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MASTER

ENVIRONMENTAL
MONITORING
AT AMES LABORATORY

Calendar Year 1977

Milo D. Voss

AMES LABORATORY, DOE
IOWA STATE UNIVERSITY
AMES, IOWA

Date Transmitted: April 1978

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ENVIRONMENTAL MONITORING AT AMES LABORATORY

Calendar Year 1977

Milo D. Voss

Ames Laboratory, USDOE
Iowa State University
Ames, Iowa 50011

Program Associates

Air & Instrumentation: L. K. Mathison
Water & Laboratory: J. F. Barry

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Environmental Monitoring at Ames Laboratory:

calendar Year 1977

ABSTRACT

This is an annual report summarizing the effluent and environmental monitoring program at the Ames Laboratory of the Department of Energy.

Earlier reports in this series concerned only environmental radioactivity and were each entitled "Survey of Environmental Radioactivity." The report for 1973 included some information on effluents, both radioactive and non-radioactive, with an assessment of the radiation dose to the public.

The 1974 report was the first in the present series of reports. An inventory of the radioactive materials and certain chemicals released to the environment is included. A summary of the radioactivity found in the environment is presented. An estimate of the radiation dose to the public resulting from the operations of the Ames Laboratory is stated.

The environmental program was modified in July of 1976.

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1. Summary

The results and conclusions from the Ames Laboratory environmental monitoring programs for the Ames Laboratory Research Reactor (ALRR) are presented in this report. The major areas of radiological monitoring were ALRR effluent air, environmental air, effluent water and environmental water. Effluent and environmental water were also monitored for chemical constituents which could be present from ALRR operations.

Air sampling showed that the isotopes detectable by gamma analyses in the ALRR stack effluent were lower in concentration than isotopes in the environmental air samples. Therefore, ALRR operations did not contribute anything to the particulate gamma activity in the atmosphere. Radioisotopes that were above background in the stack were radioactive hydrogen (H-3 or tritium) and radioactive argon (Ar-41). The average individual dose from Ar-41 and H-3 at the exclusion fence was estimated to be 5.51 mRem and the estimated dose to the entire population within a 50 mile radius of the ALRR was 244.5 man-Rem. These values are 1.1% and 0.24%, respectively, of the doses derived from the concentration guides (1).

In the liquid released from the ALRR complex, H-3 was the predominant isotope. With respect to the percentage of the concentration guide value, H-3 was a factor of 100 higher than any other constituent. Before stream dilution the average individual dose from H-3 was 12.6% of the dose derived from the concentration guide. After mixing in the receiving stream the potential dose was not more than 0.34% of the dose derived from the concentration guide (1).

During 1977 the central Iowa area experienced a severe drought which brought about water conservation efforts by the City of Ames with which the Ames Laboratory complied. As a result, consideration was given to finding a source of recyclable water that could be used for dilution of ALRR effluents.

This consideration resulted in the use of ALRR secondary cooling tower water overflow for dilution to maintain effluent quality within DOE Manual Chapter 0524 standards.

The environmental monitoring program was changed on July 1, 1976. The changes which were made are shown in a previous environmental monitoring report, IS-4139 (8). The changes were made in order to improve the cost effectiveness of the program in accord with the minimal impact of the ALRR on the surrounding environment. Media and sites which had shown no previous impact or correlation with reactor operations were eliminated. A new site was added, and the media and sites which could show impacts were retained. The changes were subject to consideration and agreement with Chicago Operations Office of DOE.

The ALRR operated under an interim National Pollution Discharge Elimination System (NPDES) Permit issued by the Environmental Protection Agency, through June 30, 1977. During the remainder of the calendar year 1977 the ALRR operated under a final NPDES permit. This permit differs from the interim permit such that the limit for hexavalent chromium is set at 0.05 mg/l.

As of July 1, 1977 the expected connection of the ALRR site to the City of Ames sanitary sewage system did not materialize. Consequently, the ALRR did not meet the NPDES limit for chromium (hexavalent) at the discharge point (drainage ditch). It is expected that the sewage line will be connected to the ALRR during 1978.

However, the instream limits for hexavalent chromium as set by the State of Iowa, have always been met and continue to be met by the operations of the Ames Laboratory. Samples taken in Onion Creek downstream from the ALRR effluent confluence point averaged 0.02 mg/l in hexavalent chromium, 40% of Iowa's standard.

II. Ames Laboratory Facilities and Locality

The facilities of the Ames Laboratory include offices, laboratories, warehouses and service buildings located among university buildings on the campus of Iowa State University (I.S.U.) in Ames, Iowa. In addition to the facilities on campus, the Ames Laboratory Research Reactor (ALRR) together with a waste handling-decontamination facility and an office-warehouse is located on a 16.2 hectares (40 acre) site approximately (Figure 1, page 33) 2.4 Km (1.5 miles) northwest of the I.S.U. campus (Figure 2) and 4.8 Km (3 miles) west and north of downtown Ames (City Hall). The site of the ALRR is about 305 m (1,000 feet) above sea level and is enclosed by an exclusion fence at 213 m (700 feet) or more centered on the reactor. The nearest non-residential building (I.S.U.) is about 244 m (800 feet) east of the reactor and the nearest residential lot is about 381 m (1250 feet) south of the ALRR.

Ames is located in central Iowa where the Squaw Creek and Skunk River come together (Figures 3 and 4). The land is gently rolling "swell and swale". The flat upland is only a little greater than 30.5 m (100 feet) above the river flood plain. The general area is about 274 m (900 feet) above sea level. The City of Ames covers 42.5 km² (16.4 square miles). The I.S.U. student population of about 19,000 is included in the Ames population numbering 40,000.* The major portion of Iowa State University and parts of Ames lie within a 3.2 Km (2 mile) radius of the Ames Laboratory Research Reactor. Within the 3.2 Km (2 mile) circle the land usage is 33% residential (Ames and I.S.U.), 25% wooded, and 42% agricultural.

The climatology of the area is temperate and continental subject to wide seasonal range in temperature, precipitation and winds. The average

*From 1970 census

annual temperature is 9.4°C (49°F). The average annual precipitation is 18.3 cm (32 inches): 90% rain, 10% snow, with small amounts of sleet and hail.

In the colder months the winds are mostly from the northwest sector averaging 29-32 Km/hour (18-20 miles/hour); in the warmer months winds are from the southeast sector averaging 19-23 Km/hour (12-14 miles/hour).

One characterization of winds is the fraction of time the wind blows from a certain direction. In the Ames area, the variations of a given wind direction between the least time or frequency and the greatest time is about a factor of two.

The average wind speed at 3 m (10 feet) above the ground is estimated at 14.4 Km/hour (9 miles/hour) and at 30.5 m (100 feet) it is 20.9 Km/hour (13 miles/hour).

An Inversion is an atmospheric condition which limits the upward rise of effluents from ventilation and smokestacks. This condition occurs in varying degrees about 290 times per year with an average duration of 14 hours.

The sources of water supply for Ames and Iowa State University are sand and gravel aquifers lying within two buried bedrock valleys, the Squaw and Skunk. Water is pumped for storage and distribution from a number of wells which are 30.5-39.6 m (100-130 feet) deep. The City of Ames pumped 7.4×10^9 liters (1898×10^6 gallons) from the well field in 1977. In addition, Iowa State University pumped 1.5×10^9 liters (224×10^6 gallons) in the same period, making the total pumped from the well field 8.9×10^9 liters (2354×10^6 gallons). Surface water contributes to the recharge of the system as water is pumped from the wells. The travel

time of water from the Skunk River to the well area is estimated at one year. The contribution to the recharge from Squaw Creek is less than that from the Skunk River. Recharge water from Squaw Creek passes through absorbing and filtering material, a mixture of clay, silt and sand which lies over the waterbearing sand and gravel.

The surface streams of particular interest to the Ames Laboratory are the Onion Creek Gulch, Onion Creek, Squaw Creek and the Skunk River. Onion Creek and Onion Creek Gulch are intermittent and non-classified streams. Squaw Creek and the Skunk River are classed as B, fresh warm water, and thus protected for wildlife, fish, aquatic and semi-aquatic life and secondary contact recreation. The classifications have been established by the Iowa Water Quality Commission. The Skunk River is changed to a Class C, protected raw water source of potable water supply, at the point of withdrawal at Oskaloosa, Iowa, 137 Km (85 river miles) downstream from Ames.

The area around Ames is generally rural with farming producing important yields of corn, soybeans, and wheat. The neighboring towns (Figure 3) are mostly small communities.

<u>City</u>	<u>Population*</u>	<u>From Ames</u>
Nevada	5,000	11 Km (7 miles) east
Ankeny	9,000	35 Km (22 miles) south
Boone	12,500	21 Km (13 miles) west
Story City	2,100	23 Km (14 miles) north

The capitol of Iowa, Des Moines, population 201,400* lies 48 Km (30 miles) south of Ames.

*From 1970 census

The total population within a circle of 80 Km (50 miles) radius is 590,500*.

The Ames Laboratory Research Reactor is fueled with uranium-235, with circulating heavy water as the coolant and moderator. The primary coolant, heavy water (D_2O), is circulated through the reactor in a closed system with a heat exchanger. The secondary heat removal system uses city supplied softened water circulated through the heat exchanger and an open cooling tower.

The reactor operates at 5,000 kilowatts thermal power level on a continuous schedule. The reactor produces up to 10^{14} neutrons/cm²/sec in various experimental facilities. The principal uses of the reactor are the production of fission products which are separated and studied, the irradiation of crystals for the study of structures and energy levels by neutron diffraction, the irradiation of materials, especially metals, for the study of radiation effects, the production of radioisotopes which are used in a variety of tracer studies, and activation of elements in materials for analytical studies.

The waste disposal/decontamination facility houses a decontamination booth and special sinks with systems for complete collection of the cleanings, a solid waste compactor, tank storage for liquids (water) with filtration and ion exchange processing systems, and evaporation and distillation systems. The output of this facility is clean equipment for reuse, Class C or better water for release to the environment; and packaged solid waste for shipment to a radioactive waste burial site.

*From 1970 census

The laboratories associated with the reactor and those in the Ames Laboratory complex on the Iowa State University campus that use radioactivity have relatively small amounts of radioactivity at any one time. The majority of the work deals with tracer studies employing relatively small amounts of radioisotopes (Ca-45, Cl-36, Co-60, Fe-59, Hf-175, Mn-54 and others). Waste from these experiments is collected and disposed of as radioactive waste.

The principal potential sources for release of radioisotopes and chemicals to the environment are the research reactor and the waste disposal/decontamination facility. Liquids released on the I.S.U. campus Ames Laboratory facilities are handled through the sanitary sewer system. Liquid and solid radioactive wastes in these facilities are collected and taken to the reactor site waste disposal facility for processing. Airborne releases are eliminated or minimized by experiment system design or source limitation. The liquid and solid contaminated wastes generated at the reactor site are transferred to the waste disposal facility for processing. Irradiated air systems of the reactor are filtered before release and are monitored. The liquid effluents from the reactor site are monitored at a single outfall site where all such wastes are released.

The effluent monitoring pertaining to these facilities and the environmental monitoring are presented in this report.

III. Definition of Terms

Average Average as used in this report is the arithmetical mean of all sample results. The activity of a sample was set equal to zero when the count rate was less than background. When the count rate was less than the detection limit, which is a function of the minimum detectable activity (4) (but greater than the instrument background) the calculated activity was used in averaging. No yearly average is the mean of the monthly averages.

**Confidence
Limits**

The confidence limits given in Table 1 indicate the accuracy of the particular value based on considerations of the count rate, count time and background, not on the distribution of sample values (4). The limits in this table have been derived for and are applicable only to the value which is stated for each media. The values used in Table 1 are typical yearly averages which appear in each media type group; that is, air, water, and bottom sediment.

Table 1
95% Confidence Limits

<u>Media Type</u>	<u>Sample Size</u>	<u>Count Time</u>	<u>Average Activity ($\pm 2\sigma$)</u>
<u>Beta</u>			
Air	152 m ³	50 min	0.098 (± 0.0094) $\times 10^{-12}$ $\mu\text{Ci/ml}$
Water	1	30 min	6.07 (± 1.35) $\times 10^{-9}$ $\mu\text{Ci/ml}$
Bottom Sediment	4 g	30 min	10.33 (± 0.71) $\times 10^{-6}$ $\mu\text{Ci/ml}$
<u>Alpha</u>			
Air	Same		0.0027(± 0.0037) $\times 10^{-12}$ $\mu\text{Ci/ml}$
Water	as		0.59 (± 0.76) $\times 10^{-9}$ $\mu\text{Ci/ml}$
Bottom Sediment	Beta		0.66 (± 0.26) $\times 10^{-6}$ $\mu\text{Ci/ml}$
<u>Tritium</u>			
Water			2.08 (± 0.50) $\times 10^{-6}$ $\mu\text{Ci/ml}$
Average Tritium Counting Efficiency = 23%			

Detection Limit The minimum detectable activity (limit) is defined as that activity which, in the same counting time, yields a count which is more than the instrument background count by three times the standard deviation of the background count (4).

The detection limit is a value of radioactivity per unit volume or mass based on the sample volume or mass, the counting procedure, and the minimum detectable activity. The detection limit is stated in Table 2 for each media.

Table 2
Detection Limits, Radiological

	Air 10^{-15} $\mu\text{Ci/ml}$	Water 10^{-9} $\mu\text{Ci/ml}$	Bottom Sediment 10^{-9} $\mu\text{Ci/g}$
Beta	4.80	1.00	250.
Alpha	3.20	0.39	100.
Tritium	--	500.	--
Ag-110m	0.13	0.13	8.81
Ba-140	0.38	0.38	25.8
Be-7	1.23	1.20	82.8
Ce-141	0.18	0.17	15.1
Ce-144	0.72	0.67	48.6
Co-60	0.14	0.15	9.6
Cs-137	0.15	0.15	10.4
La-140	0.27	0.26	18.2
Nb-95	0.13	0.13	8.9
Ru-103	0.13	0.13	8.8
Ru-106	2.75	2.70	173.
Sb-124	0.14	0.13	9.2
Sb-125	0.41	0.40	27.4
Zn-65	0.25	0.24	17.1
Zr-95	0.26	0.25	17.3

With respect to the gamma detection limits, typical counting times were 333.3 minutes. Sample volumes for air and water were 1.50×10^{10} ml and 2.2×10^4 ml, respectively. Sample mass for bottom sediment averaged 400 grams.

The non-radiological detection limits are shown in Table 3. Values less than the detection limits can be obtained. However, the values will be significantly less accurate since more judgement on the part of the analyst is needed.

Table 3
Detection Limits, Non-Radiological

Chloride	2.5 mg/l
Hexavalent Chromium	0.05 mg/l
Zinc	0.1 mg/l
Flow	1 l/min
BOD	0.25 mg/l
Fecal Coliform	1 organism/100 ml

High All highs given in this report are individual sample highs.
 Low All lows given in this report are individual sample lows.
 NDA No detectable activity.

IV. Radiological Monitoring Program

The Ames Laboratory radiological program monitors effluent (air particulate and water), environmental air particulate, river and well water and precipitation in the Ames area. Gamma analysis is generally performed on composites of samples collected over a month, quarter or the entire year. The samples are analyzed using a Nuclear Data 4096 Channel Gamma spectrometer with a high resolution Ge(Li) detector. A computer program based on ICPEAX (5) is used to determine peak energies and areas based on a gaussian fitting routine.

Individual samples are submitted to gross beta and alpha analysis. This provides an indication of the activity of the sample within 3 weeks. All alpha and beta determinations are made in a 3 inch gas proportional Sharp Low Betamatic System. The activity concentration is calculated using the following equation:

$$\text{Activity Concentration} = \frac{(\text{Counts/Time}) - \text{Background}}{(\text{Counter Efficiency})(\text{Volume})(2.22 \times 10^6 \text{ dpm}/\mu\text{Ci})} \quad (1)$$

Self-absorption was not considered. As such, the results are easily compared to other samples and to previous years. Since the alpha and beta determination is basically a screening process, this purpose is served equally as well without self-absorption corrections.

The tritium activity is determined on a 5 ml sample using a dioxane-naphthalene cocktail and a Beckman Scintillation Counter. The tritium activity concentration is also calculated using Equation 1.

A. Effluents

Air

Stack air particulate samples are collected on 5 cm (2 inch) Whatman #41 filter paper using a Gast pump with a flow rate of 5 liters per minute (3 CFM) from a sample point near the top of the ALRR stack (Figure 1). Comments describing the stack sampling program are as follows: (1) The air sampler system as operated in this sampling program, produces a particulate collection efficiency of >97% using the above filter paper, (2) Sampling is continuous with the filters being changed every working day, (3) both sample and stack flow rates are recorded, (4) gross beta and alpha activity is determined with the Sharp System after a seven day holding period, (5) gamma analysis is performed on quarterly composites of the daily samples. The Ar-41 is continuously monitored with readings taken hourly during reactor operations. The Ar-41 detector, a geiger mueller type, is calibrated twice a year. The H-3 effluent is an estimate based on the loss of primary coolant for the year and its average H-3 concentration. The presence of I-131 in the stack effluent was due to ALRR absolute filter testing procedures and was not a fuel related fission product. The other isotopes listed, except Ar-41, were due to atmospheric weapons testing. See Appendix B, tables B5 and B6 for a quarterly summary of the ALRR stack effluent results.

The activity concentration in the ALRR stack for 1977 is shown in Table 4. The stack discharge volume for 1977 was 2.60×10^{14} ml.

Table 4
ALRR Stack Effluent
($\mu\text{Ci/ml}$)

<u>Isotope</u>	<u>Concentration</u>
Gross Beta	1.06×10^{-13}
Gross Alpha	2.82×10^{-16}
Ar-41	4.91×10^{-6}
Be-7	6.21×10^{-14}
Ce-141	3.36×10^{-15}
Ce-144	1.46×10^{-14}
Cs-137	5.00×10^{-16}
H-3	3.88×10^{-6}
Nb-95	4.06×10^{-14}
Zr-95	1.09×10^{-14}
I-131	6.18×10^{-16}
Ru-103	6.43×10^{-16}
Ru-106	3.06×10^{-15}

Water

Water samples are collected twice daily, except weekends and holidays from the ALRR outfall, discharge point for the ALRR complex (Site 2R, Figure 1). Alpha and beta activity is determined by evaporating a 1 liter sample into a 3 inch aluminum planchet and counting in a Sharp Low Betamatic. Tritium is determined on a 5 ml sample with a Beckman Scintillation Counter and dioxane-naphthalene cocktail. The tritium (H-3) discharge concentration range was from 0.0002 to 6.83 times the concentration guide with an overall average factor of 0.126. Gamma scan analyses were performed on monthly composites of the morning outfall samples, AM, and afternoon samples, PM. The concentration guides (CG's), based on radiation dose to individuals in uncontrolled areas, are shown in Appendix A. See Appendix B, Table B7 for a monthly summary of the outfall results. A summary for 1977 is shown in Table 5.

Table 5
Radioactivity in the ALRR Outfall
($\mu\text{Ci/ml}$)

	Number of Samples	Average Concentration	% CG	High	Low
Gross Beta, 10^{-9}	490	7.45	0.21	45.7	1.15
Gross Alpha, 10^{-9}	490	0.11	0.36	1.86	NDA
H-3, 10^{-6}	490	378.0	12.6	20560.0	0.63
Co-60, 10^{-9}	composites	0.19	0.0006	0.124	NDA
Cs-137, 10^{-9}	composites	0.29	0.001	2.10	NDA

During 1977 the central Iowa area experienced a severe drought which lead to water conservation. In order to conserve water, consideration was given to finding sources of recyclable water which could be used as effluent dilution water. This consideration resulted in the use of ALRR secondary cooling tower water for dilution to maintain effluent quality within DOE Manual Chapter 0524 standards.

An automated discharge and make-up system is used to add fresh water to the secondary cooling system to maintain proper water quality. The use of this system produced some unique H-3 levels which were measured in some of the outfall samples collected. The water discharged is known as "blowdown" water and was the source for dilution of the effluent during the water conservation period (July to November). The "blowdown" system operates continuously and results in a discharge of 2.97×10^7 ml per day.

During the time that the water conservation effort was being applied, liquid waste was discharged during normal working hours. Typical duration of waste discharge was from 4-6 hours. Morning and afternoon effluent samples were collected as usual. Some of the analysis for H-3 showed levels greater than the Concentration Guide value for H-3. However, if these levels are corrected to include total water discharged by "blowdown" for a 24 hour day, or for that matter, a 5 day work week it can be shown that the averaged H-3 levels are below the Concentration Guide value. During normal (non-conservation) waste discharge operations, dilution water is added to liquid wastes so that H-3 levels are less than the Guide value, before being discharged to the effluent discharge pipe.

Liquid radioactive waste is sampled and treated on a batch basis. Alpha and beta activities are determined by evaporating a 100 ml sample and counting. Equation 1 with self-absorption corrections is used to calculate the alpha and beta activity concentration. Self-absorption corrections are employed because an absolute activity concentration is desired for waste discharge and the sample residue is small, less than 0.1 g, making the corrections relatively low. The tritium activity concentration is determined for a 1 ml sample. The gamma analysis is performed on the residue of an evaporated 3 liter sample. All radioactive waste generated at the laboratories located on the I.S.U. campus is collected, evaporated and disposed of as solid waste. The radioactivity in liquid waste released to the environment in 1977 is shown in Table 6.

The average outfall flow rate for 1977 was 58.6 liters per minute. This yields a total volume for 1977 of 1.8×10^9 ml. Table 6 concentrations reflect the total isotopic amount divided by the total volume. The concentration guides, based on radiation dose to individuals in uncontrolled areas, is shown in Appendix A. (From DOE Manual Chapter 0524)

Table 6
Liquid Radioactive Waste Released to the Environment

<u>Isotope</u>	<u>Amount, μCi</u>	<u>Concentration, $\mu\text{Ci/ml}$</u>	<u>% CG</u>
Gross Beta	15.2	8.44×10^{-9}	2.8×10^{-1}
Gross Alpha	0.59	3.28×10^{-10}	1.1
Ag-110m	0.74	4.11×10^{-10}	1.4×10^{-3}
Ce-141	0.13	7.22×10^{-11}	8.0×10^{-6}
Ce-144	2.99	5.38×10^{-8}	5.4×10^{-2}
Co-60	15.1	8.39×10^{-9}	2.8×10^{-2}
Cs-137	3.67	2.04×10^{-9}	1.1×10^{-2}
Eu-154	0.72	4.00×10^{-10}	2.0×10^{-3}
H-3	2.64×10^6	1.46×10^{-3}	48.0
Na-22	0.025	1.38×10^{-11}	1.6×10^{-6}
Nb-95	1.58	8.78×10^{-10}	8.8×10^{-4}
Ru-103	0.076	4.31×10^{-11}	5.4×10^{-6}
Sb-124	0.33	1.83×10^{-10}	9.2×10^{-4}
Sb-125	0.73	4.06×10^{-10}	1.4×10^{-3}
Zr-95	0.479	2.66×10^{-10}	4.4×10^{-4}

Liquid effluents leaving the I.S.U. campus facilities via city sewage lines are sampled at the Ames Water Pollution Control Plant (Site 11R, Figure 3). Effluents are sampled weekly and a composite sludge sample is processed monthly. The effluent liquid is treated the same as a river or outfall sample. The sludge sample is mixed and a 100 ml portion is filtered. After drying, the filter paper is ashed and both portions are counted for gross beta and alpha activity. Gamma analysis is performed on a composite of the year's samples. The tritium concentration is not determined on the sludge samples.

Table 7

Radioactivity in the Water Pollution Control Plant Samples (11R)

($\mu\text{Ci/ml}$)

	<u>Number of Samples</u>	<u>Beta, 10^{-9}</u>	<u>% CG</u>	<u>Alpha, 10^{-9}</u>	<u>% CG</u>	<u>Number of Samples</u>	<u>Tritium 10^{-8}</u>	<u>% CG</u>
Plant Effluent (Site 11R)	50					50		
Average		11.9	0.40	0.15	0.50		2.17	0.072
High		19.9		0.66			4.23	
Low		7.4		NDA			0.99	
Sludge Soluble	11							
Average		36.2		0.82			Not Determined	
High		68.0		6.61				
Low		7.66		NDA				
Sludge Insoluble	10							
Average		94.0		16.5			Not Determined	
High		259.0		30.6				
Low		15.8		4.20				

The result of gamma analyses on the Ames sludge shows no detectable gamma activity other than natural occurring radionuclides.

B. Environmental

Air Samples

Air samples are collected from two different locations at the Ames Laboratory on a daily (except weekends) basis for the purpose of monitoring the particulate radioactivity content of the atmosphere. The sites are located at the ALRR weather tower site (Site 1A, Figure 1) and the roof of Spedding Hall (Site 2A, Figure 2). Samples are collected over a 24 hour period, held for 7 days to allow short-lived activities to decay and then analyzed. Samples are collected on Whatman #41 7.62 cm (3 inch) diameter filter paper using a Gast pump with a flow rate of 116 liters per minute (4.1 CFM). The samples are placed directly in a Sharp Low Betamatic three inch gas proportional system and counted for gross alpha and beta activity. The filter papers are then retained until a composite sample for 90 days is collected. The composite sample is then analyzed for specific gamma emitting isotope content using a Ge(Li) detector/4096 channel analyzer. The isotopic activity that was detectable on the 1977 composites is summarized in Table 8 and shown quarterly in Appendix B, Tables B2 and B4. The gross beta and alpha activity is summarized in Table 9 and shown monthly in Appendix B, Tables B1 and B3. The Alpha High concentration shown, as well as the fission isotopes listed in Table 8, are due to fallout received from atmospheric nuclear testing during the third quarter monitoring period.

Table 8
Gamma Analysis of Air Samples
(10^{-15} $\mu\text{Ci/ml}$)

Isotope	ALRR-Site 1A		Spedding Hall-Site 2A	
	Avg	% CG	Avg	% CG
Ba-140	15.5	1.5×10^{-3}	--	--
Be-7	162.	4.05×10^{-4}	153.5	3.84×10^{-4}
Ce-141	8.98	1.79×10^{-4}	8.27	1.65×10^{-4}
Ce-144	35.6	1.78×10^{-2}	33.4	1.67×10^{-2}
Cs-137	2.58	5.16×10^{-4}	2.36	4.72×10^{-4}
I-131	0.40	4.0×10^{-6}	0.40	4.00×10^{-6}
La-140	29.5	7.37×10^{-4}	29.5	7.38×10^{-4}
Mn-54	1.08	1.08×10^{-4}	0.11	1.10×10^{-5}
Nh-95	96.6	3.22×10^{-3}	91.7	3.06×10^{-3}
Ru-103	17.3	5.77×10^{-4}	16.3	5.43×10^{-4}
Ru-106	15.1	7.55×10^{-3}	12.3	6.15×10^{-3}
Sb-125	0.97	1.08×10^{-4}	1.73	1.92×10^{-4}
Zr-95	31.1	3.11×10^{-3}	29.1	2.91×10^{-3}

Table 9
Radioactivity in Air
(10^{-12} $\mu\text{Ci/ml}$)

	Number of Samples	Beta	% CG	Alpha	% CG
ALRR--Site 1A	249				
Average		0.214	0.21	0.006	30.0
High		7.27		0.091	
Low		0.019		NDA	
Spedding Hall -- Site 2A	212				
Average		0.201	0.20	0.0052	26.0
High		1.823		0.107	
Low		0.018		NDA	

Precipitation Samples

Precipitation samples are collected on an "as it happens basis" near the weather observation tower on the ALRR site. The samples are evaporated to dryness and counted for gross alpha and beta activity. A 5 ml sample is used for tritium analysis. Gamma analysis is performed on a quarterly composite. The monthly and quarterly data are presented in Appendix B,

Tables B15 and B16, and summarized in Table 10. The total number of samples for 1977 was 20.

Table 10
Radioactivity in Precipitation
($\mu\text{Ci/ml}$)

Beta	258. $\times 10^{-9}$	I-131	3.21 $\times 10^{-9}$
Alpha	6.63 $\times 10^{-9}$	La-140	12.3 $\times 10^{-9}$
Ba-140	6.8 $\times 10^{-9}$	Nb-95	1.38 $\times 10^{-9}$
Be-7	3.31 $\times 10^{-9}$	Ru-103	1.57 $\times 10^{-9}$
Ce-141	2.31 $\times 10^{-9}$	Zr-95	1.73 $\times 10^{-9}$
Ce-144	1.65 $\times 10^{-9}$	H-3	13.2 $\times 10^{-6}$
Cs-137	2.10 $\times 10^{-9}$		

River Water Samples

River water samples are collected weekly and analyzed for tritium activity and gross alpha and beta activity. Samples are obtained from Onion Creek (Site 3R, 4R, Figure 2), the first flowing creek in the flow route of the ALRR drainage system, and the Skunk River (Site 11R, Figure 3) downstream from both the ALRR drainage system and the Ames Pollution Control Plant. In addition, samples (Clear Creek) are obtained from outside the ALRR flow route. This constitutes a control site and is numbered nine in the data. Samples are obtained whenever possible. At times the creeks are completely dry in the late summer and fall and frozen solid in the winter. If water is flowing under the ice, a sample is obtained by chopping through the ice. If there is an unusually large amount of suspended material in the sample, the sample is filtered and the soluble and insoluble portions are counted separately; otherwise, the one liter sample is evaporated to near dryness and transferred to a planchet. The planchets are placed directly in the Sharp System for counting. Tritium is determined with a 5 ml sample using liquid scintillation. Gamma analysis is performed on quarterly composites of the weekly samples. The sample results are summarized in Table 11.

Table 11
Radioactivity in River Water
($\mu\text{Ci/ml}$)

	Number of Samples	Beta 10^{-9}	% CG	Alpha 10^{-9}	% CG	Number of Samples	Tritium 10^{-6}	% CG
<u>Downstream</u>								
<u>Sites 4R,</u>								
<u>8R</u>								
Soluble	41					41		
Avg		6.81	0.227	0.27	0.9		2.42	0.081
High		11.85		1.08			5.23	
Low		2.93		NDA			0.41	
Insoluble	0					0		
<u>Upstream</u>								
<u>Sites 1R,</u>								
<u>3R</u>								
Soluble	22					22		
Avg		5.68	0.189	0.337	1.1		2.71	0.090
High		8.33		1.20			5.32	
Low		2.25		NDA			0.360	
Insoluble	0					0		
<u>Control</u>								
<u>Site 9R</u>								
Soluble	16					16		
Avg		5.46	0.18	0.290	0.97		2.34	0.078
High		22.2		1.02			4.96	
Low		2.84		NDA			0.54	
Insoluble	0					0		

Gamma analysis for River Sites 1R, 3R, 4R, 8R and 9R yielded no detectable isotopes other than naturally occurring radionuclides.

Well Water Samples

Well water samples are obtained monthly from City of Ames wells (1W, Figure 3), Iowa State University (I.S.U.) campus wells (2W, Figure 2), and from a privately owned farm well (Martin) at a location two miles north of the ALRR. The sample size is one liter and is handled in the same manner as the river water samples. No gamma activity was observed on the yearly composites of the well samples. The yearly data are presented in Appendix B, Table B14, and summarized in Table 12.

Table 12
Radioactivity in Well Water Samples
($\mu\text{Ci/ml}$)

	<u>Number of Samples</u>	<u>Beta 10^{-9}</u>	<u>% CG</u>	<u>Alpha 10^{-9}</u>	<u>% CG</u>	<u>Tritium 10^{-6}</u>	<u>% CG</u>
Average	29	4.81	0.16	0.341	1.14	2.88	0.096
High		7.75		1.08		9.73	
Low		2.52		NDA		0.29	

Bottom Sediment

Bottom sediment samples are obtained at or near the river water site on a quarterly basis. Samples are analyzed for gross alpha and beta activity. A one-liter sample is obtained from the top 5-8 cm (2-3 inches) of bottom sediment in a semi-quiescent area. The sample is mixed thoroughly and a 3-4 gram counting sample is prepared. The counting samples are dried thoroughly in an oven and then counted directly in the Sharp System. The results for 1977 are shown in Table 13 and Table B17.

Table 13
Radioactivity in Bottom Sediments
(10^{-6} $\mu\text{Ci/g}$)

	Number of Samples	Avg	Beta High	Low	Avg	Alpha High	Low
Downstream sites 2R,2F, 4R,8R	15	7.29	9.60	5.55	0.251	0.681	0.090
Upstream sites 1R,3R	7	6.59	7.21	5.76	0.181	0.333	0.050
Control Site 9R	4	5.66	6.19	5.07	0.161	0.262	NDA

Gamma analysis of bottom sediment samples (200-600 grams) yielded detectable amounts of fission products which were attributed to recent atmospheric nuclear testing. Those detected were Ce-141, Ce-144, Cs-137, Nb-95, Ru-103 and Zr-95. At Site 2R detectable amounts of Ag-110m and Co-60 were found. The presence of these isotopes occurred only at this site and is probably due to ALRR operations. These isotopes were not found in samples from Site 2F or at any other point downstream. The yearly data are presented in Appendix B Table B18.

C. Impact

From the effluent data it has been shown that the contribution to the environmental radioactivity in air from Ames Laboratory operations consisted principally of radioactive argon, Ar-41, and tritium, H-3.

Applying principles of meteorological diffusion to the stack effluent, particularly section 3-5.5.4, Long-period Average Concentration of "Meteorology and atomic energy 1968", USAEC (5) the estimates have been made for the radiation dose at the exclusion fence. The man-Rem dose for the population within an 80 Km (50 mile) radius of the reactor has been estimated using a cylindrical diffusion volume with an 80 Km (50 mile) radius and a height of 305 m (1,000 feet). The height used in the 1974 report was 610 m (2,000 feet).

Average Individual Dose at Fence Line for 1977

	Millirem
Ar-41	5.42
H-3 (tritium)	0.085
TOTAL	5.51

The 80 Km (50 mile) Man-Rem Dose for 1977 (590,500 population)

	Man-Rem
Ar-41	4.6
H-3 (tritium)	240
TOTAL	244.6

The concentration guide value for an average dose taken as 0.5 Rem/3 = 0.17 Rem yielded 100,385 man-Rem for the population within 80 Km (50 miles). Thus the man-Rem dose, derived from the concentration guide, due to Ames Laboratory operation was 0.24% of the Radiation Protection Standard.

Using the concentration guide value of 500 mRem for an individual at the exclusion fence, the dose was 1.1% of the Radiation Protection Standard.

The apparent reversal in the Ar-41 and H-3 doses under the two conditions above was due to the decay of Ar-41 during the diffusion time to distribute the Ar-41. The models for the fence line case and the 80 Km (50 mile) radius case were also different. The doses were based on the relationship of the concentration guide level exposure to the radiation protection standard in DOE Manual Chapter 0524.

There are no realistic models for the exposure due to the concentrations of radionuclides in the streams. Based on the H-3 released as waste during 1977 in the outfall, Table 6, before stream dilution, the average individual dose was 12.6% of the dose derived from the concentration guide. After mixing in the receiving stream the potential dose was not more than 0.34% of that derived from the concentration guide. H-3 has the highest percentage of the concentration guide, by a factor of 100, of any of the radioactive waste constituents shown in Table 6.

V. Non-Radiological Monitoring Program

A. Effluents

Effluent water samples are collected twice daily at the ALRR outfall.

A Beckman pH Meter is used to determine the pH of each sample. The effluent temperature is determined daily with a standard mercury centigrade thermometer when the first sample is obtained. This thermometer, -20°C to 110°C in 1°C increments, has been checked for accuracy against a 0°C to 50°C in 0.1°C increments laboratory thermometer. The flow rate is determined daily by measuring the time needed to fill a container of known volume.

Weekly effluent samples are collected for chloride, hexavalent chromium and zinc measurements. The hexavalent chromium and zinc determinations are made as soon after sampling as time permits usually within one to two days. The hexavalent chromium and zinc analyses are performed with a Hach DR Colorimeter using Hach's procedures and chemicals. Hach's hexavalent chromium analysis is based on the 1,5-Diphenylcarbohydrazine method (7). The zinc analysis is based on the Zincon method (7). The chloride determination is performed after a number of samples have been collected. The chloride determination is a Hach Chemical Company procedure based on the mercuric nitrate method (7).

The 5 day biochemical oxygen demand (BOD) and fecal coliform analysis are performed monthly. The BOD sample is a flow weighted mixture of several samples taken throughout the day. The procedures in Standard Methods (3) are followed for the BOD determination. The fecal coliform sample is a grab sample taken in a sterile glass bottle. The membrane filter technique employing gridded membrane filter paper and sterile M-FC broth ampoules from Millipore is used for the fecal coliform determination.

A summary of the non-radiological effluent data is shown in Table 14.

A monthly breakdown of these results appears in Appendix C.

Table 14

Non-Radiological Effluent Results

1977

	<u>Number of Samples</u>	<u>Average</u>	<u>High</u>	<u>Low</u>
Chlorides	44	1251 mg/l	4156 mg/l	83 mg/l
Chromium (hexavalent)	46	.53 mg/l	1.75 mg/l	.01 mg/l
Zinc	43	.26 mg/l	2.5 mg/l	0.0 mg/l
pH	431	7.75	8.8	6.4
Temperature	219	19.0°C	32°C	3°C
Flow	213	43 l/min	429 l/min	3 l/min
Biochemical Oxygen Demand (5 day)	8	3.6 mg/l	5.7 mg/l	1.5 mg/l
Fecal Coliform	11	265 */100 ml	400 */100 ml	96 */100 ml

* = organisms

B. Environmental (Non-Radiological)

The hexavalent chromium concentration was determined for samples from Sites 3R (Upstream) and 4R (Downstream) (Figure 2). The sampling and analytical procedures were as described previously. Sites 3R and 4R were dry 8 out of the 12 months in 1977, therefore, a limited number of analysis could be performed. The summary for 1977 is shown in Table 15 with a monthly breakdown in Appendix C.

Table 15

Non-Radiological Environmental Results

	<u>Number of Samples</u>	<u>Average</u>	<u>High</u>	<u>Low</u>
Site 3R--Upstream				
Chromium (hexavalent)	11	0.02 mg/l	0.04 mg/l	0.02 mg/l
Site 4R--Downstream				
Chromium (hexavalent)	11	0.02 mg/l	0.03 mg/l	0.00 mg/l

C. Impact (Non-Radiological)

The year 1977 was a very dry year for the Ames area. The stream (Onion Creek) that receives the effluent from the ALRR was dry and non-flowing for eight out of twelve months in 1977. The discharge water from the ALRR was absorbed into the ground before it reached Onion Creek. From the ALRR discharge point to Onion Creek is a distance of .8 Km (one half mile).

When samples were available from Onion Creek, analysis showed that ALRR was not affecting the water quality. The average upstream and downstream hexavalent chromium concentrations were the same.

With the exception of hexavalent chromium, all ALRR effluent samples were within the NPDES effluent guidelines. Forty-six samples were analyzed for hexavalent chromium and of these forty-six samples thirty-six samples exceeded the .05 mg/l limit. Even though the ALRR discharge water exceeded the hexavalent chromium limit, the receiving stream, Onion Creek, showed no detectable differences in Cr^{+6} above and below the ALRR. The average discharge of fecal coliform bacteria exceeded the NPDES limit of 200 organisms/100 ml by 65 organisms. The maximum limit of 400 organisms/100 ml

was never exceeded at any time. All of the 431 ALRR pH samples taken fall within the NPDES limit of pH 6.0 and pH 10.0. NPDES limits zinc to a concentration of 1 mg/l and a discharge of 0.06 Kg/day. ALRR samples showed an average zinc concentration of .22 mg/l and discharge of .01 Kg/day which are 22% and 17% respectively of the NPDES guidelines. During 1977 BOD averaged 3.6 mg/l which is 12% of the NPDES limit of 30 mg/l.

Of the 971 analyses performed relative to NPDES effluent limitations, 36 hexavalent chromium and one zinc were not within stated guidelines. However, the non-radiological impact of ALRR operations on Onion Creek and subsequent streams is negligible or non-existent as shown by Table 15.

The receiving stream, Onion Creek, is an unclassified stream according to Iowa standards for surface waters. The stream is dry a substantial portion of the year and receives no effluent from the ALRR during dry periods. There are no applicable standards for unclassified streams. Even though there are no stream standards for Onion Creek the effluent from the ALRR does not cause Onion Creek and subsequent streams to fall outside the quality levels of "Class C, potable waters", the most restrictive criteria for Iowa surface waters.

Plans are underway to connect the ALRR facility to the municipal sanitary sewer system. When this connection is made there will be no further discharges to surface water systems at the Ames Laboratory Research Reactor site. It is expected that the sewer system extension and connection will be accomplished in 1978.

Table 16
Sample Site Location

AIR

<u>Figure Reference</u>	<u>Map Symbol</u>	
1	1A	The on-site monitoring station is located approximately 122 m (400 feet) south of the reactor.
2	2A	The off-site monitoring station is located on the Spedding Hall roof approximately 1.6 Km (one mile) southeast of the reactor.

RIVER AND BOTTOM SEDIMENT

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
1,2	1R	1-DD-U	This on-site sampling point is located just above the mixing zone of the outfall in Onion Creek Gulch.
1,2	2R	Outfall	This site is the outfall and is listed as such. The bottom sediment sample is just below the outfall point in Onion Creek Gulch.
1,2	2F	Fence	Site is approximately 91 m (300 feet) downstream from outfall point at Reactor site boundary fence.
2	3R	3-On-U	This site is in Onion Creek upstream from confluence with Onion Creek Gulch.
2	4R	4-On-D	Site is approximately 305 m (1000 feet) downstream from confluence point in Onion Creek.
3	8R	8-Sk-D	Site is in the Skunk River downstream from the Squaw Creek confluence.
2	9R	9-CC	This control site is located outside the flow pattern of ALRR effluent in Clear Creek.
3	11R	11-Sk-S	This is a sample of the Ames Water Pollution Control Plant effluent.

WELLS

<u>Figure Reference</u>	<u>Map Symbol</u>	<u>Table Symbol</u>	
3	1W	City	The water wells for the City of Ames all located east of Squaw Creek. The location indicated is the water treatment plant.
2	2W	I.S.U.	The Iowa State University wells are located west of Squaw Creek.
2	3W	Martin	The Martin site is a private farm well located 3.2 Km (two miles) north of the ALRR.

Figure 1: Ames Laboratory Research Reactor Site Plan. Map drawn to scale.

Figure 2: Environmental Sampling Sites within 3.2 Km (two miles) of ALRR. Map drawn to scale.

Figure 3: Environmental Sampling Sites Within 25.7 Km (sixteen miles) of ALRR. Map drawn to scale.

Figure 4. State of Iowa. Map drawn to scale.

VII. References

1. DOE 0524, "Standards for Radiation Protection".
2. Iowa Departmental Rules, "Water Quality Standards", Chapter 16, February 12, 1974.
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USERDA, Iowa State University, Ames, Iowa 50011.

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Dr. E. S. Takle, Assistant Professor of Climatology and Meteorology

Dr. L. V. Sendlein, Professor of Earth Science

Program Assistants: G. P. Jones, Jr.

P. A. Millis

S. R. Ball

R. P. Staggs

IX. Distribution

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APPENDIX A. Applicable Standards

The radionuclide concentration standards for air and water applicable to ALRR operations are the Concentration Guides (CG's) given in Chapter 0524 of the DOE Manual (1). A summary of the concentration guides is given in Table A1. The most restrictive (uncontrolled area) Chapter 0524 Table 11 value, soluble or insoluble, is reported in Table A1.

Table A1
Concentration Guides (CG's)

	In Water ($\times 10^{-9}$ $\mu\text{Ci/ml}$)	In Air ($\times 10^{-12}$ $\mu\text{Ci/ml}$)
Alpha	30	0.02
Beta	3,000	100
Ag-110m	30,000	300
Ar-41	--	40,000
Ba-140	20,000	1,000
Be-7	2,000,000	40,000
Ce-141	90,000	5,000
Ce-144	10,000	200
Co-60	30,000	300
Cs-134	9,000	400
Cs-137	20,000	500
H-3	3,000,000	200,000
I-131	300	10,000
La-140	20,000	4,000
Mn-54	100,000	1,000
Na-22	30,000	300
Nb-95	100,000	3,000
Ru-103	80,000	3,000
Ru-106	10,000	200
Sb-124	20,000	700
Sb-125	30,000	900
Zn-65	100,000	2,000
Zr-95	60,000	1,000

Ames Laboratory has received authorization to discharge into the drainage ditch, a tributary of Onion Creek, under the National Pollutant Discharge Elimination System (NPDES). The interim NPDES effluent limitations applicable for January 1, 1977 to July 1, 1977 are specified in Table A2. Table A3 shows the permanent NPDES effluent limitations applicable after July 1, 1977.

Table A2
NPDES Interim Effluent Limitations

	Concentration		Quantity	
	Daily Avg.	Daily Max.	Daily Avg.	Daily Max.
Temperature	---	35°C	---	---
Biochemical Oxygen Demand (5 day)	30 mg/l	45 mg/l	0.6 Kg/day	0.8 Kg/day
Fecal Coliform (organisms/100 ml)	200	400	---	---
Zinc	1 mg/l	2 mg/l	0.06 Kg/day	0.12 Kg/day
pH	not less than 6.0 nor greater than 10.0			

Table A3
NPDES Permanent Effluent Limitations

	Concentration		Quantity	
	Daily Avg.	Daily max.	Daily avg.	Daily max.
Temperature	---	35°C	---	---
Biochemical Oxygen Demand (5 day)	30 mg/l	45 mg/l	---	---
Suspended Solids	30 mg/l	45 mg/l	---	---
Chromium (total)	1 mg/l	1 mg/l	0.06 Kg/day	0.06 Kg/day
Chromium (hexavalent)	0.05 mg/l	0.05 mg/l	0.003 Kg/day	0.003 Kg/day
Zinc (total)	0.5 mg/l	1.0 mg/l	0.03 Kg/day	0.06 Kg/day
pH	not less than 6.0 nor greater than 10.0			

Chapter 16 of the Iowa Department of Environmental Quality Rules, "Water Quality Standards" adopted February 12, 1974, provides instream guidelines for chlorides, hexavalent chromium, and turbidity. Chlorides and hexavalent chromium for Class C water, raw water source of potable water, should not exceed 250 mg/l and 0.05 mg/l, respectively, in the stream at the point of withdrawal. The turbidity of any receiving stream should not be increased by more than 25 Jackson turbidity units.

APPENDIX B. Radiological Results for Specific Sites

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Table B1
Air Site 1A, On-Site Station
(10^{-12} μ Ci/ml)

	Number of Samples	Beta	Alpha
Jan	21	0.066	0.002
Feb	19	0.057	0.003
Mar	22	0.082	0.005
Apr	20	0.249	0.016
May	21	0.427	0.018
Jun	22	0.335	0.008
Jul	20	0.295	0.003
Aug	22	0.198	0.002
Sep	21	0.352	0.004
Oct	21	0.267	0.002
Nov	21	0.124	0.001
Dec	20	0.095	0.001
Total	249		
Average		0.214	0.006
High		2.27	0.091
Low		0.019	NDA

Table B2
Gamma Analysis Air Site 1A
On-Site Station
(10^{-15} μ Ci/ml)

Isotope	Quarter				Average
	1	2	3	4	
Ba-140	NDA	NDA	62.0	NDA	15.5
Be-7	148.0	231.0	156.0	116.0	162.8
Ce-141	5.86	20.9	9.08	0.65	8.98
Ce-144	4.08	59.5	53.2	25.7	35.6
Cs-137	0.45	3.78	3.59	2.48	2.58
I-131	NDA	NDA	1.59	NDA	0.40
La-140	NDA	NDA	118.0	NDA	29.5
Mn-54	NDA	NDA	4.31	NDA	1.08
Nb-95	20.4	228.0	106.0	32.1	96.6
Ru-103	7.32	38.7	17.2	6.27	17.3
Ru-106	1.98	28.3	19.7	10.6	15.1
Sb-125	NDA	NDA	2.17	1.72	0.97
Zr-95	7.49	72.1	34.2	10.4	31.1

Table B3
Air Site 2A, Off-Site Station
(10^{-12} $\mu\text{Ci/ml}$)

	Number of Samples	Beta	Alpha
Jan	19	0.059	0.0022
Feb	14	0.054	0.0026
Mar	20	0.078	0.0052
Apr	16	0.200	0.0166
May	16	0.452	0.0163
Jun	18	0.307	0.0080
Jul	16	0.272	0.0038
Aug	18	0.181	0.0017
Sep	19	0.356	0.0037
Oct	21	0.248	0.0028
Nov	17	0.121	0.0011
Dec	18	0.084	0.0013
Total	212		
Average		0.201	0.0052
High		1.823	0.102
Low		0.018	NDA

Table B4
Gamma Analysis Air Site 2A
(10^{-15} $\mu\text{Ci/ml}$)

Isotope	Quarter				Average
	1	2	3	4	
Be-7	131.0	210.0	156.0	117.0	153.5
Ce-141	2.36	19.2	9.08	2.45	8.27
Ce-144	2.76	54.1	53.2	23.4	33.4
Cs-137	0.27	3.75	3.59	1.82	2.36
I-131	NDA	NDA	1.59	NDA	0.40
La-140	NDA	NDA	118.0	NDA	29.5
Mn-54	NDA	NDA	0.43	NDA	0.11
Nb-95	18.9	213.0	106.0	28.7	91.7
Ru-103	7.44	33.8	17.2	6.89	16.3
Ru-106	NDA	21.9	19.7	7.78	12.3
Sb-125	0.42	2.60	2.20	1.71	1.73
Zr-95	6.68	65.9	34.2	9.40	29.1

Table B5
ALRR Stack Effluent
(10^{-12} $\mu\text{Ci/ml}$)

	Number of Samples	Beta	Alpha
Jan	20	0.050	0.0035
Feb	19	0.048	0.0016
Mar	22	0.046	0.0032
Apr	19	0.113	0.0060
May	20	0.212	0.0101
Jun	22	0.149	0.0031
Jul	20	0.141	0.0017
Aug	22	0.217	0.0024
Sep	20	0.108	0.0011
Oct	21	0.085	0.0005
Nov	20	0.052	0.0005
Dec	20	0.041	0.0003
Total	245		
Average		0.106	0.0028
High		2.30	0.0302
Low		0.008	NDA

Table B6
Gamma Analysis ALRR Stack Effluent
(10^{-15} $\mu\text{Ci/ml}$)

Quarter	Be-7	Ce-141	Ce-144	Cs-137	I-131	Nb-95	Ru-103	Ru-106	Zr-95
1	50.4	2.21	NDA	NDA	NDA	7.82	2.69	NDA	2.44
2	101.	8.91	27.3	NDA	NDA	98.1	15.7	NDA	28.4
3	77.5	1.93	27.1	1.52	2.47	52.0	6.04	11.2	11.7
4	20.2	0.39	4.02	0.48	NDA	4.59	1.31	1.05	1.18
Average	62.1	3.36	14.6	0.50	0.618	40.6	6.43	3.06	10.9

Table B7
ALRR Outfall Activity (Map Site 2R)
($\mu\text{Ci/ml}$)

		Number of Samples	Beta 10^{-9}	Alpha 10^{-9}	Co-60 10^{-9}	Cs-137 10^{-9}	Number of Samples	Tritium 10^{-6}
Jan	AM	21	6.00	0.02	NDA	NDA	21	3.05
	PM	21	9.11	0.04	NDA	NDA	21	3.65
Feb	AM	20	5.79	0.17	NDA	NDA	20	2.58
	PM	18	6.74	0.16	0.21	NDA	18	3.07
Mar	AM	23	5.39	0.21	NDA	NDA	23	4.27
	PM	22	5.49	0.25	NDA	0.22	22	4.67
Apr	AM	18	8.66	0.12	0.27	0.86	18	7.06
	PM	19	11.07	0.18	NDA	2.10	19	4.12
May	AM	21	7.58	0.08	NDA	NDA	21	7.20
	PM	20	7.83	0.06	0.27	NDA	19	11.19
Jun	AM	22	8.77	0.04	NDA	NDA	22	5.96
	PM	22	6.66	0.10	NDA	NDA	22	7.18
Jul	AM	20	6.05	0.14	NDA	NDA	20	8.83
	PM	20	9.51	0.10	0.32	NDA	20	106.50
Aug	AM	23	7.40	0.18	NDA	NDA	23	34.5
	PM	21	8.61	0.17	1.00	NDA	21	1490.0
Sep	AM	21	7.16	0.07	NDA	NDA	20	753.8
	PM	21	8.03	0.12	0.78	1.24	20	1799.0
Oct	AM	21	8.88	0.23	0.94	1.42	21	2854.5
	PM	21	7.04	0.03	1.24	1.25	21	1782.0
Nov	AM	19	7.32	0.01	0.15	NDA	19	8.94
	PM	19	6.21	0.06	NDA	NDA	19	8.37
Dec	AM	20	5.92	0.02	0.22	NDA	20	7.65
	PM	20	7.75	0.02	NDA	NDA	20	8.37
Total		490					490	
Average			7.45	0.11	0.19	0.29		378.0
High			45.7	1.86	1.24	2.10		20560.0
Low			1.15	NDA	NDA	NDA		0.63

Table B8
River Site 1R
Upstream, Onion Creek Gulch (Drainage Ditch) (1-DD-U)
($\mu\text{Ci/ml}$)

<u>Soluble Portion</u>					
	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium 10^{-6}
Sep	1	3.29	NDA	1	2.52
Oct	1	2.34	NDA	1	2.70
Nov	1	5.54	NDA	1	5.32
Dec	0	Site Dry		0	
Total	3			3	
Average		3.72	NDA		3.52
High		5.41	NDA		5.32
Low		2.34	NDA		2.52

Table B9
River Site 3R
Upstream, Onion Creek (3-On-U)
($\mu\text{Ci/ml}$)

<u>Soluble Portion</u>					
	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium 10^{-6}
Jan	0	Site Dry		0	
Feb	0	Site Dry		0	
Mar	0	Site Dry		0	
Apr	0	Site Dry		0	
May	0	Site Dry		0	
Jun	0	Site Dry		0	
Jul	0	Site Dry		0	
Aug	2	6.40	0.42	2	2.07
Sep	5	6.48	0.71	5	2.83
Oct	4	5.05	0.18	4	2.37
Nov	4	4.48	0.32	4	2.01
Dec	4	3.42	0.26	4	3.38
Total	19			19	
Average		5.10	0.39		2.59
High		8.33	1.20		5.23
Low		2.25	NDA		0.36

Table B10
River Site 4R
Downstream, Onion Creek (4-On-D)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	0		Site Dry	0	
Feb	0		Site Dry	0	
Mar	0		Site Dry	0	
Apr	0		Site Dry	0	
May	0		Site Dry	0	
Jun	0		Site Dry	0	
Jul	0		Site Dry	0	
Aug	2	5.20	0.54	2	2.66
Sep	4	5.21	0.56	4	3.13
Oct	3	5.05	0.36	3	2.10
Nov	4	3.83	0.03	4	2.14
Dec	2	3.40	0.39	2	3.83
Total	15			15	
Average		4.57	0.35		2.69
High		6.49	1.08		4.87
Low		2.93	NDA		0.63

Table B11
River Site 8R
Downstream, Skunk River (8-Sk-D)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	0		Site Dry	0	
Feb	0		Site Dry	0	
Mar	0		Site Dry	0	
Apr	4	8.41	0.17	4	1.46
May	4	9.62	0.05	4	1.94
Jun	4	11.00	0.02	4	2.01
Jul	1	9.41	0.12	1	1.26
Aug	2	9.17	0.42	2	1.85
Sep	2	10.23	0.63	2	2.21
Oct	3	5.48	0.08	3	2.91
Nov	3	5.98	0.48	3	2.67
Dec	3	4.01	0.36	3	3.66
Total	26			26	
Average		8.11	0.23		2.26
High		11.85	0.78		5.23
Low		3.15	NDA		0.41

Table B12
River Site 9R
Control, Clear Creek (9-CC)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium 10^{-6}
Jan	0	Site Dry		0	
Feb	0	Site Dry		0	
Mar	0	Site Dry		0	
Apr	0	Site Dry		0	
May	0	Site Dry		0	
Jun	0	Site Dry		0	
Jul	0	Site Dry		0	
Aug	2	4.55	0.48	2	1.94
Sep	4	9.15	0.71	4	1.85
Oct	3	3.92	0.08	3	2.22
Nov	4	3.72	0.15	4	2.28
Dec	3	5.07	NDA	3	3.48
Total	16			16	
Average		5.46	0.29		2.34
High		22.21	1.02		4.96
Low		2.84	NDA		0.54

Table B13
River Site 11R
Ames Water Pollution Control Plant Effluent (11-Sk-S)
($\mu\text{Ci/ml}$)

Soluble Portion

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium 10^{-6}
Jan	4	13.00	0.12	4	1.68
Feb	4	15.09	0.47	4	1.63
Mar	4	12.49	0.29	4	2.94
Apr	4	11.87	0.12	4	1.94
May	4	12.48	0.85	4	2.69
Jun	5	12.09	0.13	5	2.79
Jul	4	13.03	0.08	4	2.02
Aug	4	10.98	0.03	4	2.20
Sep	5	11.11	0.31	5	1.98
Oct	4	10.92	0.09	4	1.37
Nov	4	11.03	NDA	4	2.43
Dec	4	9.39	0.06	4	2.25
Total	50			50	
Average		11.94	0.15		2.17
High		19.95	0.66		4.23
Low		7.39	NDA		0.99

No detectable gamma activity.

Table B14
Radioactivity in Wells
($\mu\text{Ci/ml}$)

Site	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Tritium, 10^{-6}
City	12	3.80	0.31	3.25
Martin	11	6.06	0.20	2.70
I.S.U.	6	4.57	0.50	2.70
Total	29			
Average		4.81	0.34	2.88
High		7.75	1.08	9.73
Low		2.52	NDA	0.29

No detectable gamma activity.

Table B15
Radioactivity in Precipitation
($\mu\text{Ci/ml}$)

	Number of Samples	Beta, 10^{-9}	Alpha, 10^{-9}	Number of Samples	Tritium, 10^{-6}
Jan	0			0	
Feb	0			0	
Mar	2	33.38	3.26	2	2.08
Apr	1	33.32	3.94	1	1.96
May	2	2075.0	49.9	2	92.8
Jun	0			0	
Jul	3	30.31	1.14	3	3.51
Aug	5	23.13	1.14	4	2.75
Sep	3	19.71	1.55	3	2.49
Oct	3	209.0	2.70	1	1.35
Nov	1	20.43	0.64	1	2.52
Dec	0			0	
Total	20			17	
Average		258.0	6.63		13.21
High		3677.0	83.0		138.0
Low		9.02	NDA		1.35

Table B16
Gamma Analysis of Precipitation
(10^{-9} $\mu\text{Ci/ml}$)
Volume (liters) 25.2

	Ba-140	Be-7	Ce-141	Ce-144	Cs-137	I-131	La-140	Nb-95	Ru-103	Zr-95
Yearly Average	6.8	3.31	2.31	1.65	2.10	3.21	12.3	1.38	1.57	1.73

Table B17
Radioactivity in Bottom Sediment
($\mu\text{Ci/gm}$)

Site	Number of Samples	Beta, 10^{-8}	Alpha, 10^{-6}
<u>Upstream</u>			
1-DD-U	3	6.12	0.18
3-On-U	4	6.94	0.18
Total	7		
Average		6.59	0.18
High		7.21	0.33
Low		5.76	0.05
<u>Downstream</u>			
Outfall	4	8.13	0.40
2F-DD-D	3	7.27	0.21
4-On-D	4	6.40	0.14
8-Sk-D	4	7.38	0.24
Total	15		
Average		7.29	0.25
High		9.60	0.68
Low		5.55	0.09
<u>Control</u>			
9-CC	4		
Average		5.66	0.16
High		6.19	0.26
Low		5.07	NDA

Table B18
Gamma Analysis of Bottom Sediment
(10^{-9} $\mu\text{Ci/gm}$)

[illegible]

APPENDIX C. Non-Radiological Results for Specific Sites

Table C1
Chemical Analysis
ALRR Outfall (Map Site 2R)

	Number of Samples	Average mg/l		
		Cl ⁻	Cr ⁺⁶	Zn ⁺²
Jan	4	1815	.42	.84
Feb	4	1187	.47	.66
Mar	5	1155	.99	.04
Apr	4	1280	.96	.16
May	4	1104	1.26	.33
Jun	5	1420	.63	.13
Jul	3	739	.14	.16
Aug	2	838	.06	.55
Sep	4	1139	.12	.38
Oct	3	1696	.08	.37
Nov	4	1106	.43	.05
Dec	3	2473	.26	.14
Total	45			
Average		1251	.53	.26
High		4156	1.75	2.5
Low		83	.01	0.0

Table C2
pH and Temperature
ALRR Outfall (Map Site 2R)

	pH				Temperature, °C			
	Number	Ave	High	Low	Number	Ave	High	Low
Jan	40	7.9	8.7	6.5	21	10	18	3
Feb	39	7.6	8.7	6.6	19	11	22	6
Mar	43	7.5	8.5	6.4	23	12	15	9
Apr	36	7.7	8.6	6.8	18	19	25	12
May	38	8.0	8.6	7.1	21	22	26	19
Jun	44	7.4	7.8	6.9	21	25	29	21
Jul	26	7.5	8.2	6.0	17	28	31	23
Aug	30	7.4	8.6	6.2	22	27	32	23
Sep	40	7.7	8.3	6.5	14	23	27	21
Oct	37	7.8	8.2	6.4	8	20	22	19
Nov	34	7.6	8.4	6.2	17	19	22	15
Dec	24	7.6	8.5	6.3	18	12	18	8
Total	431				219			
Average		7.7				19		
High		8.8				32		
Low		6.4				3		

Table C3
Flow, Biochemical Oxygen Demand and Fecal Coliform Count
ALRR Outfall (Map Site 2R)

	Flow, l/min				BOD		Fecal Coliform	
	Number	Ave	High	Low	Number	mg/l	Number	Counts/100 ml
Jan	21	45	273	4	1	3.5	0	
Feb	19	26	60	3	1	5.7	1	228
Mar	21	26	60	4	1	3.7	1	304
Apr	18	28	214	3	1	1.5	1	280
May	21	52	429	4	1	2.9	1	96
Jun	21	36	80	5	0		1	400
Jul	15	40	60	12	1	4.6	1	380
Aug	19	65	208	5	1	3.0	1	180
Sep	14	67	273	6	0	4.2	1	260
Oct	8	51	167	13	0		1	360
Nov	17	42	166	4	1	2.6	1	160
Dec	19	37	214	4	0		0	
Total	213				9		10	
Average		43				3.6		265
High		429				5.7		400
Low		3				1.5		96

Table C4
Cr⁺⁶ Concentrations
Onion Creek, Upstream (3R) and Downstream (4R)

Number of Samples	Cr ⁺⁶ , mg/l	
	Upstream Site 3R	Downstream Site 4R
dry		
dry		
dry		
dry		
dry		
dry		
dry		
dry		
dry		
2	0.02	.01
3	0.02	.02
4	0.03	.02
2	0.03	.02
11		
	0.02	0.02
	.04	.03
	.02	.00