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ER ID# 63508

DEVELOPMENT AND EVALUATION OF A RADIO FREQUENCY IDENTIFICATION SYSTEM TO MEASURE TIME SPENT AT CONTAMINATED SITES FOR MEDIUM-SIZED MAMMALS AT LOS ALAMOS NATIONAL LABORATORY

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FY97: 83K
FY98: 55.8K

INTRODUCTION

Radioactive and nonradioactive contamination of soil, vegetation, invertebrates, and small mammals has been confirmed in areas on LANL (Fresquez et al. 1996*a*, *b*, EAREG 1996, Biggs 1995, Fresquez et al. 1995*a*, *b*, *c*, Brooks 1989). Medium-sized mammals such as raccoons (*Procyon lotor*), bobcats (*Felis rufus*), striped skunks (*Mephitis mephitis*), gray foxes (*Urocyon cinereoargenteus*), squirrels, (*Spermophilus* spp., *Sciurus* spp.) and rabbits (*Sylvilagus* spp.) may be exposed to heavy metals, organic compounds, and low-level radionuclides at the Laboratory (Brooks 1989). Medium-sized mammals are important ecosystem components. They are also used as ceremonial animals by Native Americans, are an economic resource for trappers, and may be eaten. Carnivores are particularly susceptible to detrimental effects from contaminants because of their acidic digestive systems (which increases the bioavailability of some contaminants) and because of the biomagnification of some contaminants in food chains (Petron 1993, Kendall et al. 1990, Oehme 1978, Stickel 1975).

Although LANL annually conducts extensive monitoring of radioactive and nonradioactive contaminant levels in groundwater, surface water, soils, sediments, the atmosphere, and foodstuffs (EAREG 1996), little information is available on the occurrence of contaminants in natural vegetation (Fresquez et al. 1996*b*, Fresquez 1995*c*, Wenzel et al. 1987) and herbivores (Biggs 1995, Fresquez et al. 1995*a*). To date, no data is available on contaminants in medium-sized mammals. Accumulation of contaminants in individuals and transfer along food chains are among the more important processes, which must be evaluated to predict contaminant effects on the environment (Petron 1993, Martin and Coughtrey 1982, Ketchum et al. 1975).

Because of their relatively low densities and frequently nocturnal habits, medium-sized mammals are difficult to study. Previously, the only technique to document movements of individual animals was radiotelemetry. We are evaluating a new application of radio frequency identification (RFID) technology. This technology allows us to remotely record the amount of time individual animals spend at a potential release site (PRS) for contaminants. The RFID system consists of a monitor, automatic data recorder, and remote camera system, continuously monitoring an unlimited number of animals of different species at a specific site of interest. Once developed, this system can be used for studies of animal exposure to, uptake of, and transport of radioactive and nonradioactive contaminants anywhere animal exposure to point

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sources of contaminants is a concern, including LANL and other DOE facilities. Knowledge of contaminant levels and transport routes is used to evaluate risks of contaminants to the environment, and provides data to examine clean-up options.

RFID technology allows a very small (23 mm x 3.2 mm) glass-encapsulated "tag" to be subcutaneously implanted in animals with a syringe and needle. Tags last for the lifetime of the animal. As a marked animal walks through a portal monitor (Figure 1), the monitor can record the identification number of the animal from the tag, along with the date and the time. The technology is similar to a barcode reader. In combination with a remotely activated camera, this system records the time, date. and species as animals enter and leave a PRS, and allows the investigator to determine the ratio of marked to unmarked animals of each species using a site.

The objectives of this project are:

- To develop and evaluate a system which will allow LANL to efficiently document the amount of time spent at a potential release sites by individual animals.
- To determine whether medium-sized mammals on LANL exhibit elevated levels of metals or radionuclides.
- To collect data during the evaluation process on the relationship between the amount of time spent at a PRS, and levels of contamination.

METHODS

We fenced a PRS so that the monitor provided the only easy access to the site. The monitor and fencing were assembled around the radioactive liquid waste treatment lagoon for the Los Alamos Neutron Science Center (LANSCE) at Technical Area 53 (TA-53). LANSCE is a national user facility at Los Alamos National Laboratory that provides intense sources of pulsed spallation neutrons for neutron research and applications. Operation of the linear accelerator and associated cooling systems produces radioactively contaminated liquid wastes. All potentially radioactive liquid wastes are collected and delivered to 2 sets of holding tanks. The waste is retained in the holding tanks until short half-life constituents decay completely. Tank contents are then pumped to the TA-53 radioactive liquid waste treatment lagoon. LANSCE is located on a mesa in the pinyon-juniper zone. During 1998, we improved the fence from 1997 by burying chicken wire along the bottom of the fence, to prevent animals digging under, and by adding a solar-powered electrical "hot wire" along the top of the fence to discourage animals from climbing over. The RFID monitor was placed as an opening in the fence through which animals could access the lagoon. Trailmaster® cameras were placed to photograph any animal passing through the monitor. We operated the monitor and cameras continuously during 1998 to document use of the lagoon area by marked and unmarked animals.

Medium-sized mammals (rock squirrels, raccoons, striped skunk, and bobcat) were captured using cage traps during March through July 1998. Animals were captured at TA-53 in two different areas (Figure 2): within 400 m of the lagoon (at the lagoon), and more than 400 m from the lagoon (away from the lagoon). Animals were also captured in Guaje and Rendija canyons on Santa Fe Forest Service lands. Captured animals were taken to an animal holding facility. There, we anesthetized the animals, inserted RFID tags between their shoulder blades, took measurements, and collected 2-4 g of hair. Animals were retained in the holding facility overnight and urine was collected in trays beneath the cages. We released animals at their capture site the next day. Urine samples were submitted to CST at LANL to analyze the concentration of tritium. This was done for both 1997 and 1998 samples in 1998. Hair samples

were submitted to CST at LANL to test for concentrations of metals, including aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag) and thallium (Tl). Results of contaminants samples were analyzed assuming that samples with nondetectable results had levels equal to ½ of the detection limit.

PROGRESS AND RESULTS

Animal Capture

Between 1 March 1998 and 31 July 1998 we captured 35 animals a total of 56 times. Animals captured included 32 rock squirrels, 1 raccoon, 1 striped skunk, and 1 bobcat. At TA-53, 19 rock squirrels, 2 raccoons, 1 striped skunk, and 1 bobcat either were implanted with RFID tags and or retained RFID tags from 1997. Six rock squirrels and 1 striped skunk initially captured in 1997 were recaptured in 1998. In addition, 1 raccoon initially captured in 1997 was detected going through the RFID monitor in 1998. Thirteen rock squirrels were captured in Guaje and Rendija Canyons on Santa Fe National Forest land and sampled. Contaminant levels in these animals were used for comparison to levels in animals captured at TA-53. However, seven hair samples from the control area animals were not submitted in FY98 because funding ran out.

Effectiveness of the RFID Monitor

Of the 23 marked animals at TA-53, 4 animals (2 rock squirrels, 1 raccoon, and 1 bobcat) passed through the RFID monitor a total of 25 times between 1 March and 31 September 1998. Eight pairs of readings appeared to represent 1 rock squirrel entering and leaving the lagoon area. The time the squirrel spent in the lagoon area ranged from 6 min. 3 sec. to 1 hr. 40 min. 40 sec. The bobcat also had 1 set of paired readings. It remained in the lagoon area 16 min. 23 sec. All other readings (7) were unpaired. The large increase in the proportion of paired readings in 1998 (72%) versus 1997 (44%) suggests our fence modification did improve our detection of animals using the lagoon. Despite the larger number of passages in 1998 (25 in 1998, 9 in 1997), we detected the same number of animals (4) in each year. We took 6 photographs of rock squirrels, 7 photographs of raccoons, 12 photographs of cottontail rabbits, 1 photograph of a mouse and 2 photographs of birds at the monitor between 15 April and 11 July. We are currently developing and analyzing the remaining photographs for FY98.

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Contaminants Analyses

Urine was used in liquid scintillation analysis to measure levels of tritium. Median values of tritium for animals captured on LANL in 1998 are presented in Table 1. The highest value recorded was for a raccoon captured on May 28, 1998. This animal had 1.1 million pCi/L of tritium in its urine. Levels of tritium in water samples taken once a month from the lagoon during April-July ranged from 3.2 million pCi/L to 14.7 million pCi/L. A raccoon was photographed entering the lagoon early in the morning (01:12) of May 25, 1998, and leaving late that night (23:46). It is possible that we captured and sampled this same individual 3 days later.

An analysis of tritium levels in rock squirrel urine from three different areas (at the lagoon, away from the lagoon, and control) found significant differences among the groups in both 1997 (Kruskal-Wallis test, test statistic = 7.5, P = 0.024) and 1998 (Kruskal-Wallis test, test statistic = 19.96, P = 0.000). Rock squirrels from the lagoon area had significantly higher

concentrations of tritium in their urine than animals away from the lagoon or in the control area in both years. Median values of tritium and ranges for 1997 and 1998 for rock squirrels from different areas are presented in Table 2. Plots of tritium values over time in rock squirrels from the lagoon area for 1997 and 1998 are presented in Figure 2.

During 1997 we submitted muscle and bone samples from rock squirrels captured at the lagoon area that died during the capture process. These individuals (1M, 1F) were pooled for radionuclide analyses. We found 0.0137 pCi/g ash of americium-241, 0.0077 pCi/g ash of plutonium-238, 0.0009 pCi/g ash of plutonium-239, and 15500 pCi/L of tritium in muscle tissue. In bone tissue, we found 0.0029 pCi/g ash of americium-241, 0.0014 pCi/g ash of plutonium-238, 0.0009 pCi/g ash of plutonium-239, and 16200 pCi/L of tritium. No animals were submitted from this project in 1998. However, rock squirrels were collected from perimeter and regional locations by the Contaminants Monitoring Team (ESH-20) in 1998, and comparisons of rock squirrels from the different locations will be presented in the 1998 Environmental Surveillance Report.

Median values metal concentrations in hair samples for each species captured on LANL in 1998 are presented in Table 1. We tested for significant differences in levels of metals in rock squirrel hair among areas (animals captured at the lagoon, animals captured away from the lagoon, and animals captured in the control area) using Kruskal-Wallis tests (Table 3). There was no significant evidence of elevated levels of metals in animals from TA-53, although there was a slight trend toward higher levels of lead.

CONCLUSIONS AND DELIVERABLES

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The RFID monitor and tags were very effective at documenting animal passages into the lagoon area. However, we were surprised at the low number of marked animals visiting the lagoon relative to the number of animals with elevated levels of tritium when compared to control animals. Although only 2 rock squirrels were recorded entering the lagoon, 11 of the 15 rock squirrels tested from the lagoon area had tritium levels above 1550 pCi/L, the highest value recorded in the control area. This data strongly suggests that indirect routes of uptake are important in the transport of tritium from the TA-53 lagoon to wildlife.

Toxicity from metals occurs in critical organs, frequently the liver, kidney, or brain. For most metals, there is often not a close correlation between metals in hair and metals in critical organs. Therefore, the analysis of hair samples for metal concentrations is primarily useful as a screening tool. We have little information on the significance of our aluminum, arsenic, barium, beryllium, or chromium values. Both aluminum and barium occur naturally at relatively high concentrations in soils of Los Alamos County (Ferenbaugh et al. 1990). Ranges of selenium observed in our study were similar to those observed in a control population of raccoons (0.47-1.7 μg/g) that were used in a study in California (Clark et al. 1989). This suggests that our animals were not exposed to excessive levels of selenium. For animals in which cadmium was detected, concentrations in hair were as high or higher than in beavers in an industrially cadmium-contaminated river in Germany. No population-level effects were observed in the German beaver population (Nolet et al. 1994).

Lead in hair has frequently been used as an indicator of exposure. A safety limit of 9 μg/g in hair has been proposed for children (Revich 1994). Five animals (4 rock squirrels, 1 raccoon) exceeded this level at TA-53 in our study in 1997, with 1 rock squirrel having > 25

μg/g. No animals exceeded this level in 1998. Beryllium was the only metal to be significantly different among areas in both 1997 and 1998. The reason for this pattern is not known. Liquid wastes contaminated with high levels of metals are not released into the lagoon. Therefore, any excessive metal concentrations observed in animals around TA-53 are the result of contaminants from historical activities and not of current use of the lagoon waters.

We have proposed using the TA-53 population of rock squirrels as a sample population with known contamination to develop techniques for examining genetic damage in wildlife populations. We have received commitments for 25K from the Environmental Restoration Project and 10K from the Contaminants Monitoring Team to conduct this work during FY99. We are preparing a publication to be submitted to a peer-reviewed journal based on the 1997 and 1998 results of this project.

PUBLICATIONS AND PRESENTATIONS

Presentations:

- Fourth Wildlife Society Conference, 21-27 September 1997, Snowmass, CO (poster with published abstract).
- Second Symposium of Biological Research in the Jemez Mountains, 7 November 1997, Santa Fe, NM (presentation with published abstract).
- Thirty-first Joint Annual Meeting, Arizona and New Mexico Chapters of the Wildlife Society and the Arizona-New Mexico Chapter of the American Fisheries Society, 5-7 February 1998, Sierra Vista, AZ (poster).
- WERC Seminar Series, New Mexico State University, 9 February 1998, Las Cruces, NM (presentation).
- DRC Science and Technology Review, ES&H Division, 22 April 1998, Los Alamos, NM (poster).

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Publications:

- Technology Development, Evaluation, and Application FY1997 Progress Report, Los Alamos National Laboratory LA-13438-PR, Los Alamos, NM. Pages 4-8.

LITERATURE CITED

Biggs, J., K. Bennett, and P. R. Fresquez. 1995. Radionuclide contaminant analysis of small mammals at Area G, TA-54, 1994. Los Alamos National Laboratory report LA-13015-MS, Los Alamos, NM.

Brooks, G. H., Jr. 1989. The comparative uptake and interaction of several radionuclides in the trophic levels surrounding the Los Alamos Meson Physics Facility (LAMPF) waste water ponds. Los Alamos National Laboratory thesis LA-11487-T, Los Alamos, NM.

Clark, D. R., Jr., P. A. Ogasawara, G. J. Smith, and H. M. Ohlendorf. 1989. Selenium accumulation by raccoons exposed to irrigation drainwater at Kesterson National Wildlife Refuge, California, 1986. Arch. Environ. Contam. Toxicol. 18:787-794.

Environmental Assessments and Resource Evaluations Group (EAREG). 1996. Environmental surveillance at Los Alamos during 1994. Los Alamos National Laboratory report LA-13047-ENV, Los Alamos, NM.

Ferenbaugh, R. W., E. S. Glodney, and G. H. Brooks. 1990. Sigma Mesa: background elemental concentrations in soil and vegetation, 1979. Los Alamos National Laboratory report LA-11941-MS, Los Alamos, NM.

Fresquez, P. R., M. A. Mullen, J. K. Ferenbaugh, and R. A. Perona. 1996*a*. Radionuclide and radioactivity in soils within and around Los Alamos National Laboratory, 1974 through 1994: Concentrations, Trends, and Dose Comparisons. Los Alamos National Laboratory report LA-13149-MS, Los Alamos, NM.

Fresquez, P. R., E. L. Vold, and L. Naranjo, Jr. 1996*b*. Radionuclide concentration in/on vegetation at Radioactive-Waste Disposal Area G during the 1995 growing season. Los Alamos National Laboratory progress report LA-13124-PR, Los Alamos, NM.

Fresquez, P. R., D. A. Armstrong, and J. G. Salazar. 1995*a*. Radionuclide concentrations in elk that winter on Los Alamos National Laboratory lands. Los Alamos National Laboratory report LA-12795-MS, Los Alamos, NM.

Fresquez, P. R., D. R. Armstrong, and J. G. Salazar. 1995*b*. Tritium concentrations in bees and honey at Los Alamos National Laboratory. Los Alamos National Laboratory report LA-12872-MS, Los Alamos, NM.

Fresquez, P. R., T. S. Foxx, and L. Naranjo, Jr. 1995*c*. Strontium concentration in chamisa (*Chrysothamnus nauseosus*) shrub plants growing in a former liquid waste disposal area in Bayo Canyon. Los Alamos National Laboratory report LA-13050-MS, Los Alamos, NM.

Kendall, R. J., J. M. Funsch, and C. M. Bens. 1990. Use of wildlife for on-site evaluation of bioavailability and ecotoxicity of toxic substances found in hazardous waste sites. Pages 241-255 in S. S. Sandhu, W. R. Lower, F. J. de Serres, W. A. Suk, and R. R. Tice, eds. *In Situ* evaluation of biological hazards of environmental pollutants. Plenum Press, New York, NY.

Ketchum, B. H., R. G. V. Boelens, N. Fimreite, E. E. Kenaga, Q. Laham, H. Metzner, F. Moriarty, I. C. Munro, H. Remmer, and D. Saward. 1975. Movements of heavy metals and organohalogens through food chains and their effects on populations and communities. Pages 285-310 in A. D. McIntyre and C. F. Mills, ed. Ecological Toxicological Research. Plenum Press, New York, NY.

Martin, M. H., and P. J. Coughtrey. 1982. Biological Monitoring of Heavy Metal Pollution: Land and Air. Applied Science Publishers, New York, NY.

Nolet, B. A., V. A. A. Dijkstra, and D. Heidecke. 1994. Cadmium in beavers translocated from the Elbe River to the Rhine/Meuse Estuary, and the possible effects on population growth rate. Arch. Environ. Contam. Toxicol. 27:154-161.

Oehme, F. W. 1978. Mechanisms of heavy metal inorganic toxicities. Pages 69-85 in F. W. Oehme, ed. Toxicity of Heavy Metals in the Environment, Part 1. Marcel Dekker, Inc., New York, NY.

Petron, S. E. 1993. Biological transfer of contaminants in terrestrial ecosystems. Pages 144-175 in J. T. Maughan, ed. Ecological Assessment of Hazardous Waste Sites. Van Nostrand Reinhold, New York, NY.

Revich, B. A. 1994. Lead in hair and urine of children and adults from industrialized areas. Arch. Environ. Health 49:59-62.

Stickel, W. H. 1975. Some effects of pollutants in terrestrial ecosystems. Pages 25-74 in A. D. McIntyre and C. F. Mills. Ecological Toxicological Research. Plenum Press, New York, NY.

Wenzel, W. J., T. S. Foxx, A. F. Gallegos, G. Tierney, and J. C. Rodgers. 1987. Cesium-137, Plutonium-239/240, Total Uranium, and Scandium in trees and shrubs growing in transuranic waste at Area B. Los Alamos National Laboratory report LA-11126-MS, Los Alamos, NM.

Table 1. Number of animals with detectable values[a] (n) and median values[b] with range (in parentheses) of metals (μg/g) and tritium (pCi/L) found in hair for animals captured in 1998 at Los Alamos National Laboratory[c].

	Rock squirrel (18)[d]		Raccoon (1)		Bobcat (1)		Striped skunk (1)	
	n	Median	n	Median	n	Median	n	Median
Al	18	310 (700)	1	340	1	170	1	370
Sb	2	0.05 (0.2)	1	0.34	1	0.05	1	0.04
As	0	0.2 (0)	1	0.2	0	0.2	0	0.2
Ba	18	11.0 (24.6)	1	14.0	1	15	1	9.5
Be	6	0.035 (0.051)	0	0.35	0	0.35	0	0.35
Cd	0	0.45 (0)	1	1.3	0	0.45	0	0.45
Cr	3	0.45 (1.15)	1	1.6	0	0.45	0	0.45
Cu	18	11.5 (52.9)	2	12.0	1	9.7	1	6.1
Pb	18	2.55 (8.1)	2	14.0	1	1.3	1	2.1
Hg	3	0.15 (0.45)	0	0.15	0	0.15	1	0.5
Ni	1	2.0 (2.2)	0	2.0	0	2.0	0	2.0
Se	18	1.05 (1.0)	1	2.0	1	1.0	1	1.0
Ag	2	1.0 (1.3)	0	1.0	0	1.0	0	1.0
Tl	18	0.021 (0.047)	1	0.066	0	0.01	0	0.017
Tritium	17	2890 (41980)	1	1081000		-	1	20

[a]Detection limits were: As, 0.4; Be, 0.07; Cd, 0.90; Cr, 0.95 Ni, 4.0; Se, 0.3; Ag, 2.0; Tl, 0.3: Hg, 0.3.
[b]Nondetectable values were reported as ½ the detection limit for the purposes of analyses.
[c]All animals were captured at TA-53.
[d]The number of animals of each species tested (N) follows the name of the species in the table.

Table 2. Tritium concentrations (pCi/L) in rock squirrel urine from animals captured in 1997 and 1998 in three locations: at the lagoon, away from the lagoon, and at the control area.

Year	At Lagoon		Away from Lagoon		Control Area		Test Statistic and P[c]
	n	Median	n	Median	n	Median	
1997	8	4000 (9900)	3	1720 (8310)	4	585 (950)	7.5, P = 0.024
1998	15	4490 (41670)	2	250 (60)	13	-20 (2150)	19.964, P = 0.00

Table 3. Number of animals with detectable values[a] (n) and median values[b] (μg/g) with range (in parentheses) of metals found in hair of rock squirrels captured in three locations: at the lagoon, away from the lagoon, and at the control area.

Metals	At Lagoon (15)[c]		Away from Lagoon (3)		Control Area (6)		Test Statistic and P[d]
	n	Median	n	Median	n	Median	
Al	15	340 (700)	3	270 (100)	6	375 (400)	
Sb	15	0.05 (0.2)	3	0.05 (0.05)	6	0.045 (0.08)	
As	0	0.2 (0)	0	0.20 (0)	1	0.2 (0.7)	
Ba	11	11.0 (24.6)	3	19.0 (12.8)	6	17.5 (9.0)	4.92, P = 0.085
Be	3	0.035 (0.051)	2	0.77 (0.44)	3	0.056 (0.085)	6.03, P = 0.049
Cd	0	0.45 (0)	0	0.45 (0)	0	0.045 (0)	
Cr	3	0.45 (1.15)	0	0.45 (0)	0	0.045 (0)	
Cu	15	7.8 (8.3)	3	7.0 (4.2)	6	8.9 (4.1)	
Hg	3	0.15 (0.45)	1	0.15 (0.15)	0	0.015 (0)	
Pb	15	2.7 (8.1)	3	2.5 (1.2)	6	1.0 (0.9)	5.249, P = 0.072
Ni	1	2.0 (2.2)	0	2.0 (0)	0	2.0 (0)	
Se	15	1.1 (1.0)	3	1.0 (0.6)	6	0.65 (1.0)	
Ag	1	1.0 (1.3)	0	1.0 (0)	0	1.0 (0)	
Tl	15	0.020 (0.047)	3	0.026 (0.015)	6	0.025 (0.012)	

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[a]Detection limits were: As, 0.4; Be, 0.07; Cd, 0.9; Cr, 0.9; Ni, 4.0; Se, 0.3; Ag, 2.0; Tl, 0.3: Hg, 0.3.
[b]Nondetectable values were reported as ½ the detection limit for the purposes of analyses.
[c]The number of animals tested (N) in each location follows the location name in the table.
[d]Kruskal-Wallis test statistics and probability levels are included for those metals which had significant differences among groups at the $\alpha = 0.10$ level.

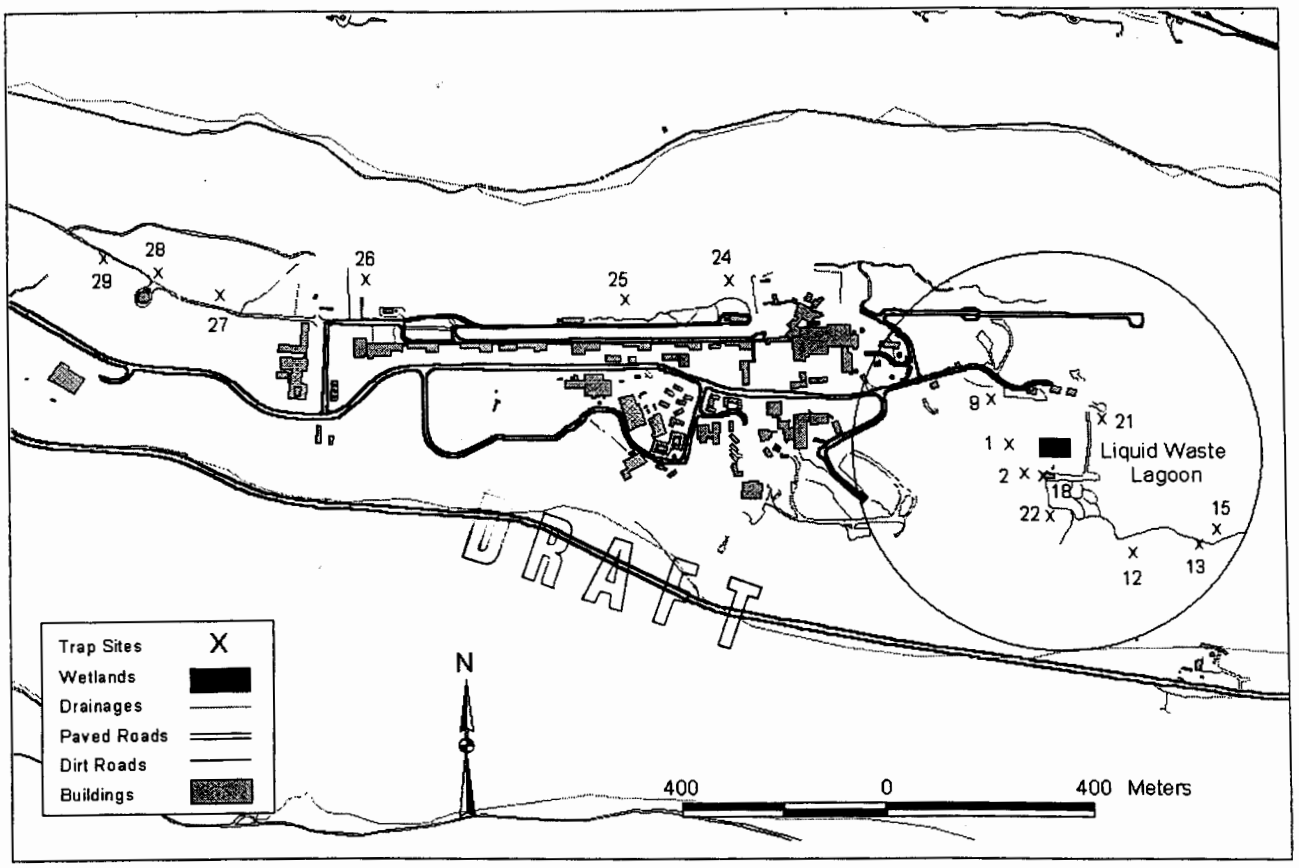

Figure 1. Locations of traps at TA-53. The circle is a 400-m buffer around the liquid waste lagoon. Animals captured inside the circle are considered to be at the lagoon. Animals captured outside the circle are considered to be away from the lagoon.

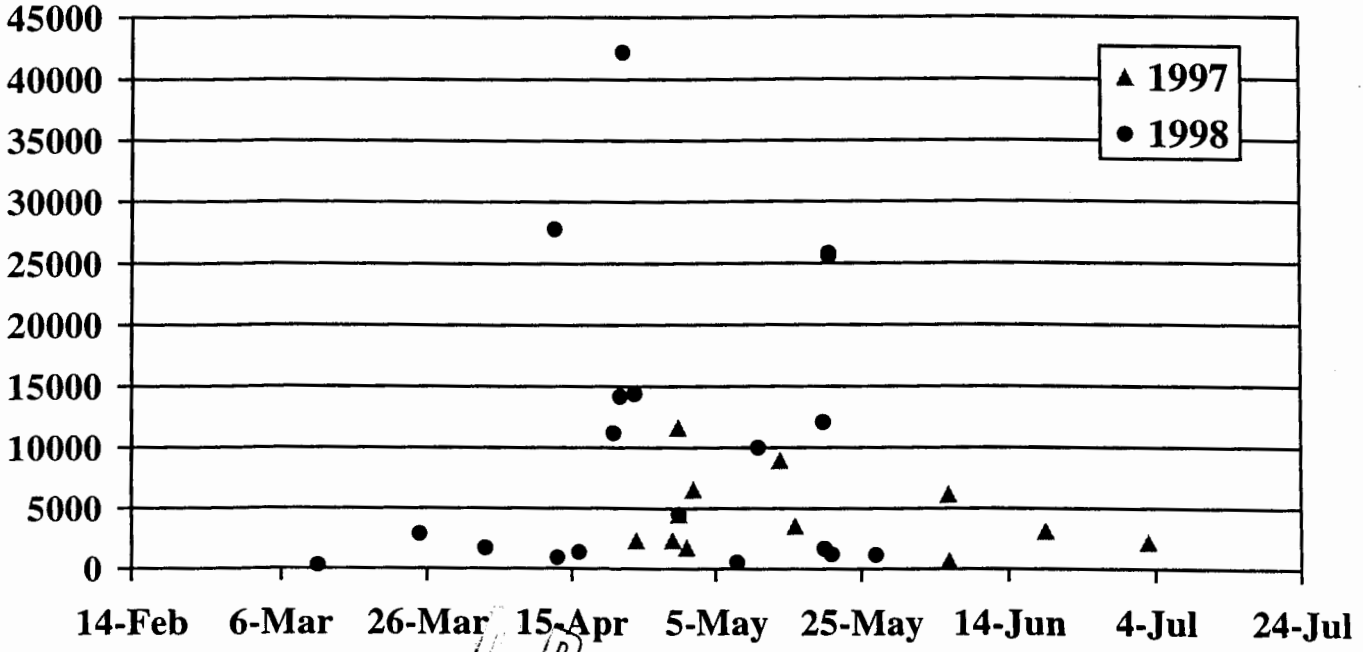

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Figure 2. Graph showing tritium concentration (pCi/L) in urine from rock squirrels captured in the lagoon area by date in 1997 and 1998.