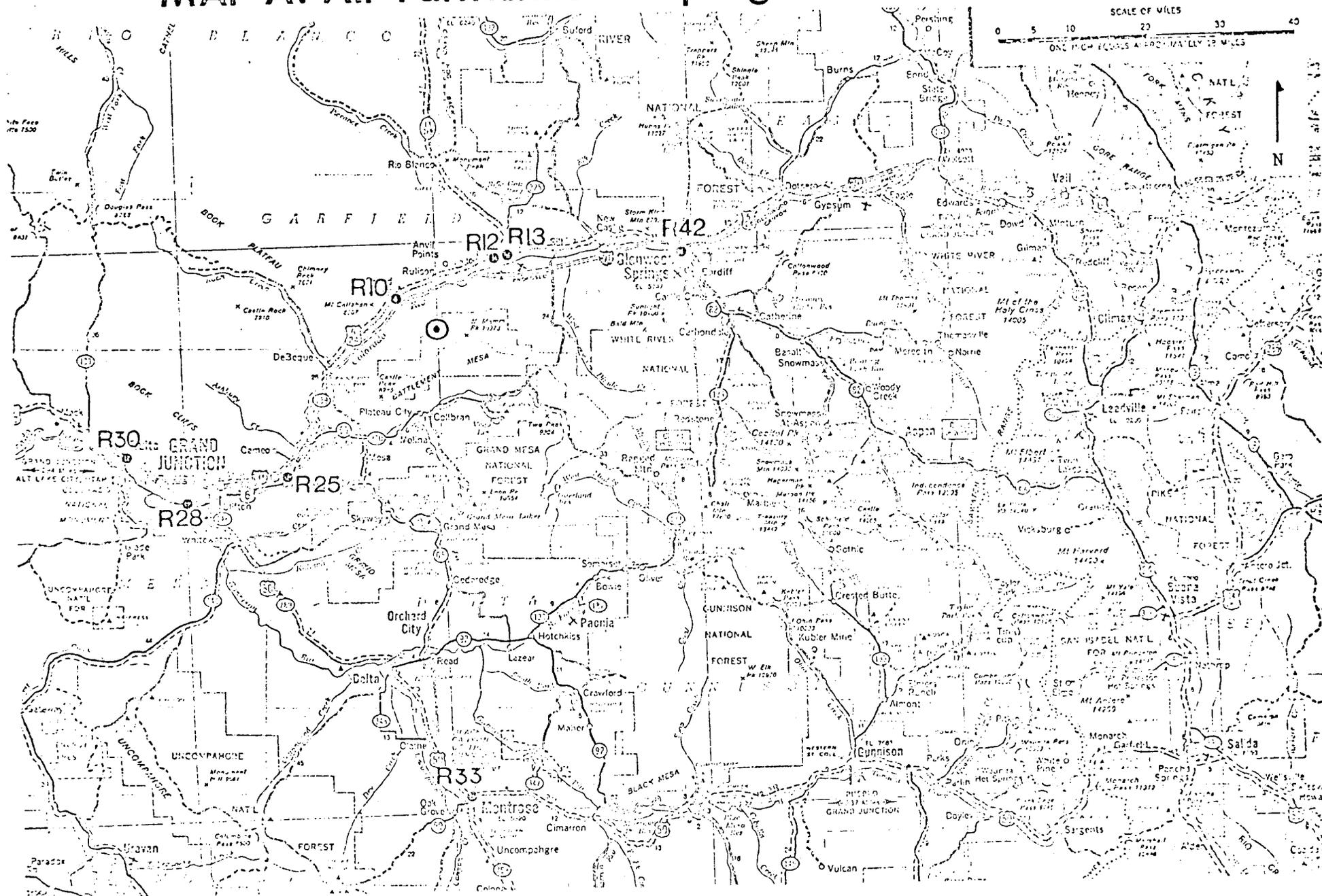
Figure 5 is a typical gamma spectrum showing the major gamma emitting radioisotopes in the environment as detected from a composite of filters from R10. The period represented is the fourth quarter of 1970 during which 41,846 m<sup>3</sup> of ambient air was sampled. A total of 374 gamma scans were made of individual filters from the network stations during the year.

No radioactive contribution from the Rulison flaring was detected on any air filter sample by the analyses discussed above. A summary of the individual station data is included in the Appendix. All radioactivity concentrations are reported in picocuries per cubic meter (pCi/m<sup>3</sup>).

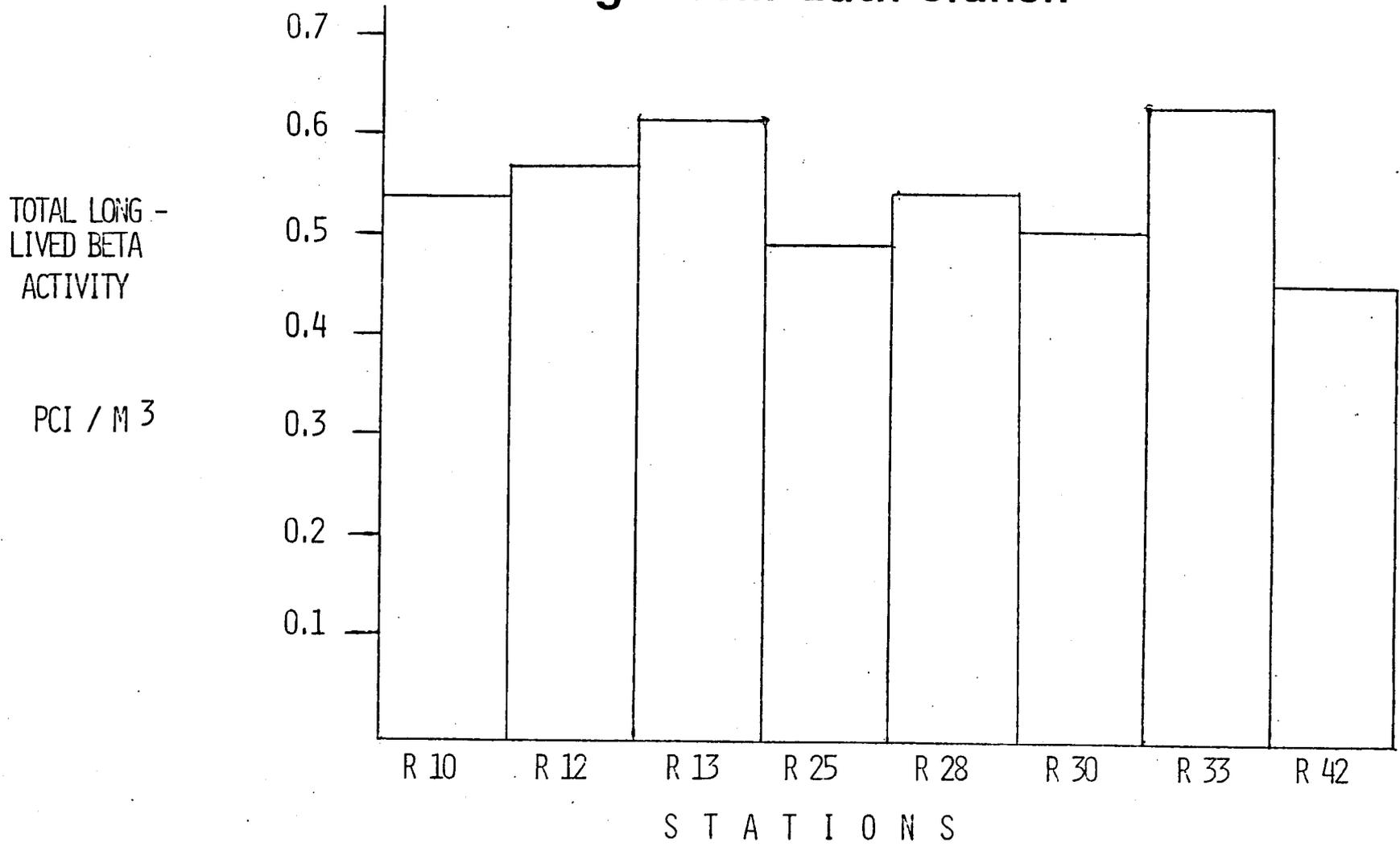
SAMPLING SITES - ORIENTATION FOR MAP A

Map Symbol	Location
R10	Town of Grand Valley Air Pollution Control (APC) station #73
R12	Town of Rifle APC station #48
R13	Town of Rifle APC station #69
R25	Town of Palisade APC station #66
R28	Town of Grand Junction APC station #67
R30	Town of Fruita APC station #62
R33	Town of Montrose APC station #47
R42	Town of Glenwood Springs APC station #46
⊙	Rulison Site

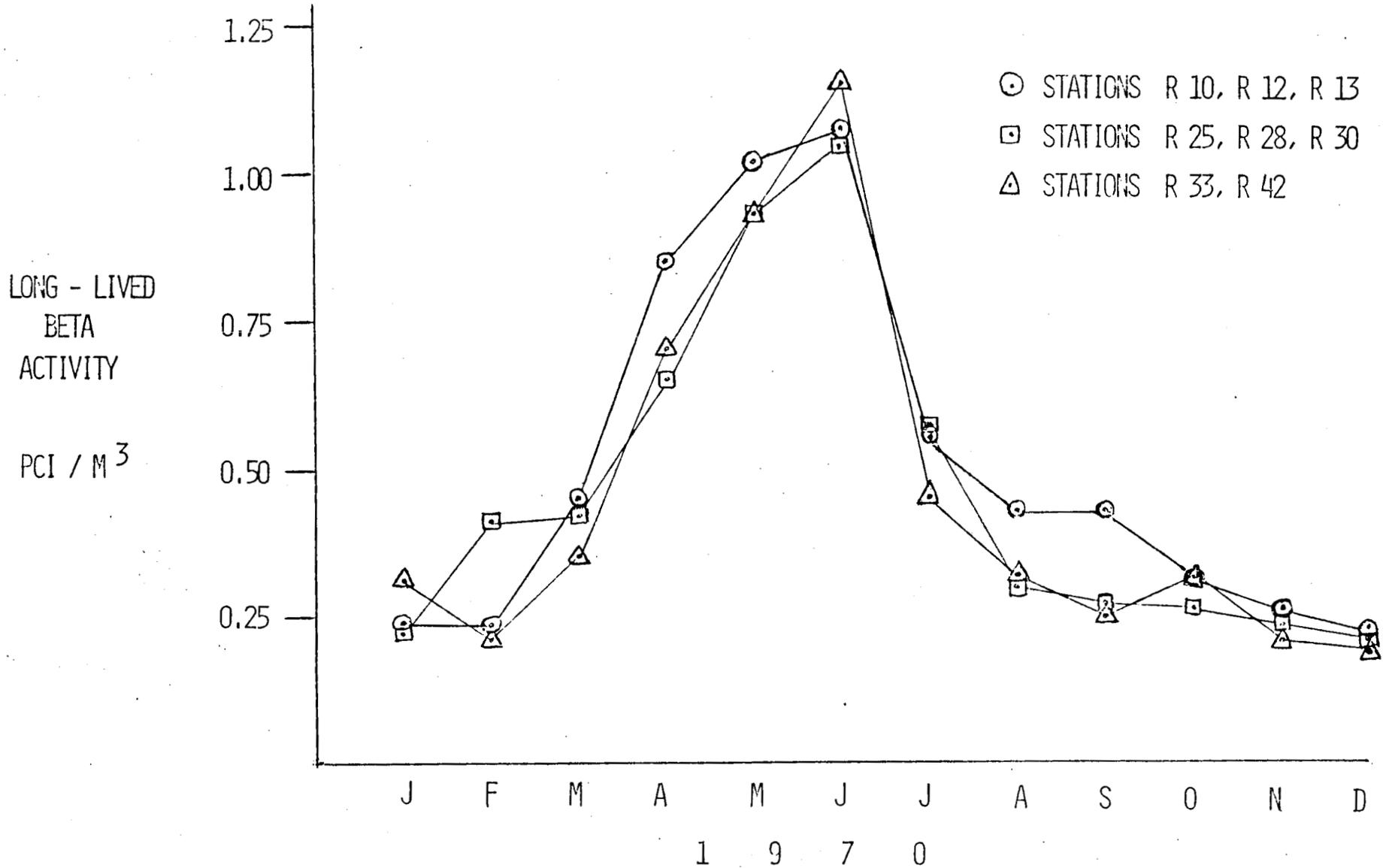
# MAP A. Air Particulate Sampling Sites



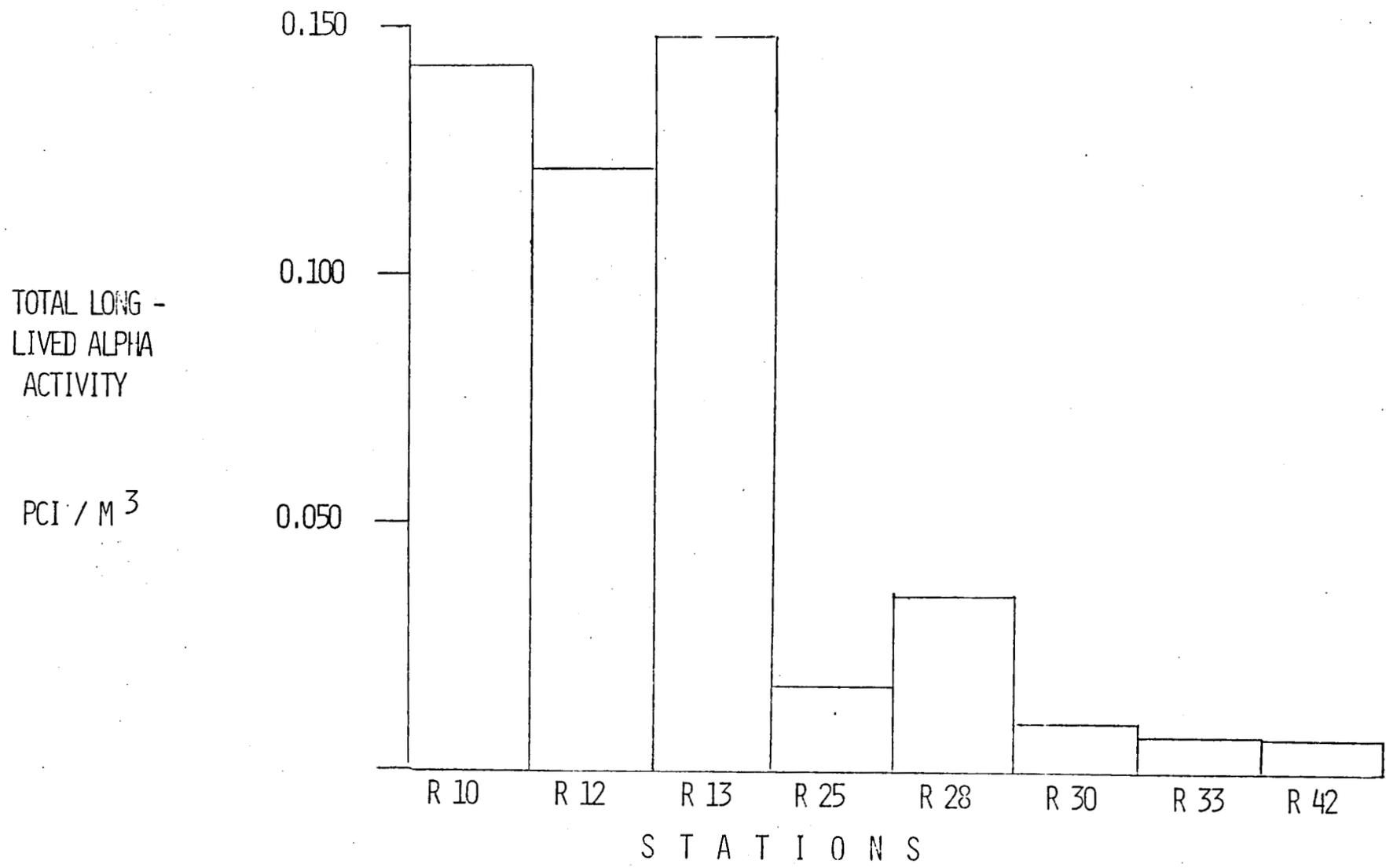
**FIGURE 1. Average From Each Station**



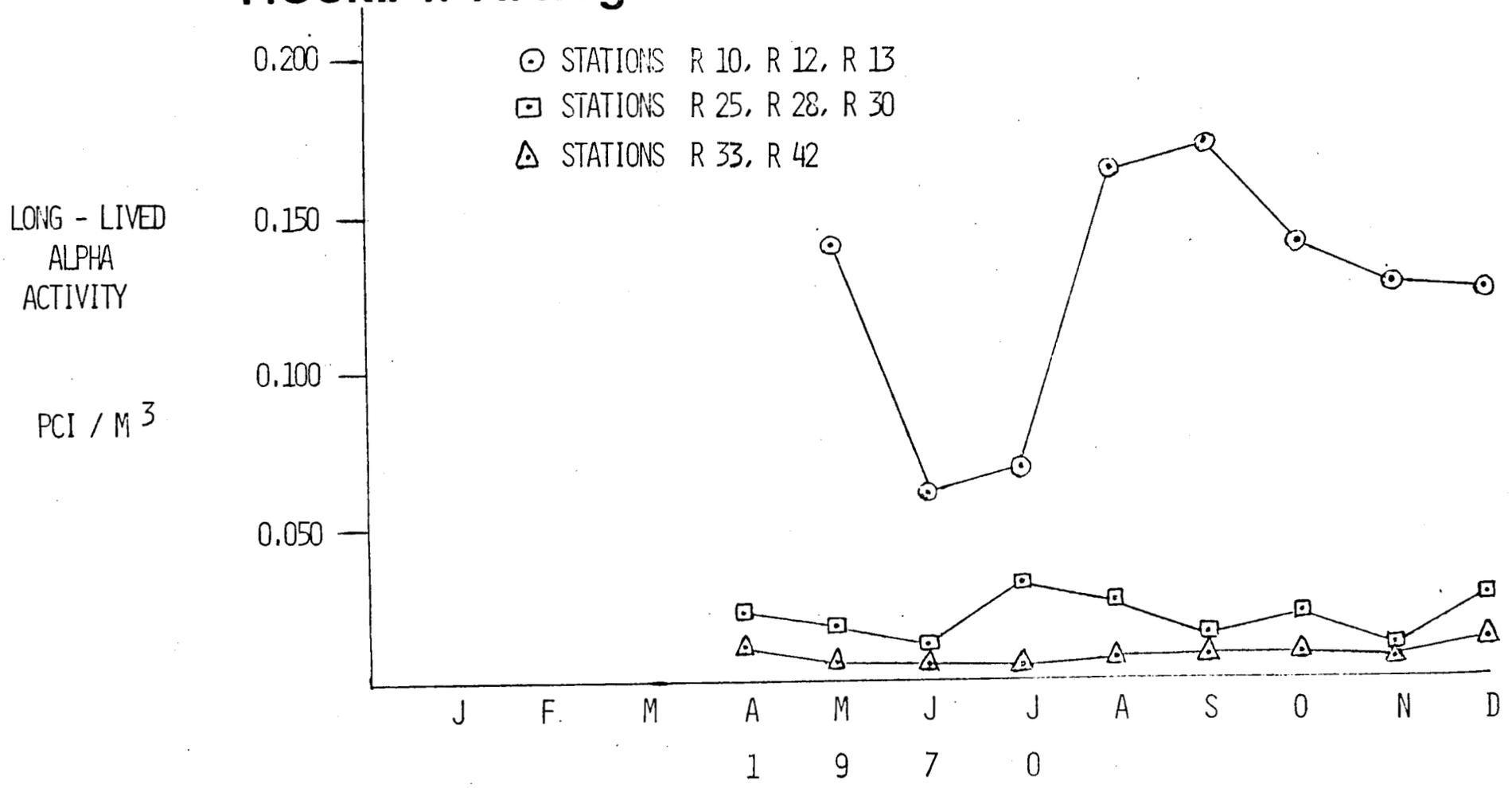
**FIGURE 2. Average Per Month**



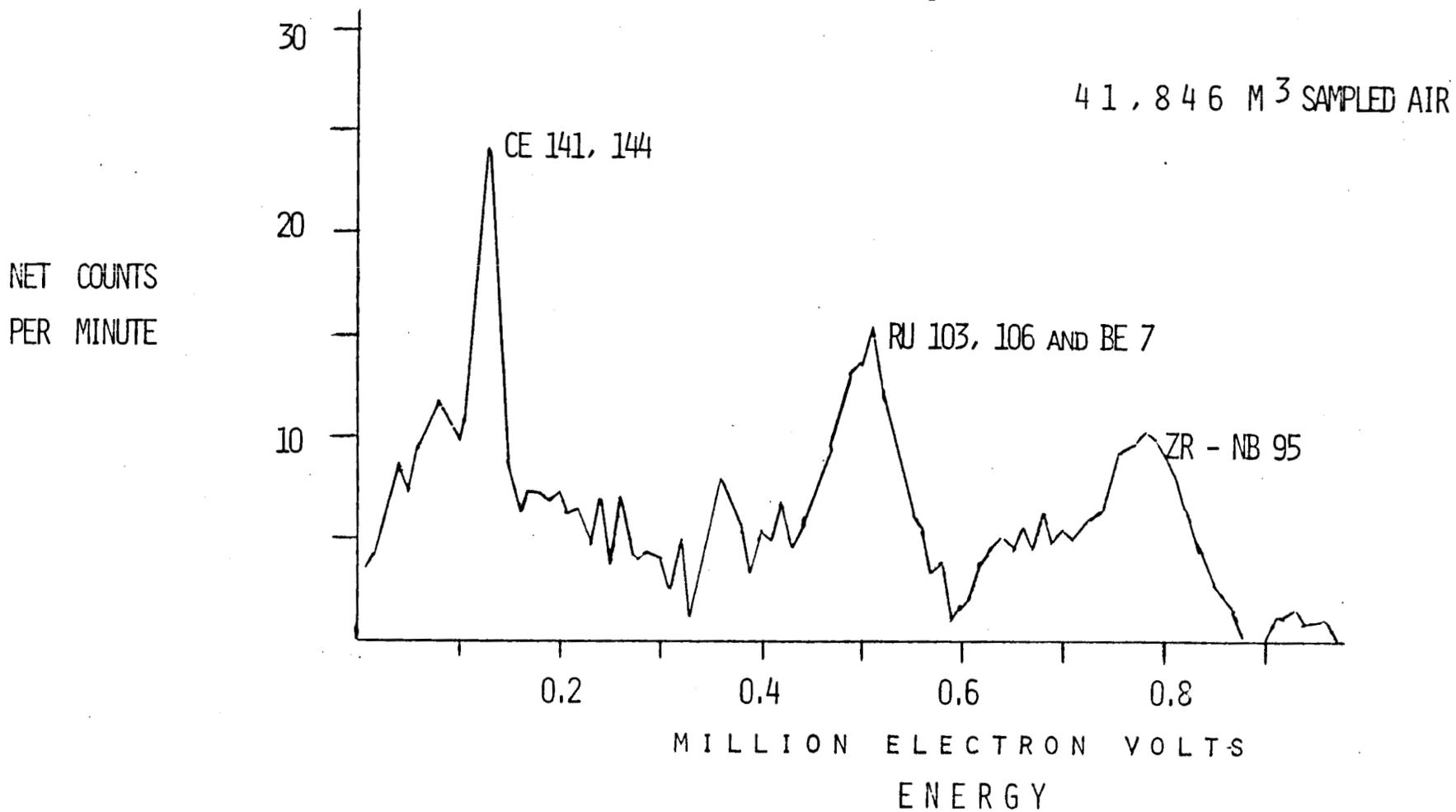
### FIGURE 3. Averages From Each Station



**FIGURE 4. Averages Per Month**



### FIGURE 5. Air Filter Gamma Spectrum



## DISCUSSION

### AIR MOISTURE SAMPLES

The Department developed tritium ( $^3\text{H}$ ) analysis capabilities during 1970. Tritium levels in air moisture samples from off-site stations were measured prior to reentry and during each flaring period thereafter. A total of 49 samples from eleven stations were analyzed. Cryogenic samplers utilizing dry ice ( $\text{CO}_2$ ) and a dehumidifier were used for air moisture collection. The sites are located on Map B. Individual collection times varied from 50 minutes to 18 hours, but the optimum collection time appeared to be 3 to 4 hours. Each sampling period was correlated with a particular flaring phase and meteorological condition.

The graph in Figure 6 depicts the maximum tritium activity and average tritium activity for each period. The average tritium concentration for all samples was within the background range of about 5 to 10 picocuries per cubic meter ( $\text{pCi}/\text{m}^3$ ) of ambient air. Only one analysis showed significant activity above this level. The reading of  $28.1 \text{ pCi}/\text{m}^3$  was obtained from a sample taken at R2 on December 2 and is much below the maximum permissible concentration (MPC) of  $66,000 \text{ pCi}/\text{m}^3$  for tritium.

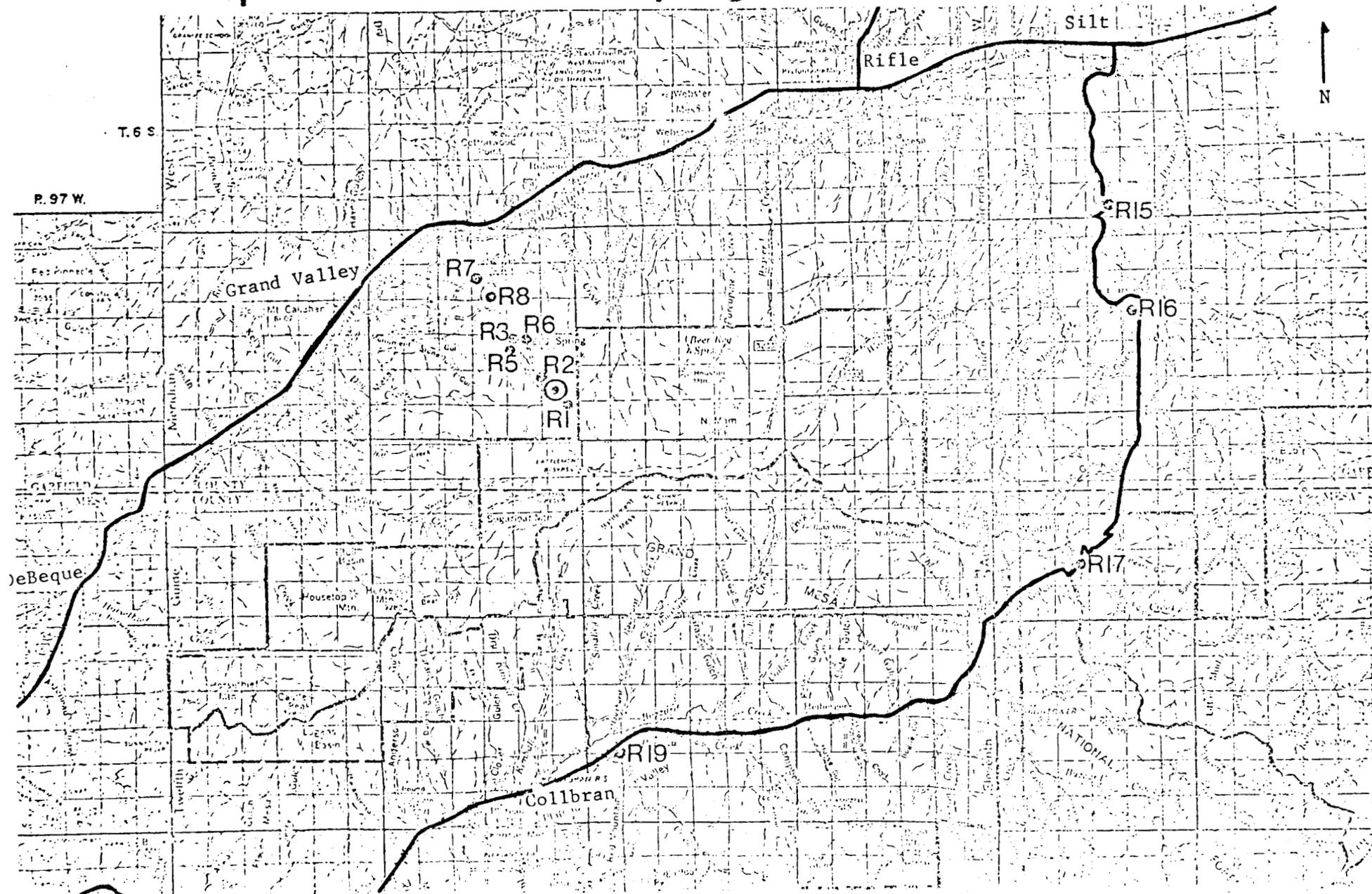
The complete data are tabulated in the Appendix.

SAMPLING SITES - ORIENTATION FOR MAP B

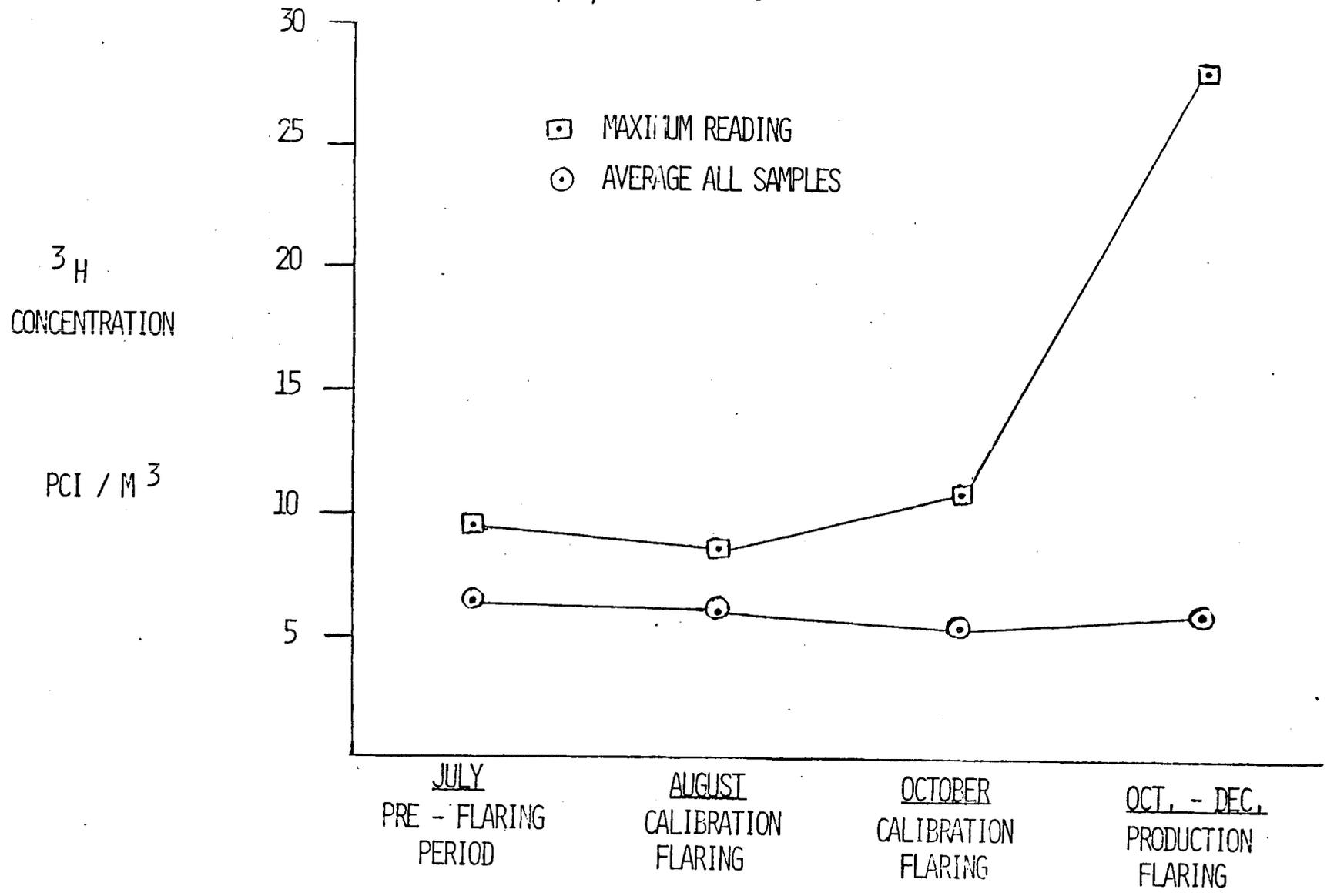
Map Symbol	Location
R1	Near Battlement Creek south of Rulison site
R2	Near Battlement Creek north of Rulison site
R3	Near Battlement Creek at the Command Post (CP)
R5	Intercept A (West helicopter pad)
R6	Intercept C (East helicopter pad)
R7	Clem Ranch
R8	Burtard Ranch
R15	Ranch six miles south of Silt
R16	Fairview School
R17	Silt-Collbran divide summit
R19	Highway #330 and Vega Reservoir road junction
⊙	Rulison Site

# Map B. Air Moisture Sampling Sites

Scale of Miles  
0 1 2 3 4 5



### FIGURE 6. Tritium (<sup>3</sup>H) Activity in Ambient Air



## DISCUSSION

WATER SAMPLES

Radioactivity in water data are obtained from a network of 40 stations which are located on Maps C and D. A total of 633 analyses were performed on 209 samples submitted during 1970. Samples were routinely analyzed for total alpha and total beta radioactive concentrations and for tritium ( $^3\text{H}$ ). Radium 226 ( $^{226}\text{Ra}$ ) was determined only when the total alpha activity of a sample exceeded 10 picocuries per liter (pCi/l) of water. The results reflect the variable ranges of radioactivity normally seen in the springs and surface waters of Western Colorado.

Six precipitation samples in the form of snow were collected and analyzed for alpha, beta and tritium. These were from sites most adjacent to the Rulison exclusion area. One result from a sample taken at the exclusion area boundary on December 3 showed a slight increase above background tritium levels. This was to be expected because on-site sampling in the flare stack exclusion area also revealed increased tritium activity during this period.

Average tritium concentrations in surface waters are shown on the bar graph in Figure 7. Results from stations on Battlement Creek are compared to data from other watershed areas. The following list gives the grouping of sampling sites and the number of samples averaged for each group.

R1	1	sampling site	6	samples averaged
R2	1	" "	6	" "
R3	1	" "	10	" "
Plateau Creek drainage	3	sampling sites	14	" "
Colorado River drainage	11	" "	34	" "
Gunnison River drainage	8	" "	24	" "
White River drainage	2	" "	7	" "
Yampa River drainage	2	" "	5	" "

The range of averages is within what are considered normal limits for tritium in these waters. Variations are probably due to climatic and geographical factors which are presently not clearly defined.

Figure 8 illustrates the average tritium activity shown for the network of nine municipal water stations. The Grand Valley water supply (most proximal to the Rulison site) is the lowest, while those from Collbran and Carbondale are the highest. The sources of all three are springs or small streams from high altitude terrain. All of these tritium data for municipal supplies are within the observed normal concentration limits and reflect no measurable contribution from Project Rulison flaring.

All of the water and precipitation analysis data are found in the Appendix.

SAMPLING SITES - ORIENTATION FOR MAPS C AND D

## Map Symbol

## Location

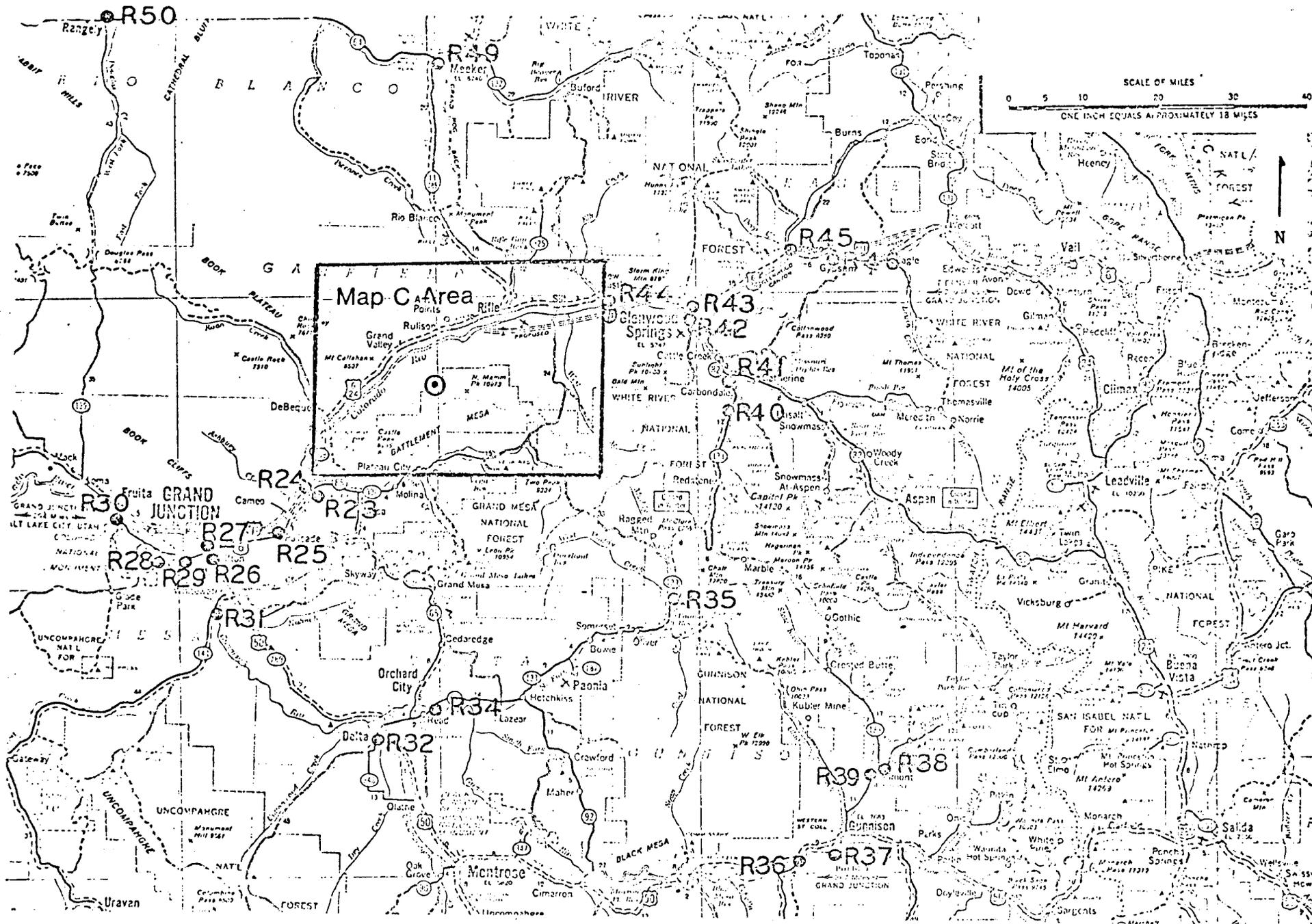
R 1	East Battlement Creek upstream from Rulison site
R 2	East Battlement Creek downstream from Rulison site
R 3	Main Battlement Creek downstream from Rulison site
R 4	Rulison Exclusion Area boundary
R 9	Colorado River at Grand Valley bridge
R10	Town of Grand Valley
R11	Colorado River at Rulison bridge
R12	Town of Rifle-Beaver Creek Plant
R13	Town of Rifle-Graham Plant
R14	Colorado River at Silt bridge
R18	Buzzard Creek at Highway 330 bridge
R20	Vega Reservoir outlet
R21	Town of Collbran
R23	Plateau Creek at I-70 bridge
R24	Colorado River at Cameo gauging station
R25	Town of Palisade
R26	Colorado River at Clifton bridge
R27	Ute Water Conservancy District
R28	Town of Grand Junction
R29	Colorado River at Highway 50 bridge
R30	Colorado River at Fruita
R31	Gunnison River at Whitewater
R32	Uncompahgre River at Delta
R34	Gunnison River at Austin
R35	Muddy Creek upstream from Paonia Reservoir
R36	Gunnison River downstream from Gunnison
R37	Tomichi Creek at Gunnison
R38	Taylor River at Almont
R39	East River at Almont
R40	Crystal River south of Carbondale
R41	Town of Carbondale
R42	Town of Glenwood Springs
R43	Roaring Fork River at Glenwood Springs
R44	Colorado River at Newcastle
R45	Colorado River at Dotsero
R46	Eagle River at Gypsum
R47	Yampa River at Milner
R48	Yampa River at Maybell
R49	White River at Meeker
R50	White River at Rangely



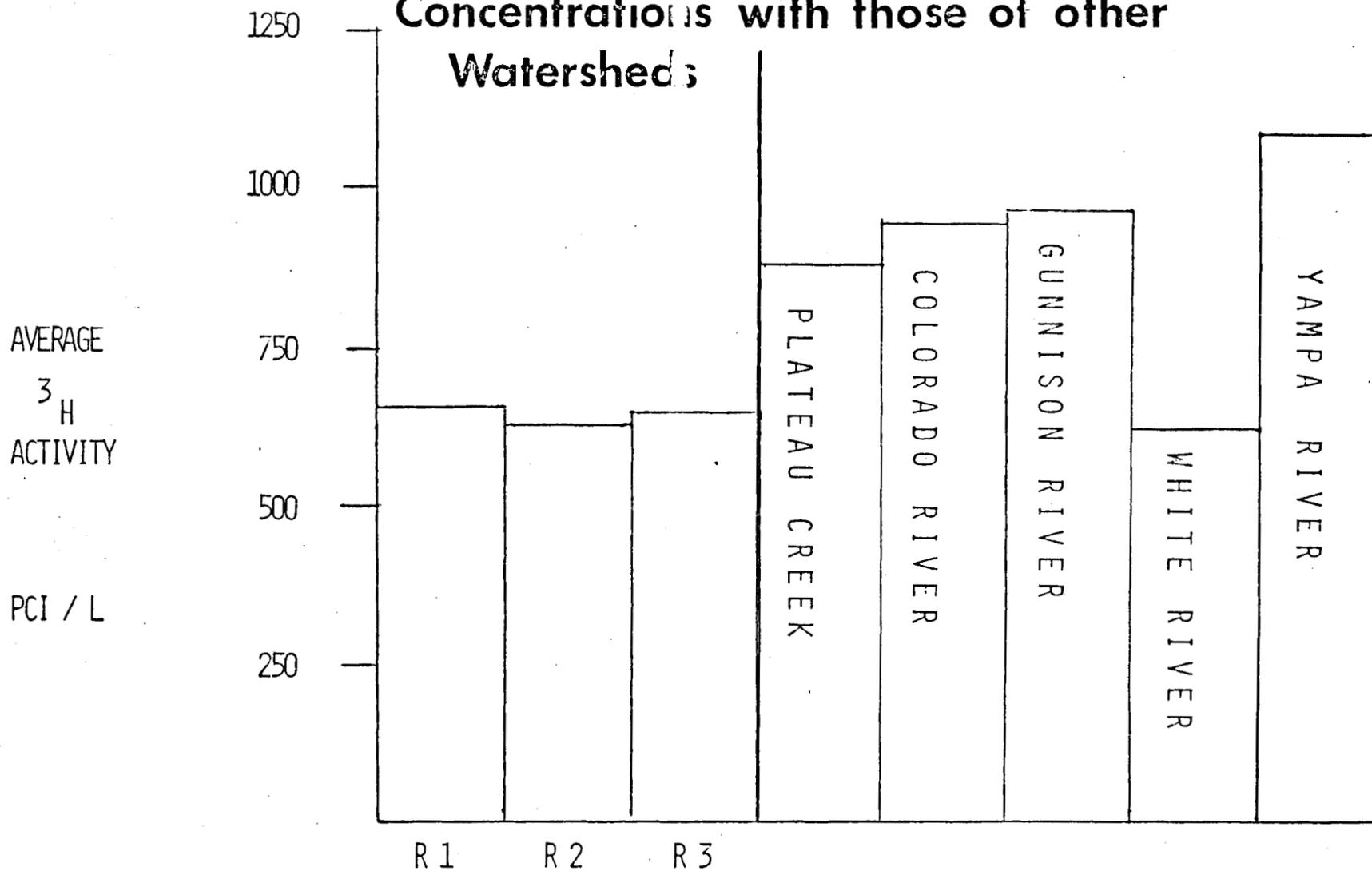
Rulison Site

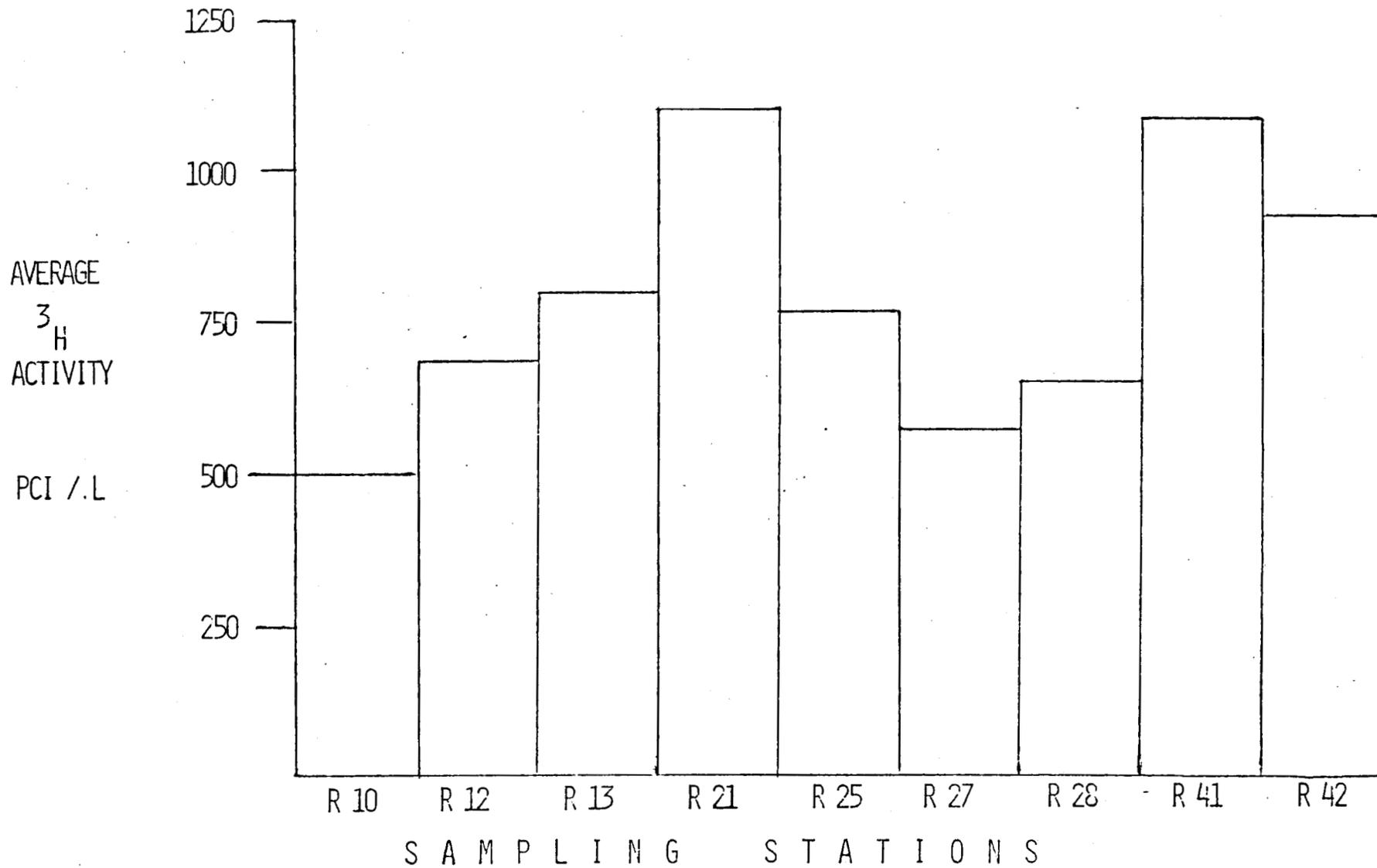


# Map D. Water Sampling Sites



**FIGURE 7. Comparison of Battlement Creek Tritium ( $^3\text{H}$ ) Concentrations with those of other Watersheds**



**FIGURE 8. Tritium ( $^3\text{H}$ ) Activity in Municipal Water**

## DISCUSSION

MILK SAMPLES

During 1970, 52 milk samples were collected from six milksheds considered to be within the Rulison area of interest. These were composite route samples and did not represent the milk from any individual producer. The approximate areas represented are outlined on Map E and are listed below:

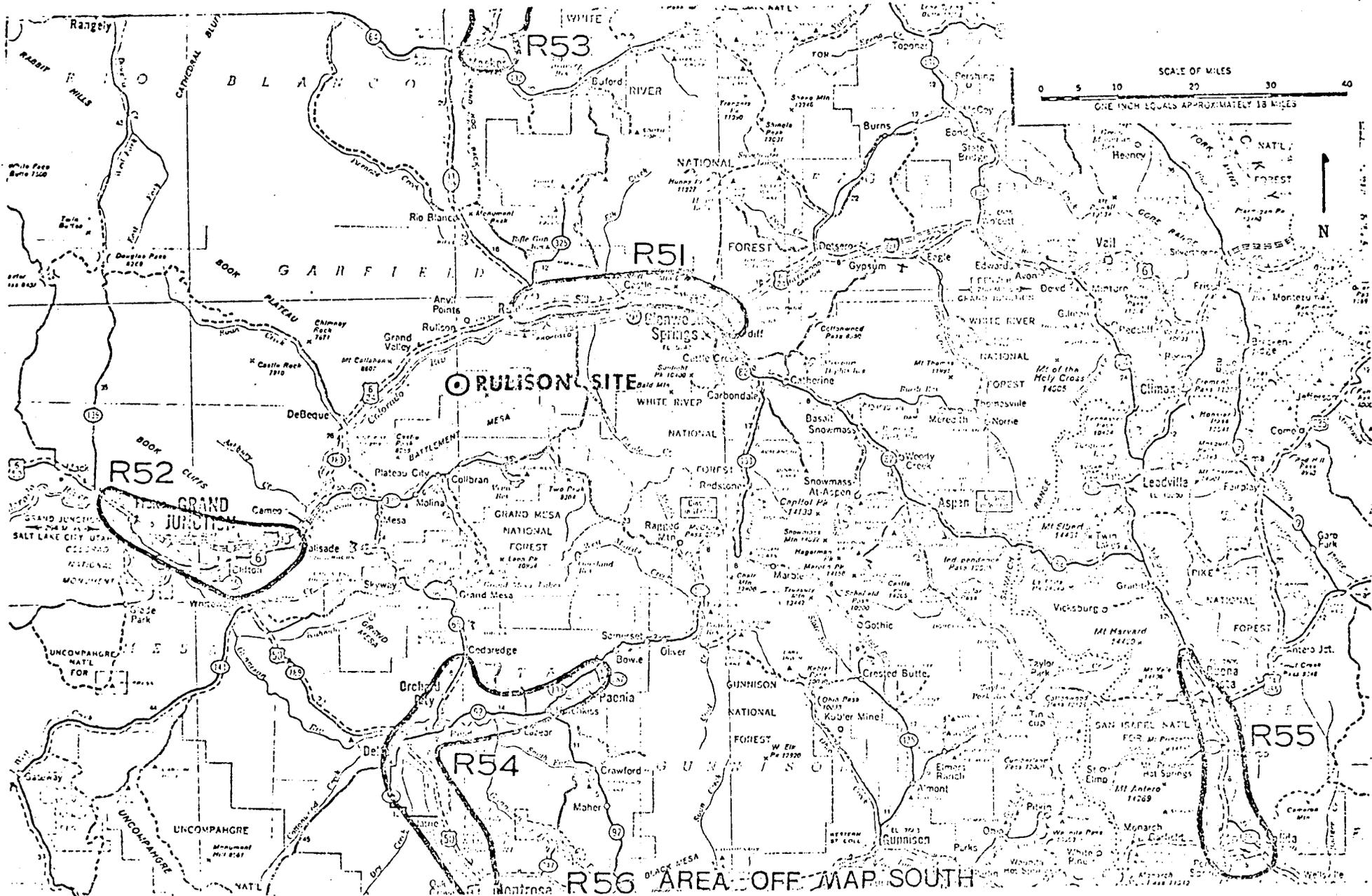
Map Symbol	Location	Elevation Above Sea Level
R51	Rifle - Glenwood Springs	5,580 ft.
R52	Grand Junction - Fruita	4,790 ft.
R53	Craig - Meeker	6,575 ft.
R54	Delta - Paonia - Montrose	5,575 ft.
R55	Salida - Buena Vista	7,620 ft.
R56	Durango - San Juan Basin	6,730 ft.

Gamma spectrometry was used to determine the activity levels of iodine 131 ( $^{131}\text{I}$ ), barium 140 ( $^{140}\text{Ba}$ ) and cesium 137 ( $^{137}\text{Cs}$ ) in each sample. The analytical results were within accepted variations and showed no radioactive contribution from the Rulison flaring.

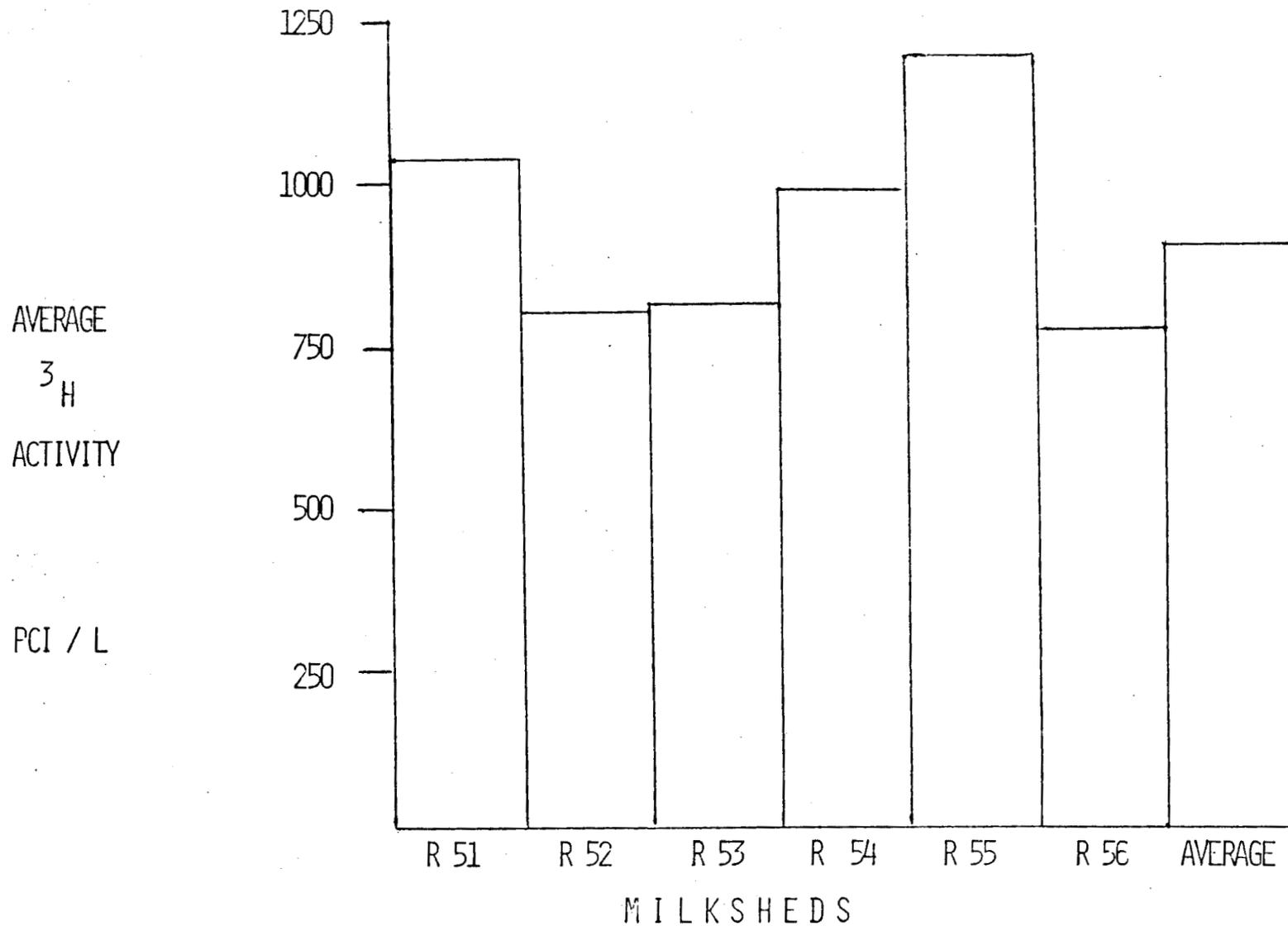
Fifty tritium ( $^3\text{H}$ ) analyses were made on these samples. The average tritium activity for each milkshed is shown in Figure 9. The overall average for all samples equaled 900 picocuries per liter (pCi/l) of milk. The variations exhibited on the graph may be due to factors such as altitude, climate, weather and feeding practices, but are presently undefined. No differences are noted in the data between the Rulison preflaring and postflaring periods.

The milk analysis data are all tabulated in the Appendix.

# MAP E. Milk Sampling Areas



**FIGURE 9. Tritium ( $^3\text{H}$ ) Activity in Milk**



## ACKNOWLEDGEMENTS

The Division of Occupational and Radiological Health is grateful for the assistance and cooperation it has received from many agencies and individuals in this environmental surveillance endeavor. A hopefully complete listing follows:

Colorado Department of Health  
Division of Air Pollution Control  
Division of Laboratories  
Division of Sanitation and Engineering  
Division of Water Pollution Control

Environmental Protection Agency  
Southwestern Radiological Health Laboratory,  
Las Vegas, Nevada

United States Atomic Energy Commission  
Nevada Operations Office, Las Vegas, Nevada

United States Geological Survey, Denver, Colorado

Lawrence Radiation Laboratory, Livermore, California

Eberline Instrument Company, Santa Fe, New Mexico

Mesa County Health Department, Grand Junction, Colorado

San Juan Basin Health Unit, Durango, Colorado

Austral Oil Company, Houston, Texas

CER Geonuclear Corporation, Las Vegas, Nevada

Private individuals and municipal officials in the Morrisania  
Mesa Community, Grand Valley, Rifle, Collbran, and throughout  
the Rulison area of interest.

## S T A N D A R D S

The concentrations listed include radioactive materials of interest in all department surveillance activities, that are found in the environment.

## Maximum Permissible Concentration

The Maximum Permissible Concentrations (MPC) stated below are based on the recommendations of the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection (NCRP) and the Federal Radiation Council (FRC). These recommendations are incorporated into the regulations of the Department and those of the U. S. Atomic Energy Commission. The levels stated are those relating to general population exposures and are rounded, conservatively, to the second significant digit.

	Chemical form	
	insoluble	soluble
Air*(picocuries/cubic meter)		
Unidentified radionuclides 1)	0.007	0.007
Unidentified radionuclides 2)	33.0	33.0
Americium 241	1.3	0.066
Cerium 141	1600.0	6600.0
Cerium 144	66.0	100.0
Hydrogen 3	66000.0	66000.0
Krypton 85	100000.0	100000.0
Lead 210	2.6	1.3
Plutonium 238	0.33	0.023
Plutonium 239	0.33	0.020
Polonium 210	2.3	6.6
Ruthenium 103	330.0	6600.0
Ruthenium 106	66.0	1000.0
Uranium - natural	0.66	1.0
Zirconium-Niobium 95	330.0	1300.0
Water*(picocuries/liter)		
Unidentified radionuclides 1)	10.0	10.0
Unidentified radionuclides 2)	1000.0	1000.0
Americium 241	6600.0	1300.0
Cerium 141	30000.0	30000.0
Cerium 144	3300.0	3300.0
Hydrogen 3	1000000.0	1000000.0
Lead 210	66000.0	33.0
Plutonium 238	10000.0	1600.0
Plutonium 239	10000.0	1600.0
Polonium 210	10000.0	230.0
Ruthenium 103	26000.0	26000.0
Ruthenium 106	3300.0	3300.0
Uranium - natural	6600.0	6600.0
Zirconium-Niobium 95	20000.0	20000.0
Radium 226 in water supplies 3)	<u>Any</u>	
	3.0	
Radium 226 in water supplies 4)	20.0	
Iodine 131 in milk 4)	100.0	
Strontium 90 in milk 4)	200.0	

\*Air is used as an example of inhalation exposure and water is used as ingestion exposure. Where the ingestion exposure is from solid material, the units are expressed as picocuries/1000 grams.

- 1) Any single radionuclide which decays by alpha emission or spontaneous fission.
- 2) Any single radionuclide with a decay mode other than alpha emission or spontaneous fission and with a radioactive half-life greater than 2 hours.
- 3) The Department's limit for accepting a municipal water supply or source without additional qualification on total Radium intake. Units are picocuries/liter.
- 4) FRC Range I maximum total daily intake. Units are picocuries/day. Concentrations occurring in Range I require only minimal surveillance activities.

A picocurie is defined as one millionth-millionth of a Curie or 2.22 disintegrations/minute.

## P R O C E D U R E S

The procedures described include all radiological health analysis procedures used on a "routine" basis, although a specific surveillance program may not employ all the procedures contained herein.



## Air Filter Analysis

### Routine

Air samples are collected by persons manning the individual sampling stations. In practically all instances, these are state and local governmental personnel.

Particulate air filter sample pads routinely are stored at least seven (7) days post collection prior to counting to allow the short-lived naturally-occurring Radon and Thoron daughter radioactive material to decay from the sample.

Alpha determinations are made using a 4 inch diameter photomultiplier tube coated with zinc sulfide connected to an appropriate counting register. Analysis counting time is 10 minutes per sample. Calibration factors for this system include corrections for counting efficiency, sample and sample media self-absorption, aliquot of sample actually seen by the detector and sample media collection efficiency.

Beta determinations are made using an 8 inch x 10 inch external proportional chamber connected to an appropriate counting register. Analysis counting time is 4 minutes per sample. Calibration factors for this system incorporate the items previously stated for alpha determinations.

The net counts per minute are converted to concentrations, i.e. picocuries per cubic meter of air ( $\text{pCi}/\text{m}^3$ ), by multiplying the net counts per minute by the calibration factor and dividing by the air flow for the sampling period (previously determined).

In the case of an emergency situation, air filter samples can be counted on receipt in the counting facility. The counting rates will normally be elevated if the sample is counted before at least 4 days have elapsed since collection of the sample because of Radon and Thoron progeny.

Should alpha or beta determinations be abnormal for the post-counting period, alpha or gamma spectrometry or special analyses are used to determine the cause of the abnormality.

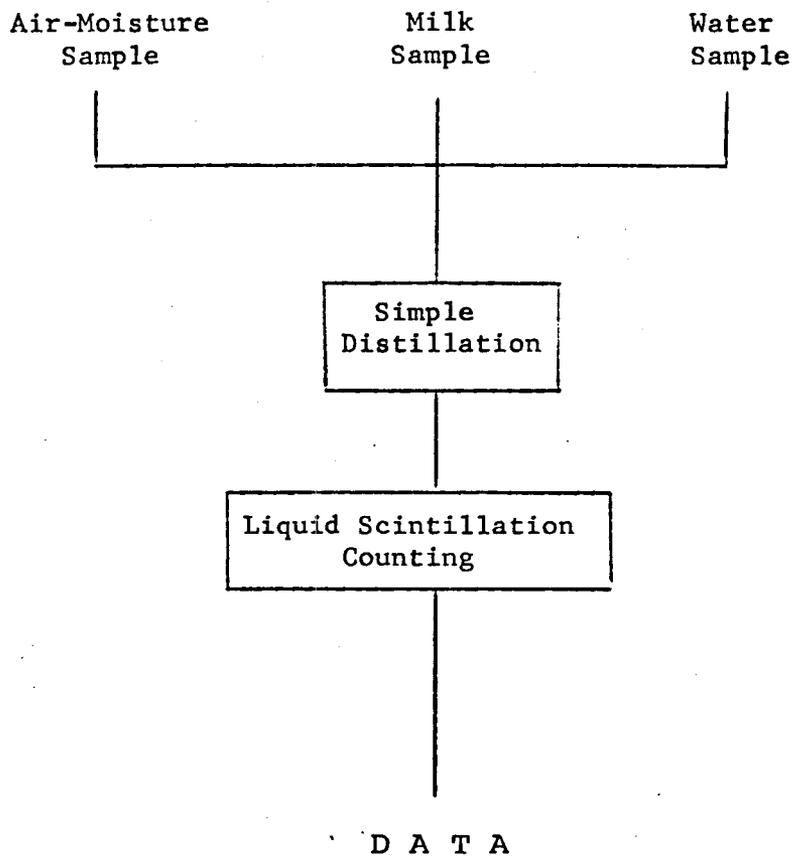
Gamma spectrometry is routinely used, whether the sample is abnormal or not, during surveillance of Plowshare events such as Project Rulison.

### Special

In special situations, special analysis techniques are used to identify specific radionuclides not easily discernible by the previously mentioned procedures. Such is the case with the air filters collected for the U. S. Atomic Energy Commission's Rocky Flats Plant Surveillance Program conducted by the Department. In this instance, air filter samples collected are analyzed for Plutonium content and concentrations of Plutonium 238 and Plutonium 239 are determined.

Nominal minimum detectable activities are 0.003 picocurie Total Alpha per cubic meter and 0.02 picocurie Total Beta per cubic meter of air.

TRITIUM DETERMINATION FLOW CHART



### Tritium In Water Determination

Tritium released to the environment from nuclear facilities is generally in gaseous form. Tritium atoms readily exchange with the stable hydrogen (Hydrogen 1) and forms tritiated water with the available oxygen in the atmosphere.

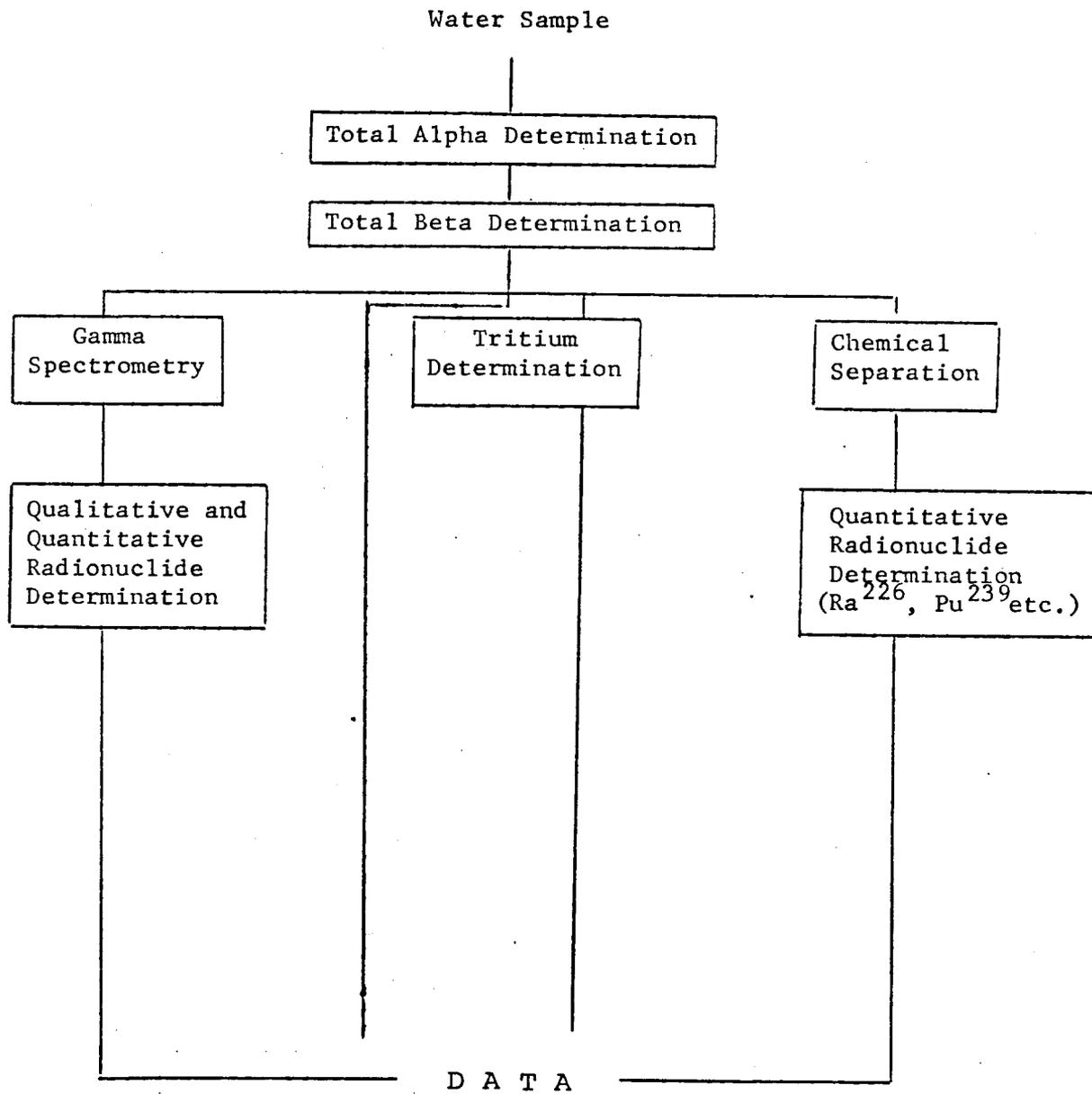
Because of this situation, tritium levels can be monitored by analyzing water from any environmental or biological system. Samples submitted may be water taken from the ambient atmosphere by cryogenic sampling devices, milk samples, well and surface water source samples and urine. The latter is useful in determining body burden levels of personnel who work with large quantities of Tritium, while the others are used in determining the effects of the facilities and their activities on the environment.

The liquid samples collected are slowly distilled in a simple distillation apparatus. Five milliliters of the distillate is placed in a counting vial with twenty milliliters of liquid scintillation solvent (a p-dioxane mixture). The sample is counted for 100 minutes in a counter which has about a 26% counting efficiency for Tritium in this solution.

By knowing the moisture content of the sampled air, calculations can be made to determine the concentration of Tritium in the sampled atmosphere.

The minimum detectable activity which can be observed with this system is 500 picocuries of Tritium per liter of water and approximately 1 picocurie of Tritium per cubic meter of air.

## WATER ANALYSIS FLOW CHART



## Water Sample Analysis

Water samples may be collected by the Division Staff or by other Divisions in the State Health Department, local health departments, other state and local governmental agencies and others.

In some instances, the collection of these samples are on pre-arranged schedules while others are collected due to specific interest.

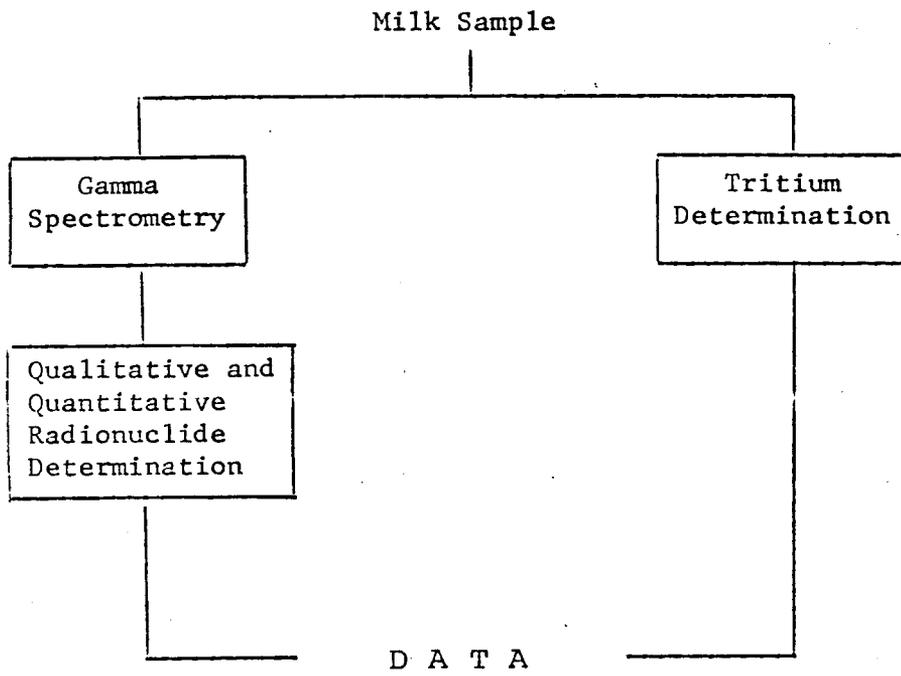
Total alpha and beta determinations are accomplished on a 100 milliliter portion of the sample evaporated on a counting planchet. Where the total solids are excessive for the above determination (greater than 20 milligrams deposited per square centimeter of planchet surface) a smaller portion is used. Normally the alpha determination requires a 100 minute counting time, while 10 minutes is used for the beta determination. A proportional counter having an automatic sample changer and "alpha" and "beta" plateaus is used for these determinations. Calibrations are based on natural Uranium and Cesium 137 for alpha and beta determinations respectively. Special analysis calibrations utilize the radionuclide of interest. If either of these analyses is abnormal, either gamma spectrometry or special analysis utilizing chemical separation is used to determine the cause of the abnormality.

A tritium analysis is performed on water samples collected near facilities where tritium is stored or used in large quantities.

Bismuth 210, Polonium 210 and Lead 210 are other determinations done by the Department but not on a routine basis. Uranium analysis is accomplished by strictly chemical procedures.

The minimum detectable activity for alpha and beta concentrations approximates 8 picocuries per liter of water and is 0.1 picocurie/liter for Radium 226.

MILK ANALYSIS FLOW CHART



## Milk Analysis

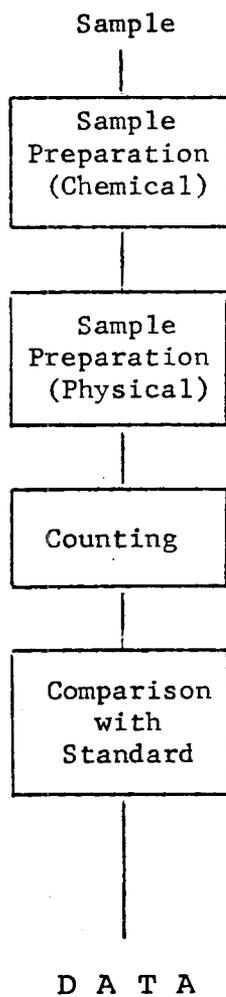
Milk samples are collected with the cooperation of the Milk, Food and Drug Section of the Department's Engineering Division, local health departments and milk producing or processing plants and associations.

Normally one-half to one gallon of milk is obtained per sample, and is preserved by the addition of 5 milliliters of formaldehyde. The frequency of collection of samples from the various milk producing areas of the state depends on the surveillance system and its status.

Samples are received by the radiation counting facility of the Department's Occupational and Radiological Health Division within 2 days after sampling and are analyzed as soon thereafter as possible.

Routine analysis is accomplished by gamma spectrometry with Iodine 131, Barium-Lanthanum 140, Cesium 137 and natural Potassium concentration determined. Gamma efficiency curves are available to determine the concentration of any gamma emitting radionuclide in a 2 quart sample. This "compton-continuum subtraction-gamma efficiency" procedure has not been utilized to date, as there has not been an instance of any gamma emitting radionuclides above minimum detectable activities ( $\sim$  20-25 picocuries per liter).

Because Tritium (Hydrogen 3) is a radionuclide of interest in Plowshare activities and the Public Service Company of Colorado's Fort St. Vrain Nuclear Power Generating Station at Platteville, Tritium determinations are made on all milk samples produced in these respective vicinities.

SPECTROMETRIC DETERMINATIONS  
FLOW CHART

## Spectrometric Determinations

Analysis for any specific radioactive material involves the emission, the emission's energy and the radioactive half-life of the material in question.

Alpha particle and gamma ray emissions are given off by the nucleus of the radioactive atom at discrete or specific energies. By the use of alpha or gamma spectrometry, emissions and their energies can be determined. Should emission energies from different radioactive materials be similar, chemical separation of the materials will ease the determination.

Qualitation and quantitation is accomplished through the use of known source emission energies and amount of material. Counting at different times enable half-life determinations to be made.

### Alpha

As an alpha particle does not penetrate air easily, counting of the sample is done under a high vacuum. The sensing portion of the system is a silicon surface barrier detector which is coupled with a power supply, pulse shapers, counting register and a pulse height analyzer unit. Pulses of different energies are sorted accordingly and the readout of the unit describes the emission energies.

### Gamma

As a gamma ray penetrates most environmental materials easily, sample preparation is generally concerned with fitting the sample size and shape to a uniform geometry for counting. The detector is a sodium iodide crystal which is optically coupled to a photomultiplier tube. This tube changes the scintillations in the crystal to an electrical pulse and then provides amplification. Pulse shapers, a pulse height analyzer unit and its readout complete the unit. Pulses of different energies are sorted accordingly and the readout describes the emission energies.

A P P E N D I X

AIR PARTICULATE SURVEILLANCE

Month	N	Total Long Lived Beta pCi/m <sup>3</sup>				Total Air Volume m <sup>3</sup>	N	Total Long Lived Alpha pCi/m <sup>3</sup>				Total Air Volume m <sup>3</sup>
		$\bar{X}$	Max.	Min.				$\bar{X}$	Max.	Min.		
GRAND VALLEY (Map Designation R10)												
1												
2												
3												
4	3	0.83	0.90	0.78	7,652							
5	4	0.87	1.19	0.60	10,426							
6	4	1.03	1.70	0.58	10,377							
7	5	0.56	0.91	0.16	13,220	5	0.077	0.276	0.007	13,220		
8	3	0.51	0.60	0.38	6,569	3	0.271	0.608	0.071	6,569		
9	1	0.62	0.62	0.62	2,251	1	0.314	0.314	0.314	2,251		
10	9	0.25	0.52	0.07	21,292	9	0.124	0.317	0.004	21,292		
11	2	0.27	0.28	0.26	7,882	2	0.141	0.148	0.126	7,882		
12	5	0.27	0.40	0.20	12,672	5	0.144	0.199	0.053	12,672		
Year	36	0.53	1.70	0.07	92,341	25	0.142	0.608	0.004	63,886		

## RIFLE (Map Designation R12)

1	2	0.26	0.41	0.10	4,420						
2	2	0.20	0.25	0.16	4,420						
3	10	0.46	1.00	0.11	21,990	2	0.172	0.260	0.084	4,420	
4	10	0.86	1.48	0.33	21,580	8	0.245	0.572	0.063	17,150	
5	11	1.09	1.75	0.59	22,860	11	0.144	0.417	0.018	22,860	
6	9	1.15	2.18	0.44	18,370	9	0.073	0.239	0.007	18,370	
7	6	0.56	1.16	0.32	12,240	6	0.088	0.187	0.024	12,240	
8	10	0.40	0.68	0.16	20,600	10	0.092	0.287	0.016	20,600	
9	10	0.36	0.64	0.21	20,520	10	0.118	0.324	0.017	20,520	
10	5	0.24	0.33	0.17	11,470	5	0.109	0.187	0.057	11,470	
11	7	0.22	0.32	0.09	16,870	7	0.085	0.203	0.016	16,870	
12	7	0.17	0.26	0.11	16,022	7	0.107	0.191	0.008	16,022	
Year	89	0.57	2.18	0.09	191,362	75	0.121	0.572	0.007	160,522	

## RIFLE (Map Designation R13)

1	2	0.22	0.27	0.17	4,902						
2	2	0.26	0.27	0.26	4,902						
3	7	0.44	0.90	0.27	17,026	1	0.614	0.614	0.614	2,451	
4	1	1.81	1.81	1.81	2,540	1	0.626	0.626	0.626	2,540	
5	10	1.11	1.72	0.51	25,003	10	0.135	0.347	0.014	25,003	
6	10	1.04	1.91	0.40	25,479	10	0.046	0.110	0.013	25,479	
7	6	0.54	0.90	0.30	14,884	6	0.040	0.105	0.004	14,884	
8	7	0.39	0.80	0.18	18,566	7	0.129	0.492	0.016	18,566	
9	9	0.49	1.21	0.12	22,546	9	0.225	0.929	0.020	22,546	
10	7	0.48	1.39	0.14	17,822	7	0.185	0.656	0.024	17,822	
11	7	0.30	0.61	0.10	17,555	7	0.156	0.367	0.015	17,555	
12	3	0.24	0.44	0.09	7,573	3	0.124	0.197	0.033	7,573	
Year	71	0.62	1.81	0.09	178,798	61	0.147	0.929	0.004	154,419	

AIR PARTICULATE SURVEILLANCE

Month	N	Total Long Lived Beta pCi/m <sup>3</sup>			Total Air Volume m <sup>3</sup>	N	Total Long Lived Alpha pCi/m <sup>3</sup>			Total Air Volume m <sup>3</sup>
		$\bar{X}$	Max.	Min.			$\bar{X}$	Max.	Min.	
PALISADE (Map Designation R25)										
1	2	0.10	0.11	0.09	4,354					
2	1	0.10	0.10	0.10	2,084					
3	8	0.39	0.56	0.22	21,396					
4	8	0.50	0.86	0.01	21,440	5	0.016	0.024	0.001	13,367
5	9	0.85	1.25	0.41	24,135	8	0.017	0.038	0.003	21,444
6	9	1.09	1.66	0.54	23,300	9	0.008	0.015	0.001	23,300
7	8	0.51	1.04	0.21	19,906	8	0.012	0.028	0.001	19,906
8	10	0.30	0.61	0.12	25,251	10	0.025	0.083	0.006	25,251
9	8	0.24	0.45	0.11	20,136	8	0.008	0.023	0.001	20,136
10	7	0.33	0.87	0.13	10,309	7	0.018	0.041	0.003	10,309
11	7	0.24	0.47	0.05	12,590	7	0.015	0.027	0.002	12,590
12	7	0.20	0.37	0.10	13,576	7	0.023	0.042	0.004	13,576
Year	84	0.49	1.66	0.01	198,477	69	0.016	0.083	0.001	159,879
GRAND JUNCTION (Map Designation R28)										
1	4	0.43	0.75	0.08	10,603					
2	6	0.63	1.17	0.30	16,843					
3	10	0.44	0.79	0.28	27,894	1	0.204	0.204	0.204	2,773
4	10	0.67	1.23	0.19	26,508	7	0.039	0.213	0.009	18,270
5	9	0.94	1.36	0.41	24,567	8	0.028	0.107	0.001	21,874
6	10	1.06	1.75	0.37	26,796	10	0.018	0.102	0.002	26,796
7	9	0.59	1.08	0.29	22,795	9	0.071	0.288	0.004	22,795
8	10	0.32	0.61	0.18	25,977	10	0.044	0.153	0.007	25,977
9	10	0.30	0.56	0.12	25,201	10	0.030	0.133	0.001	25,201
10	7	0.23	0.48	0.13	14,846	7	0.033	0.107	0.003	14,846
11	8	0.23	0.38	0.05	15,086	8	0.015	0.020	0.009	15,086
12	7	0.24	0.39	0.13	13,050	7	0.025	0.039	0.008	13,050
Year	100	0.54	1.75	0.05	250,166	77	0.037	0.288	0.001	186,668
FRUITA (Map Designation R30)										
1	2	0.15	0.21	0.08	4,992					
2	2	0.18	0.22	0.15	4,861					
3	10	0.43	0.73	0.15	25,140	1	0.019	0.019	0.019	2,451
4	10	0.77	1.44	0.23	25,085	7	0.008	0.017	0.001	16,642
5	5	1.01	1.53	0.45	13,055	5	0.010	0.015	0.005	13,055
6	9	1.04	1.92	0.39	23,555	9	0.007	0.020	0.002	23,555
7	10	0.57	1.20	0.28	24,522	10	0.009	0.013	0.001	24,522
8	10	0.32	0.67	0.09	23,651	10	0.010	0.022	0.002	23,651
9	10	0.28	0.63	0.10	27,029	10	0.007	0.013	0.001	27,029
10	7	0.25	0.59	0.17	14,357	7	0.011	0.019	0.003	14,357
11	8	0.25	0.42	0.06	14,532	8	0.003	0.005	0.001	14,532
12	6	0.20	0.29	0.03	8,763	5	0.036	0.136	0.012	7,328
Year	89	0.51	1.92	0.03	208,542	72	0.009	0.136	0.001	167,122

AIR PARTICULATE SURVEILLANCE

Month	N	Total Long Lived Beta pCi/m <sup>3</sup>				Total Air Volume m <sup>3</sup>	N	Total Long Lived Alpha pCi/m <sup>3</sup>				Total Air Volume m <sup>3</sup>
		$\bar{X}$	Max.	Min.				$\bar{X}$	Max.	Min.		
MONTROSE (Map Designation R33)												
1	2	0.52	0.90	0.13	4,894							
2	2	0.32	0.49	0.16	4,690							
3	9	0.42	0.60	0.16	22,142	1	0.008	0.008	0.008	2,365		
4	9	0.88	1.55	0.27	22,389	6	0.012	0.026	0.003	14,640		
5	11	1.17	1.95	0.52	26,591	11	0.007	0.015	0.001	26,591		
6	10	1.27	3.34	0.22	23,491	10	0.008	0.018	0.002	23,491		
7	4	0.39	0.80	0.19	9,665	4	0.005	0.011	0.001	9,665		
8	4	0.33	0.55	0.16	9,298	4	0.007	0.012	0.003	9,298		
9	10	0.23	0.48	0.14	22,301	10	0.009	0.013	0.001	22,301		
10	8	0.40	1.81	0.12	16,965	8	0.006	0.014	0.001	16,965		
11	6	0.19	0.35	0.07	12,561	6	0.008	0.014	0.001	12,561		
12	6	0.19	0.34	0.11	12,683	6	0.006	0.017	0.001	12,683		
Year	81	0.63	3.34	0.07	187,670	66	0.008	0.026	0.001	150,560		

## GLENWOOD SPRINGS (Map Designation R42)

1	2	0.10	0.12	0.09	5,207					
2	2	0.12	0.15	0.09	5,207					
3	9	0.27	0.52	0.02	23,589					
4	10	0.51	0.90	0.15	26,215	7	0.010	0.023	0.001	18,337
5	11	0.68	1.13	0.34	28,796	11	0.006	0.015	0.002	28,796
6	10	1.04	2.08	0.24	23,169	10	0.004	0.012	0.001	23,169
7	10	0.51	0.99	0.20	23,930	9	0.004	0.011	0.001	21,528
8	8	0.31	0.71	0.10	19,664	8	0.006	0.022	0.001	19,664
9	10	0.29	0.62	0.09	25,097	10	0.008	0.020	0.001	25,097
10	7	0.24	0.74	0.11	13,774	7	0.011	0.017	0.005	13,774
11	8	0.24	0.47	0.13	13,619	7	0.010	0.021	0.002	11,934
12	7	0.21	0.43	0.11	11,794	7	0.020	0.028	0.011	11,794
Year	94	0.45	2.08	0.02	220,061	76	0.008	0.028	0.001	174,093

## All Eight Air Stations, Entire Year

- 644 0.54 3.34 0.01 1,527,417 521 0.053 0.929 0.001 1,217,149

N = Number of samples

$\bar{X}$  = Average activity in picocuries per cubic meter (pCi/m<sup>3</sup>)

Max. = Highest activity sample

Min. = Lowest activity sample

Total air volume = Sum of air volumes sampled

AIR MOISTURE SURVEILLANCE

Collection Date		Collection Time			Tritium Content	
Month	Day	From Hour	To Hour	Month Day	pCi/1 of water	pCi/m <sup>3</sup> of air
BATTLEMENT CREEK SOUTH OF RULISON SITE (Map Designation R1)						
8-18		1130	1430		1333 ± 523	8.2
BATTLEMENT CREEK NORTH OF RULISON SITE (Map Designation R2)						
7-14		1515	1800		972 ± 524	7.0
7-15		1800	1155	7-16	664 ± 520	4.3
8-17		1515	1605		699 ± 515	4.7
8-18		1350	1500		942 ± 518	5.1
10- 4		0840	1525		1644 ± 514	5.1
10- 5		0915	1930		2729 ± 528	9.8
10- 5		1930	1115	10- 6	3118 ± 533	10.8
10-29		1100	1610		4223 ± 548	6.5
12- 2		0900	1300		21849 ± 733	28.1
BATTLEMENT CREEK AT THE COMMAND POST (Map Designation R3)						
8-17		1455	1620		747 ± 516	4.6
10-26		1620	0920	10-27	3625 ± 540	7.0
10-27		0930	1255		625 ± 501	IFB
10-28		0920	1825		1735 ± 516	3.1
10-29		1010	1555		1440 ± 512	1.5
12- 2		0840	1340		IFB	IFB
INTERCEPT A (WEST HELICOPTER PAD) (Map Designation R5)						
10- 4		0800	1500		912 ± 505	3.3
10- 5		0825	1200		905 ± 504	4.1
INTERCEPT C (EAST HELICOPTER PAD) (Map Designation R6)						
10- 4		0745	1440		IFB	IFB
10- 5		0810	1150		725 ± 502	3.4
CLEM RANCH (Map Designation R7)						
7-14		1415	1845		1231 ± 527	8.9
7-15		1845	1130	7-16	1010 ± 525	5.2
10- 4		0655	1135		3325 ± 536	9.4
10- 5		0830	1400		678 ± 501	3.3
10-26		1625	0845	10-27	1237 ± 509	2.7
10-27		0850	1320		IFB	IFB
10-28		0905	1755		1725 ± 515	3.1
10-29		0945	1545		1120 ± 507	1.4
12- 2		0830	1430		2897 ± 527	5.2
12- 2		1430	1730		740 ± 498	IFB

AIR MOISTURE SURVEILLANCE

Collection Date		Collection Time		Tritium Content		
Month	Day	From Hour	To Hour	Month Day	pCi/l of water	pCi/m <sup>3</sup> or air
BERTARD RANCH (Map Designation R8)						
10-	4	0815	1900		IFB	IFB
10-	4	1900	0845	10-5	IFB	IFB
10-	5	0845	1900		IFB	IFB
10-	5	1900	1045	10-6	IFB	IFB
10-	6	1715	1020	10-7	556 ± 500	IFB
10-	28	0910	1810		1385 ± 511	2.5
RANCH SIX MILES SOUTH OF SILT (Map Designation R15)						
10-	5	1430	2025		827 ± 503	4.7
FAIRVIEW SCHOOL (Map Designation R16)						
7-	15	1515	2115		1297 ± 528	7.6
8-	18	1445	1930		1227 ± 522	8.5
10-	5	1450	2010		549 ± 499	2.5
10-	27	1515	2015		3319 ± 536	6.0
SILT-COLLBRAN DIVIDE SUMMIT (Map Designation R17)						
7-	15	1515	2030		1580 ± 532	5.5
8-	17	1500	1800		984 ± 519	6.3
10-	5	1515	1955		654 ± 501	2.9
10-	27	1540	1750		598 ± 500	IFB
HIGHWAY #330 AND VEGA RESERVOIR ROAD JUNCTION (Map Designation R19)						
7-	15	1630	2110		1290 ± 528	5.6
8-	17	1535	1710		901 ± 518	5.9
8-	18	1605	1845		603 ± 514	4.3
10-	5	1600	1925		IFB	IFB

IFB - equal to or less than 500 pCi/l <sup>3</sup>H

PRECIPITATION AND WATER SURVEILLANCE

Sample Number	Date Month Day	Total Alpha	Radioactivity (pCi/l) Total Beta	Radium-226	Tritium
PRECIPITATION					
NEAR BATTLEMENT CREEK SOUTH OF RULISON SITE (Map Designation R1)					
IW253	12- 2	IFB	14 ± 9		IFB
NEAR BATTLEMENT CREEK NORTH OF RULISON SITE (Map Designation R2)					
754	1- 9	IFB	8 ± 8		729
IW255	12- 2	5 ± 4	22 ± 10		518 ± 495
NEAR BATTLEMENT CREEK AT THE COMMAND POST (Map Designation R3)					
IW256	12- 2	IFB	IFB		912 ± 501
RULISON EXCLUSION AREA BOUNDARY (Map Designation R4)					
752	1- 9	IFB	IFB		IFB
IW254	12- 3	IFB	23 ± 10		2334 ± 520
WATER					
EAST BATTLEMENT CREEK UPSTREAM FROM RULISON SITE (Map Designation R1)					
1128	4- 9	IFB	IFB		IFB
M7	6-22	IFB	IFB		606 ± 502
M67	7-14	IFB	IFB		703 ± 504
M219	8-18	11 ± 8	IFB	0.17 ± 0.10	607 ± 514
M410	10- 3	IFB	IFB		IFB
IW244	12- 2	IFB	IFB		1018 ± 502
EAST BATTLEMENT CREEK DOWNSTREAM FROM RULISON SITE (Map Designation R2)					
M5	6-22	IFB	IFB		831 ± 505
M64	7-14	IFB	IFB		936 ± 507
M220	8-18	IFB	IFB		IFB
M412	10- 3	IFB	IFB		IFB
IW198	10-28				IFB
IW191	10-29	IFB	IFB		IFB
MAIN BATTLEMENT CREEK DOWNSTREAM FROM RULISON SITE (Map Designation R3)					
753	1- 9	IFB	IFB		IFB
1127	4- 9	IFB	IFB		IFB
M4	6-22	IFB	IFB		697 ± 504
M65	7-14	IFB	IFB		993 ± 508
M221	8-18	IFB	IFB		781 ± 516
M404	10- 4	IFB	IFB		664 ± 501
M439	10- 7	IFB	IFB		IFB
IW189	10-28	IFB	IFB		IFB
IW201	10-29	IFB	IFB		IFB
IW247	12- 2	IFB	IFB		843 ± 500

PRECIPITATION AND WATER SURVEILLANCE

Sample Number	Date Month Day	Radioactivity (pCi/l)			Tritium
		Total Alpha	Total Beta	Radium-226	

COLORADO RIVER AT GRAND VALLEY BRIDGE (Map Designation R9)

M441	10- 7	12 $\pm$ 15	IFB	0.19 $\pm$ 0.10	861 $\pm$ 504
IW188	10-28	4 $\pm$ 14	IFB	0.16 $\pm$ 0.10	996 $\pm$ 507
IW199	10-29	6 $\pm$ 12	IFB	0.18 $\pm$ 0.10	735 $\pm$ 502

TOWN OF GRAND VALLEY (Map Designation R10)

755	1- 9	IFB	IFB		IFB
977	2-25	14 $\pm$ 10	IFB	0.04	IFB
M1125	4- 9	IFB	IFB		IFB
M2	6-22	IFB	IFB		IFB
M66	7-14	5.2 $\pm$ 10.5	IFB	0.18 $\pm$ 0.10	IFB
M212	8-19	14 $\pm$ 10	IFB	0.42 $\pm$ 0.12	IFB
M407	10- 4	IFB	IFB		IFB
M440	10- 7	IFB	IFB		IFB
IW200	10-29	7 $\pm$ 10	IFB	IFB	IFB
IW246	12- 2	IFB	IFB		IFB

COLORADO RIVER AT RULISON BRIDGE (Map Designation R11)

978	2-25	23 $\pm$ 13	IFB	2.82 $\pm$ 0.26	716
IW249	12- 2	2 $\pm$ 14	IFB		1021 $\pm$ 502

TOWN OF RIFLE-BEAVER CREEK PLANT (Map Designation R12)

M1166	4-16	IFB	IFB		695 $\pm$ 492
M1	6-22	IFB	IFB		804 $\pm$ 505
M213	8-19	IFB	IFB		IFB
M442	10- 7	IFB	IFB		IFB
IW186	10-28	IFB	IFB		797 $\pm$ 503
IW203	10-29	14 $\pm$ 10	IFB	0.11 $\pm$ 0.09	IFB
IW251	12- 4	IFB	IFB		974 $\pm$ 501

TOWN OF RIFLE-GRAHAM PLANT (Map Designation R13)

1165	4-16	IFB	IFB		705 $\pm$ 492
M443	10- 7	IFB	IFB	0.21 $\pm$ 0.10	890 $\pm$ 505

COLORADO RIVER AT SILT BRIDGE (Map Designation R14)

IW197	10-30	4 $\pm$ 14	IFB	0.22 $\pm$ 0.10	663 $\pm$ 501
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BUZZARD CREEK AT HIGHWAY 330 BRIDGE (Map Designation R18)

M217	8-19	9 $\pm$ 11	IFB	0.21 $\pm$ 0.10	IFB
IW202	10-30	IFB	IFB	IFB	866 $\pm$ 504
M405	10- 5				1186 $\pm$ 508

PRECIPITATION AND WATER SURVEILLANCE

Sample Number	Date Month Day	Total Alpha		Radioactivity (pCi/l) Total Beta Radium-226		Tritium

## VEGA RESERVOIR OUTLET (Map Designation R20)

M69	7-15	IFB	IFB			831 ± 505
M216	8-19	44 ± 10	46 ± 13	0.12 ± 0.09		IFB
IW195	10-30	IFB	IFB			715 ± 502
M408	10- 5					905 ± 504

## TOWN OF COLLBRAN (Map Designation R21)

M1223	5- 7	IFB	IFB			
M32	7- 2	IFB	9 ± 9			811 ± 505
M81	7-15	9 ± 11	IFB	0.22 ± 0.10		1043
M215	8-19	7 ± 11	IFB	IFB		956 ± 518
IW187	10-27	4 ± 10	IFB	IFB		1220 ± 509
IW302	11-23	12 ± 11	IFB			
M661	12- 9	IFB	IFB			1227 ± 532
M409	10- 5					1369 ± 511

## PLATEAU CREEK AT I-70 BRIDGE (Map Designation R23)

M976	2-25	10 ± 10	10 ± 9	0.12 ± 0.09		882 ± 495
1126	4- 9	12 ± 12	12 ± 10			1169
M12	6-25	IFB	IFB			777 ± 505
M83	7-15	13 ± 12	IFB	0.31 ± 0.11		
M214	8-19	13 ± 13	IFB	0.72 ± 0.15		1100 ± 520
M406	10- 5	7 ± 12	15 ± 10	0.11 ± 0.09		1105 ± 507
IW190	10-29	IFB	IFB	IFB		928 ± 505
IW248	12- 3	12 ± 13	IFB			878 ± 500

## COLORADO RIVER AT CAMEO GAUGING STATION (Map Designation R24)

R1117	1-	13 ± 12	IFB	0.24 ± 0.11		
R1547	3-	4 ± 13	IFB			
R1903	4-23	IFB	IFB			
R2178	6- 3	IFB	IFB			1207 ± 527
M3	6-25	IFB	IFB			1202 ± 510
R839	10-	5 ± 11	IFB	0.12 ± 0.08		649 ± 501
IW194	10-29	IFB	10 ± 9	0.17 ± 0.10		IFB
R973	11-	IFB	IFB	IFB		644 ± 497
R1101	11-	7 ± 13	IFB			
IW245	12- 3	7 ± 15	IFB			1001 ± 502
R1223	12-	24 ± 20	IFB			585 ± 523

## TOWN OF PALISADE (Map Designation R25)

M34	7- 3	IFB	IFB			720 ± 504
M484	10-19	IFB	IFB			625 ± 501
M547	10-21	9 ± 7	IFB	IFB		555 ± 496
IW303	12- 1	IFB	IFB			1395 ± 534
M664	12- 9	IFB	IFB			542 ± 522

PRECIPITATION AND WATER SURVEILLANCE

Sample Number	Date Month Day	Total Alpha	Radioactivity (pCi/l)		Tritium
			Total Beta	Radium-226	
COLORADO RIVER AT CLIFTON BRIDGE (Map Designation R26)					
IW314	4- 9	8.7 ± 11.5	IFB	0.31 ± 0.12	
UTE WATER CONSERVANCY DISTRICT (Map Designation R27)					
M33	7- 3	IFB	IFB		653 ± 503
M485	10-19	IFB	IFB		564 ± 500
M546	10-21	IFB	IFB		
IW305	11-23	IFB	IFB		
M662	12-10	IFB	IFB		IFB
TOWN OF GRAND JUNCTION (Map Designation R28)					
1164	4-14	IFB	IFB		IFB
M10	6-24	IFB	IFB		1165 ± 510
M486	10-19	IFB	IFB		591 ± 500
M545	10-21	IFB	IFB		
IW304	12- 1	IFB	IFB		IFB
M667	12-10	IFB	IFB		IFB
COLORADO RIVER AT HIGHWAY 50 BRIDGE (Map Designation R29)					
979	2-25	10 ± 13	IFB	0.22 ± 0.1	1152 ± 498
IW312	4- 7	19.5 ± 14	11 ± 9	0.24 ± 0.11	1642 ± 533
COLORADO RIVER AT FRUITA (Map Designation R30)					
R1116	1-	IFB	IFB		
R1300	2-	11 ± 14	IFB		1080 ± 502
R1548	3-	2 ± 12	IFB		
R1902	4-23	IFB	IFB		
R227	7-15	IFB	IFB		1489 ± 514
R385	7-	11 ± 16	IFB	0.22 ± 0.10	999 ± 507
R962	10-20	5 ± 16	IFB	IFB	
R969	11-	1 ± 15	IFB	0.13 ± 0.09	977 ± 501
R1099	11-	1 ± 12	IFB		
1225	12-	11 ± 16	IFB		IFB
GUNNISON RIVER AT WHITEWATER (Map Designation R31)					
R1114	1-	IFB	IFB		
R1297	2-	IFB	IFB		872 ± 495
R1557	3-	9 ± 12	IFB		1423 ± 506
R1908	4-24	IFB	IFB		
R243	7-16	19 ± 16	IFB	0.16 ± 0.09	
R395	7-	14 ± 16	IFB	0.08 ± 0.08	867 ± 505
R968	11-	IFB	IFB	IFB	648 ± 497
R1222	12-	54 ± 20	10 ± 10		IFB

PRECIPITATION AND WATER SURVEILLANCE

Sample Number	Date Month Day	Total Alpha	Radioactivity (pCi/l) Total Beta	Radium-226	Tritium
UNCOMPAHGRE RIVER AT DELTA (Map Designation R32)					
R1109	1-	44 ± 22	IFB	IFB	
R1245	2-	45 ± 24	IFB		
R1553	3-	20 ± 24	IFB		
R1912	4-24	10 ± 15	13 ± 10		
R240	7-16	10 ± 12	IFB	0.12 ± 0.09	
R388	7-	IFB	IFB		683 ± 503
R389	8-	14 ± 20	IFB	0.29 ± 0.11	1383 ± 512
R965	11-	3 ± 20	IFB	0.10 ± 0.09	
R1188	12-	127 ± 31	18 ± 11		IFB
GUNNISON RIVER AT AUSTIN (Map Designation R34)					
R1108	1-	13 ± 8	IFB	0.08 ± 0.08	
R1296	2-	IFB	IFB		
R1552	3-	IFB	IFB		
R1911	4-24	IFB	IFB		
R237	7-16	11 ± 10	IFB	0.13 ± 0.09	
R966	11-	IFB	IFB		
R1187	12-	30 ± 11	IFB		538 ± 522
MUDDY CREEK UPSTREAM FROM PAONIA RESERVOIR (Map Designation R35)					
M18	7-16	IFB	IFB		818
GUNNISON RIVER DOWNSTREAM FROM GUNNISON (Map Designation R36)					
R1826	4-15	IFB	IFB		
R136	7-	IFB	IFB		1004 ± 519
R814	10-	IFB	IFB		722 ± 502
R930	10-15	IFB	IFB	IFB	1034 ± 506
TOMICHI CREEK AT GUNNISON (Map Designation R37)					
1051	1- 5	16 ± 8	IFB		
R866	1-29	23 ± 8	IFB		
R1569	2-	13 ± 8	IFB		
R1458	3-	16 ± 7	IFB		
R1825	4-15	12 ± 8	IFB	0.16 ± 0.11	
R137	7-	IFB	IFB		922 ± 518
R528	8-	IFB	IFB		1237 ± 510
R931	10-15	12 ± 8	IFB		701 ± 502
TAYLOR RIVER AT ALMONT (Map Designation R38)					
867	1-29	9 ± 7	IFB		
R1571	3-	IFB	IFB		
R1828	4-15	IFB	IFB		
R2127	6- 3	IFB	IFB		1086 ± 526
R527	8-	IFB	IFB		1254 ± 510
R929	10-15	IFB	IFB		794 ± 503

PRECIPITATION AND WATER SURVEILLANCE

Sample Number	Date Month Day	Radioactivity (pCi/l)			Tritium
		Total Alpha	Total Beta	Radium-226	
EAST RIVER AT ALMONT (Map Designation R39)					
R886	1- 5	IFB	IFB		
R1301	2-	5 $\pm$ 13	10 $\pm$ 10		1752 $\pm$ 511
R1570	3-	IFB	IFB		1114 $\pm$ 502
R1827	4-15	IFB	IFB		
R2126	6- 3	IFB	IFB		1487 $\pm$ 531
R526	8-	IFB	IFB		1149 $\pm$ 509
R928	10-15	IFB	IFB		859 $\pm$ 504
CRYSTAL RIVER SOUTH OF CARBONDALE (Map Designation R40)					
M9	6-26	IFB	IFB		929 $\pm$ 507
M403	10- 5				946 $\pm$ 505
TOWN OF CARBONDALE (Map Designation R41)					
M8	6-26	IFB	IFB		1562 $\pm$ 515
M411	10- 4	IFB	IFB		607 $\pm$ 500
TOWN OF GLENWOOD SPRINGS (Map Designation R42)					
M6	6-26	IFB	IFB		774 $\pm$ 505
IW250	12- 1	IFB	IFB		1069 $\pm$ 503
ROARING FORK RIVER AT GLENWOOD SPRINGS (Map Designation R43)					
R1794	4-10	IFB	IFB		
R163	7- 8	IFB	IFB		
R398	7-	IFB	IFB	0.15 $\pm$ 0.09	979 $\pm$ 507
R981	11-	IFB	IFB		788 $\pm$ 499
COLORADO RIVER AT NEWCASTLE (Map Designation R44)					
R1793	4-10	11 $\pm$ 12	IFB	IFB	
R2030	5-10	IFB	IFB		
M11	6-25	IFB	IFB		1262 $\pm$ 511
R162	7- 8	16 $\pm$ 11	IFB	0.16 $\pm$ 0.10	
M218	8-19	5 $\pm$ 11	IFB	0.26 $\pm$ 0.11	685 $\pm$ 515
R842	10-	IFB	11 $\pm$ 10		1075 $\pm$ 507
R980	11-	7 $\pm$ 13	IFB	0.15 $\pm$ 0.10	1015 $\pm$ 502
R1104	11-	5 $\pm$ 12	IFB		
IW252	12- 4	11 $\pm$ 15	IFB		1056 $\pm$ 502

PRECIPITATION AND WATER SURVEILLANCE

Sample Number	Date Month Day	Radioactivity (pCi/l)		Tritium
		Total Alpha	Total Beta Radium-226	
COLORADO RIVER AT DOTSERO (Map Designation R45)				
R1602	3-	IFB	IFB	
R1795	4-10	IFB	11 ± 9	
R164	6-18	IFB	IFB	1126 ± 524
R848	10-	IFB	IFB	1027 ± 506
R982	11-	IFB	IFB	720 ± 498
R1106	11-	IFB	IFB	
EAGLE RIVER AT GYPSUM (Map Designation R46)				
R1603	3-	IFB	IFB	
R1796	4-10	IFB	IFB	
R400	7-	11 ± 15	IFB	0.23 ± 0.10
R983	11-	5 ± 10	IFB	0.09 ± 0.09
YAMPA RIVER AT MILNER (Map Designation R47)				
R1771	4- 9	IFB	10 ± 5	
R2245	6-15	IFB	IFB	1077 ± 509
R376	7-	IFB	IFB	1217 ± 510
R944	10-15	IFB	IFB	1117 ± 507
YAMPA RIVER AT MAYBELL (Map Designation R48)				
R2095	5-26	IFB	IFB	
R379	7-	IFB	IFB	1054 ± 508
R947	10-15	IFB	IFB	1014 ± 506
WHITE RIVER AT MEEKER (Map Designation R49)				
894	1-	IFB	IFB	
R2108	5-26	IFB	IFB	
R153	6-16	IFB	IFB	654 ± 517
R2252	7-16	IFB	IFB	
R601	9-10	9 ± 11	IFB	IFB
WHITE RIVER AT RANGELY (Map Designation R50)				
R1137	1-	14 ± 10	IFB	0.16 ± 0.09
R1360	2-	IFB	IFB	IFB
R1588	3-	6 ± 12	IFB	IFB
R2251	6-16	IFB	IFB	670 ± 503
R598	9-10	9 ± 11	IFB	0.11 ± 0.09
R950	10-15	IFB	IFB	756 ± 502
				IFB
IFB - equal to or less than 6 pCi/l alpha				
equal to or less than 8 pCi/l beta				
equal to or less than 0.1 pCi/l <sup>226</sup> Ra				
equal to or less than 500 pCi/l <sup>3</sup> H				

MILK SURVEILLANCE

Sample Number	Date		Radioactivity (pCi/l)			
	Collected Month Day	Analyzed Month Day	Iodine 131	Barium 140	Cesium 137	Tritium

## RIFLE-GLENWOOD SPRINGS (Map Designation R51)

565	4-13	4-16	33	IFB	63	778 ± 519
567	4-	4-29	IFB	IFB	IFB	1093 ± 526
4428	5-11	5-15	IFB	IFB	IFB	934 ± 524
569	6-22	6-24	IFB	IFB	IFB	1238 ± 528
4430	8- 3	8- 6	IFB	IFB	IFB	868 ± 506
4432	8-31	9- 3	IFB	IFB	IFB	1366 ± 512
4434	10-12	10-15	IFB	IFB	IFB	784 ± 504
<u>4436</u>	12- 7	12-10	IFB	IFB	IFB	<u>1075 ± 508</u>

N=8

 $\bar{X}=1042$ 

## GRAND JUNCTION-FRUITA (Map Designation R52)

4050	3-18	3-20	IFB	IFB	25	785 ± 519
3886	4-14	4-16	IFB	IFB	IFB	733 ± 518
3890	4-20	4-23	IFB	IFB	IFB	895 ± 520
3891	4-22	4-24	IFB	IFB	IFB	685 ± 518
3892	4-22	4-24	IFB	IFB	IFB	888 ± 520
149	7-16	7-24	IFB	IFB	IFB	905 ± 506
3132	12-20	12-28	IFB	IFB	IFB	623 ± 489
3129	12-21	12-24	IFB	IFB	IFB	IFB
3130	12-21	12-24	IFB	IFB	IFB	675 ± 490
3133	12-21	12-28	IFB	IFB	IFB	862 ± 492
3131	12-22	12-24	IFB	IFB	IFB	588 ± 488
3134	12-23	12-28	IFB	IFB	IFB	948 ± 493
3135	12-24	12-30	IFB	IFB	IFB	824 ± 492
3136	12-25	12-30	IFB	IFB	IFB	1010 ± 494
<u>3137</u>	12-26	12-30	IFB	IFB	IFB	<u>1052 ± 495</u>

N=15

 $\bar{X}= 798$ 

## CRAIG-MEEKER (Map Designation R53)

564	4-15	4-16	IFB	IFB	IFB	661 ± 517
4429	5-13	5-15	IFB	IFB	IFB	605 ± 519
570	6-23	6-25	IFB	29	IFB	564 ± 519
4431	8- 4	8- 6	37	IFB	IFB	677 ± 503
4433	9- 1	9- 3	IFB	IFB	IFB	1285 ± 511
4435	10-13	10-15	IFB	IFB	IFB	863 ± 505
<u>4437</u>	12- 8	12-10	IFB	IFB	IFB	<u>1065 ± 508</u>

N=7

 $\bar{X}= 817$

MILK SURVEILLANCE

Sample Number	Date		Radioactivity (pCi/l)			Tritium
	Collected Month Day	Analyzed Month Day	Iodine 131	Barium 140	Cesium 137	

## DELTA-PAONIA-MONTROSE (Map Designation R54)

5955	7-21	7-22	IFB	IFB	IFB	816 ± 519
5956	7-21	7-22	IFB	IFB	IFB	568 ± 516
574	10- 5	10- 7	IFB	IFB	IFB	1685 ± 515
575	10- 5	10- 7	IFB	IFB	32	1054 ± 506
<u>3126</u>	10- 5	10- 7	IFB	IFB	IFB	797 ± 503

N=5

 $\bar{X}$ = 984

## SALIDA-BUENA VISTA (Map Designation R55)

563	3-10	3-12	IFB	IFB	IFB	981 ± 522
566	4-22	4-22	IFB	IFB	IFB	1198 ± 524
568	6- 3	6- 5	IFB	IFB	IFB	1411 ± 530
571	7- 6	7- 9	IFB	IFB	IFB	-----
572	7-28	7-30	IFB	IFB	IFB	1336 ± 512
573	8-23	8-25	IFB	IFB	IFB	1033 ± 507
<u>3128</u>	12-21	12-22	IFB	IFB	IFB	1149 ± 496

N=6

 $\bar{X}$ =1185

## DURANGO-SAN JUAN BASIN (Map Designation R56)

1945	1-20	1-22	IFB	IFB	IFB	768 ± 519
1947	2-17	2-19	IFB	IFB	IFB	861 ± 520
1949	3-16	3-20	IFB	IFB	35	575 ± 516
1950	4-21	4-22	IFB	IFB	IFB	-----
1876	4-22	4-23	IFB	IFB	IFB	1332 ± 526
1877	6-15	6-18	IFB	IFB	31	878 ± 523
1878	7-20	7-22	IFB	IFB	IFB	750 ± 519
1879	8-18	8-21	IFB	IFB	IFB	624 ± 514
1880	9-14	9-17	IFB	IFB	IFB	IFB
<u>1881</u>	12-21	12-22	IFB	IFB	IFB	IFB

N=9

 $\bar{X}$ = 754

IFB - equal to or less than 25 pCi/l gamma  
 - equal to or less than 500 pCi/l <sup>3</sup>H

N = Number of samples

 $\bar{X}$  = Average activity in picocuries per liter (pCi/l) of milk