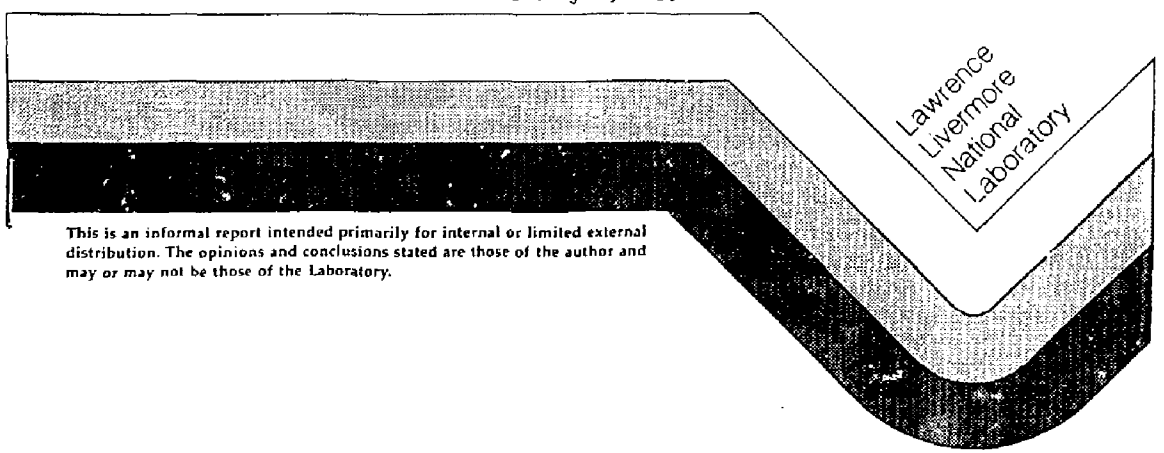
UCID-20641 PART I

ENVIRONMENTAL RADIOLOGICAL STUDIES DOWNSTREAM FROM THE RANCHO SECO NUCLEAR POWER GENERATING STATION - 1985

V.E. Noshkin
K.M. Wong
R.J. Eagle
J.L. Brunk
T.A. Jokela

February 6, 1986



UCID 20641 Part I

UCID--20641-Pt.1

DE86 011014

ENVIRONMENTAL RADIOLOGICAL STUDIES DOWNSTREAM FROM THE RANCHO SECO NUCLEAR POWER GENERATING STATION - 1985.

V.E. Noshkin

K.M. Wong

R.J. Eagle

J.L. Brunk

T.A. Jokela

TABLE OF CONTENTS

PART I

Abstract 1

Introduction 2

Sample Collection, Processing, and Analysis 4

General Comments 4

Aquatic Organisms Sampling and Processing 4

Sediment and Soil Sampling 6

Water Sampling and Processing 8

Gamma Spectrometry Analysis and Data Reduction 8

Results and Discussion 11

Aquatic Organisms 11

Concentrations of Radionuclides in Sediment and Soil Samples . 20

Concentrations of Radionuclides in Water Samples 23

a) Groundwater Samples 23

b) Creek Water Samples. 23

Concentrations of Radionuclides in Parts of Water Hyacinth . . 28

Concentrations of Radionuclides in Beef Samples 28

Conclusions 30

Recommendations for Future Studies 32

Acknowledgment 34

References 35

TABLE OF CONTENTS

Part II

Appendix I	Concentrations of Radionuclides in Fish	1
Appendix II	Concentrations of Radionuclides in Frog Legs	71
Appendix III	Concentrations of Radionuclides in Crayfish	74
Appendix IV	Concentrations of Radionuclides in Sediments	76
	Creek Sediments	77
	Retention Basin Sediments	79
Appendix V	Concentrations of Radionuclides in Soil Samples	80
Appendix VI	Concentrations of Radionuclides in Water Samples	82
	Concentrations of Radionuclides in Ground Water Samples	83
	Concentrations of Radionuclides in Creek Water Samples 1984 and 1985	84
	Concentrations of Radionuclides in Retention Basin Water Samples	86
	Concentrations of Radionuclides in Regenerate Hold-Up Tanks Sampled	87
Appendix VII	*Concentrations of Radionuclides in Parts of* Water Hyacinth	88
Appendix VIII	Concentrations of Radionuclides in Beef Samples	90

ABSTRACT

In this report are summarized the information compiled in 1985 while assessing the environmental impact of radionuclides previously discharged with aqueous releases from the Rancho Seco Nuclear Power Generating Plant. In October 1984, the quantities of gamma-emitting radionuclides in water discharged to Clay Creek from the plant were reduced below operationally defined detection limits for liquid effluents. However, radionuclides previously discharged persist in the downstream environment and are found in many aquatic dietary components. ^{134}Cs and ^{137}Cs are the primary gamma-emitting radionuclides detected in the edible flesh of different fish, crayfish, and frogs. Concentrations of ^{137}Cs in fish from downstream regions began to decrease at the time the decision was made and implemented to minimize the amount of cesium radionuclides in aqueous discharges. The mean concentration of ^{137}Cs in the flesh of all species of fish during October 1985 was, on the average, 28% of the mean concentration measured in fish caught during October 1984 from comparable downstream locations. Concentrations in the flesh of fish decreased with both time and distance from the plant in 1985. Coefficients for exponential equations are generated, from a least square analysis, that relate the change in concentration of ^{137}Cs in fish to distance downstream and time between March and October 1985. Concentrations of ^{137}Cs in surface creek sediments also decreased in the downstream direction much in the same manner as concentrations decreased in fish. However, there was no significant difference in the radiocesium concentrations in surface sediments collected from comparable locations during both 1984 and 1985. It was expected to observe the same fractional decrease in concentration with time in both fish and creek sediment. This does not appear to be the case. The concentration of ^{134}Cs during the year was 35±5% of the concentration of ^{137}Cs in fish. If the concentrations of ^{137}Cs continue to decline with the effective half-lives of 205 d and 85 d, determined for bluegill and bass, respectively, by the end of 1986 concentrations of ^{137}Cs in fish from any downstream location should be less than 1 pCi/g.

INTRODUCTION

The Rancho Seco Nuclear Power Generating Station, operated by the Sacramento Municipal Utility District (SMUD), is located in Sacramento County near the town of Clay, California.

Steam-generator leaks, which occurred at the plant in May 1981, November 1982, September 1983, and July 1984, contributed low-level quantities of some fission and activation products to wastewaters that were collected in holdup tanks located on-site. The type and quantity of radionuclides in the liquid waste contained in each holdup tank were determined by SMUD prior to releasing the material to on-site retention basins.

Periodically the contents, or fractions of the contents, in the basins were diluted and discharged to Clay Creek. The water in this stream flows to the site-boundary fence, 0.6 km from the point of discharge, and continues until it intersects Hadselville Creek, 3.0 km downstream from the plant. Water from Hadselville Creek intersects Laguna Creek 6.5 km downstream from the plant. Laguna Creek water drains into the Cosumnes River at a point near Twin Cities Road between Interstate Highway 5 and State Highway 99.

A change in processing procedures at the plant in late October 1984 reduced the amounts of the principal gamma-emitting radionuclides in the liquid wastes to quantities below the operationally defined detection limits for liquid effluents at Rancho Seco (1).

In the spring of 1984, we initiated a program to obtain site-specific analytical information regarding the concentrations and fate of the gamma-emitting radionuclides discharged with liquid wastes from Rancho Seco. A major priority, for off-site dose assessments, was to determine the levels of radionuclides, in particular ^{134}Cs and ^{137}Cs, associated with the edible parts of organisms in the aquatic food pathway to man.

As the study progressed during 1984, we were requested to expand the program to provide radiological information that could be used by SMUD in dose estimates for the surrounding population from other pathways, including terrestrial pathways, not covered in the original program. The reason for including terrestrial pathways stemmed, in part, from the analytical results obtained from analyses in 1984 of the downstream sediments. Only 21% of the cesium isotopes released from Rancho Seco could be accounted for in stream sediments sampled to a distance of 27 km from the plant. Approximately

300 mCi of ^{137}Cs were discharged between the months of April and September during 1981-1984; this amount represented 60% of the total ^{137}Cs released since aqueous discharges began in 1981. Many local ranchers use water from the creeks during the spring and summer to irrigate a variety of crops; therefore, a substantial amount of ^{137}Cs and ^{134}Cs released from the plant during this period of each year could have been transferred to the nearby irrigated ranchlands.

The results from the scientific studies conducted during 1984 are summarized in reports (2,3,4,5) published in late 1984 and early 1985.

We believe that during the short tenure of this program there have been some notable scientific contributions to better understand the distribution, fate, and accumulation by aquatic and terrestrial organisms of the different gamma-emitting radionuclides previously discharged with the wastewater. There still, however, remains substantial gaps in our understanding of the fate of the residual levels of radioactivity in the environment.

Releases of ^{134}Cs and ^{137}Cs (the two radionuclides contributing the major fraction of the estimated dose to individuals) and other gamma-emitting radionuclides from Rancho Seco stopped in mid-October 1984. However, continued studies in the local environment was warranted to provide reasonable assurance to the local population, government agencies, and other interested parties that no individual in the future will receive an annual dose to the whole body from radioactivity previously discharged that exceeds the EPA guideline of 25 mrem. The creek was posted with no fishing signs in December 1984. Any future dose from the aquatic organism consumption pathway will be zero to individuals abiding with this restriction. However, this restriction cannot continue indefinitely.

There have been no adequate studies to assess contamination of food products or the biological availability of radiocesium when components in stream-bed sediments are the source of radionuclides. This is the current situation (a sedimentary source term) in the aquatic environmental downstream of Rancho Seco, providing no further releases occur from the plant. An objective of high priority in 1985 was then to determine the rate at which the ^{137}Cs and ^{134}Cs concentrations change in fish and other organisms from the creek so that reasonable decisions could be made to either lift or continue fishing restrictions or to consider other remedial actions that may involve cleanup or isolation of the radioactivities previously discharged.

Additional downstream sampling stations were added in 1985 to better define relationships developed in 1984 between concentrations in fish and downstream distance. In 1985, a major effort was devoted to obtain samples of crayfish and frogs, identified as food products during the land and aquatic use survey in 1984 (2), for which there was no radiological information in 1984. In this report are presented a summary and discussion of the analytical results generated from the environmental samples collected during 1985. Some of the studies represent continuations of efforts initiated in 1984 while others developed from recommendations (5) made after an assessment of our results from the first year of effort.

SAMPLE COLLECTION, PROCESSING, AND ANALYSIS

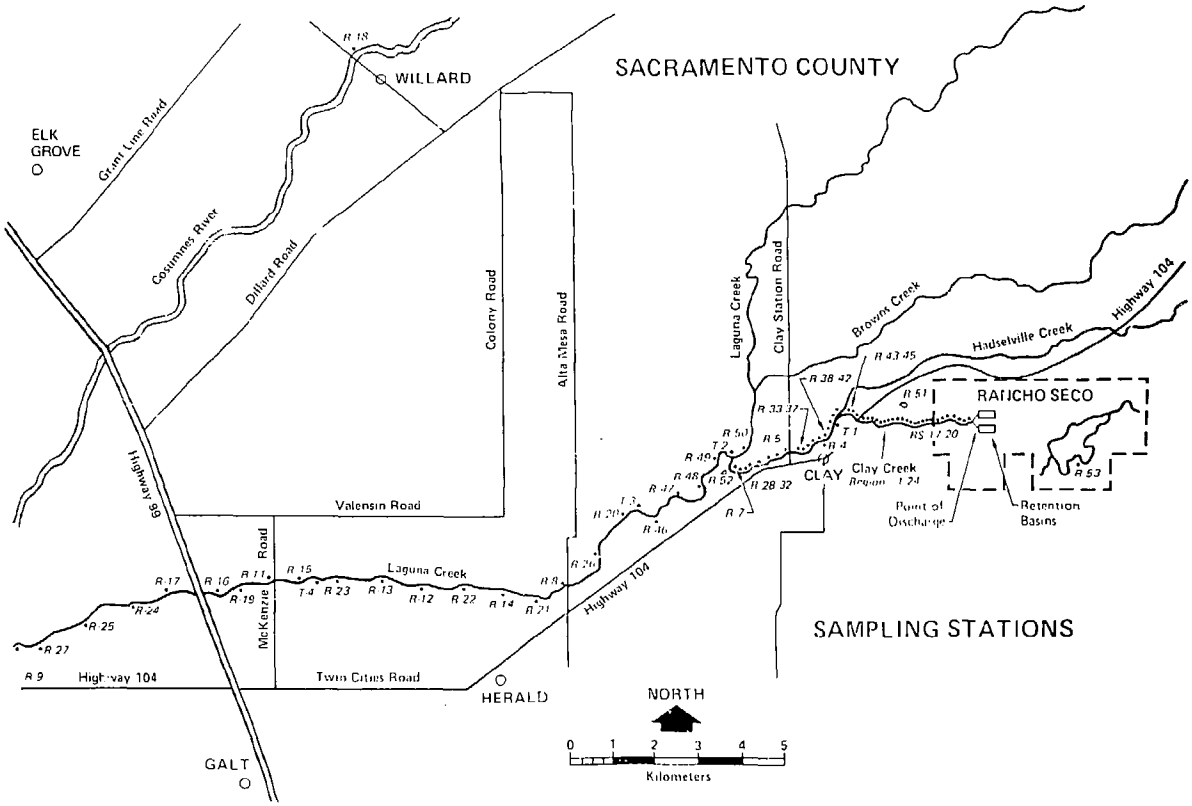
General Comments

In Table 1 are shown the types and number of samples collected for analysis during 1985. Locations of the downstream sampling stations referenced in this report are shown in Fig. 1. Detailed discussions of the collection methods, sample processing, and analysis can be found in previously published reports (3,4,5). The following are abbreviated versions of these discussions.

Aquatic Organism Sampling and Processing

All personnel involved with sample collections had valid Scientific Collector's Permits for 1985. Fish collections were made using fishing gear with either bait or artificial lures. This method was adopted over other authorized fishing methods, or other methods such as chemical immobilization or electric shock, because it best mimicked the method used by local fishermen. Thus, the fish sampled would be more representative of the species normally caught from the creeks for consumption and would not be an indiscriminate collection of different species indigenous to California streams. A total of 701 fish were collected for analyses from 8 downstream locations in 1985. Of this total, 375, 144, and 182 were, bluegill, bass, and catfish, respectively. In addition, a selection of market samples were also analyzed for the assessment of fallout background levels in fish. The

Figure 1. Location of sampling stations.


SACRAMENTO COUNTY
WILLARD
ELK GROVE
Grant Line Road
Cosumnes River
Dillard Road
Colony Road
Alta Mesa Road
Laguna Creek
Clay Station Road
Brown's Creek
Hadselville Creek
Highway 104
RANCHO SECO
Clay Creek
CLAY
Point of Discharge
Retention Basins
Valensin Road
Highway 99
McKenzie Road
Laguna Creek
Twin Cities Road
Highway 104
HERALD
GALT
SAMPLING STATIONS
NORTH
0 1 2 3 4 5
Kilometers

land and aquatic use survey (2) indicated that bluegill, bass, and catfish were the species normally caught for consumption by the local residents. This fact justified the choice of the fish sampled for analysis.

Crayfish were captured in commercial traps using cat food for bait. Frogs were speared at night from downstream locations on the creeks. We are indebted to Mr. Roy Marciel of the staff at Rancho Seco for assisting with the frog collections.

Samples were kept on ice and returned to Lawrence Livermore National Laboratory (LLNL), where the organisms were frozen until processed. Standard length, sex, and fresh whole-body weight of each fish were recorded, and the fish were dissected to separate the edible flesh for analysis. The primary mode of accumulation of cesium by freshwater fishes has been shown to be via absorption from food or ingested sediments, rather than by direct uptake from water (6). Thus, samples from the gastrointestinal tract (GIT) were taken from fish caught at several locations to determine the nature of the food eaten and the radionuclides associated with the ingested material. The flesh and GIT contents from fish of the same species, collected from the same sampling site, were sometimes pooled for analysis. The judgment to analyze single or pooled samples of fish was based on anticipated concentrations at the sampling sites. Each sample was dried in ovens at 90°C to constant dry weight, homogenized, and transferred to aluminum or plastic container for analysis by gamma spectrometry.

Frog legs were separated from the body, skinned, and deboned to provide samples of edible flesh. The flesh from small frogs were often pooled for analysis. The edible portion of the crayfish was separated from several individuals and pooled for analysis.

Sampling and processing the terrestrial animal and vegetation samples have been previously described (5).

Sediment and Soil Sampling

The same devices used to collect sediment and soil samples in 1984 were used to obtain samples in 1985. Sediment to a depth of 12 cm was collected from the creeks using a stainless steel hand corer; the entire 12-cm section was dried, ball-milled, sieved (to remove large rocks), and analyzed as a single sample.

Table 1. Types of environmental samples collected and analyzed for gamma-emitting radionuclides in 1985.

Sample type	No. of samples collected	No. of subsamples analyzed
Fish		
Bluegill	375	110
Bass	144	99
Catfish	182	98
Other aquatic samples		
Frog	88	33
Crayfish	48	9
Water hyacinth	10	20
Stream sediment	53	48
Stream water	46	92
Terrestrial samples		
Cow (and background sample)	5	9
Grass, pasture	2	2
Silage	1	1
Soil	12	12
Well water	20	20
Honey	1	1
TOTAL	987	554

Water Sampling and Processing

Fifty-liter water samples were usually obtained at stations in conjunction with the fish collections. Water was pumped through 1-μm (pore size) cartridge filters into 15-gal polyethylene containers and was returned to LLNL for processing. Cesium isotopes were first concentrated on ammonium molybdophosphate (AMP), the AMP was separated from the water by filtration, and the cesium was then separated from the AMP and prepared as solid samples for analysis on Ge(Li) detectors. The 1-μm filters containing the particulate material were ashed at 450°C, and concentrations of radionuclides in the particulate material were determined by gamma spectrometry.

Unfiltered ground water was sampled for analysis from a number of domestic fresh-water wells located in the vicinity of Rancho Seco. Fifty liter samples were obtained at each of the locations shown in Fig. 2. The samples were processed as described above for ^{134}Cs and ^{137}Cs. Tritium measurements were made on aliquots from the same samples.

Gamma-Spectrometry Analysis and Data Reduction

Gamma-spectrometry measurements were made on all samples at LLNL using a variety of Ge(Li)-diode detector systems. Counting times were usually 1000 min or longer for each sample. A general purpose computer program, called GAMANAL (7), was used for the data reduction of all gamma-ray spectra. In GAMANAL, the observed photopeak in the measured spectra is compared to that in a library of photopeaks of gamma-ray fission and activation products and naturally occurring radionuclides to identify the radionuclides in the sample. The program then applied correction factors for sample size, density, counting time, counting geometry, and decay to convert the measured counting rate to pCi/g of sample on the reference date sampled. All radionuclides routinely released to the waterway from the plant are included in the library. The program also generated an upper-limit amount of specific radionuclides based on those spectra regions where signals would be seen if the radionuclide were present in detectable quantities. Our mean minimal detectable concentrations (based on a counting time of 1000 min) for each of the principal longer-lived gamma-emitting radionuclides previously discharged to Clay Creek are shown in Table 2. These values are averages for the

Figure 2. Location of domestic groundwater wells sampled.

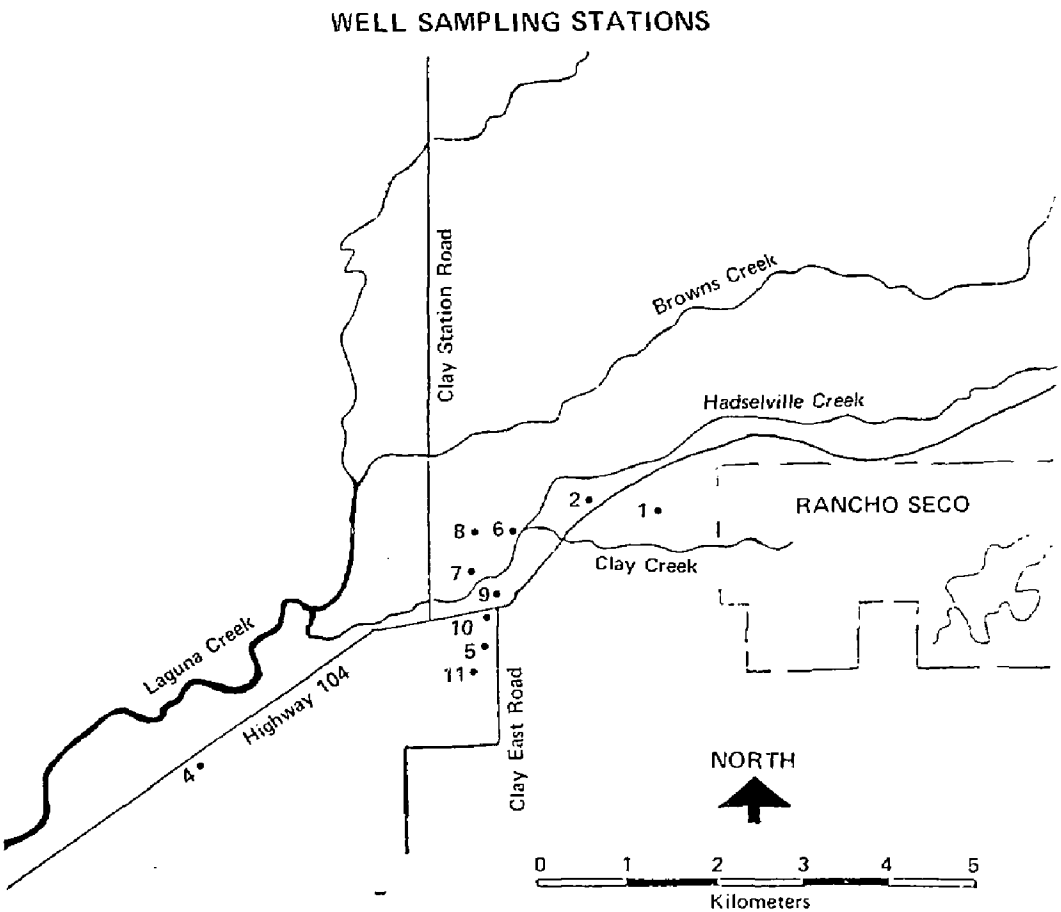

WELL SAMPLING STATIONS
Clay Station Road
Browns Creek
Hadselville Creek
RANCHO SECO
Clay Creek
Laguna Creek
Highway 104
Clay East Road
1
2
4
5
6
7
8
9
10
11
NORTH
0
1
2
3
4
5
Kilometers

Table 2. Mean detection limits of selected gamma-emitting radionuclides released in liquid effluents from Rancho Seco (pCi/sample).[a]

Radionuclide	^{58}Co	^{60}Co	^{54}Mn	^{110m}Ag	^{137}Cs	^{134}Cs	^{125}Sb	^{131}I
Detection limit (pCi/sample)	1	1	1	1	1	1	3	2

[a] Based on a counting time of 1000 min.

different sample configurations (geometries) used and are independent of sample weight. Samples prepared for analysis ranged in weight from a fraction of a gram, for dry stomach contents of fish, to over 300 g for dry soil. Detection limits based on a per-gram basis are therefore different for samples of different weights.

Quality of data has always been an important aspect of our analytical measurements. As a standard practice, 5 to 10% of our time is devoted to quality-assurance work in all projects involving analytical measurements. This quality-assurance work includes:

- Analysis of background samples and blanks.
- Instrument calibration.
- Duplicate sampling and analysis.
- National and international interlaboratory standardization.
- Replicate measurements.
- Analysis and calibration traceable to National Bureau of Standards (NBS) samples.
- Appropriate statistical analysis of the results.

RESULTS AND DISCUSSION

All individual sample results appear in a separate volume, UCID-20641 Part II (Appendices), of this report.

Aquatic Organisms

Concentrations of the radionuclides measured in the muscle-tissue and stomach-content samples of the fish from the different stations sampled in 1985 are given in Appendix I. All results have been decay corrected to the date of collection. Data in the Appendix are arranged to show concentrations in the samples of fish from the downstream station sampled in chronological order. The concentrations are listed relative to fresh wet weight but the dry/wet weight ratios provided may be applied to convert concentrations to a dry weight basis. Other than ^{134}Cs and ^{137}Cs, no gamma-emitting radionuclides from plant discharges were above detection limits in the flesh of the fish.

Evaluation of the concentrations of ^{90}Sr in the flesh of fish was made after radiochemically separating strontium from a selected number of flesh samples from fish collected during 1984, 0.5 km downstream of Rancho

Seco. The concentrations of ^{90}Sr (Table 3) were below detection limits in all samples processed for analysis. Concentrations of ^{137}Cs measured in the respective samples previously reported (3,5) are also shown in Table 3 for comparison. The concentrations of ^{137}Cs in the flesh of these fish are at least 3 to 4 orders of magnitude larger than that of ^{90}Sr .

Representative fish from the July 1985 collections at station RS-17 were dissected to provide samples of muscle tissue, bone, skin, stomach contents, viscera that includes heart, kidney and GIT (stomach lining, intestinal lining, and spleen), liver, and gonad for analysis. The percentage the organ or tissue was of the whole body fresh weight was also determined for bluegill, bass, and catfish and is given in Table 4 along with the concentrations of ^{134}Cs and ^{137}Cs measured in the tissues and organs. All previous dose estimates computed by SMUD for the aquatic food consumption pathway have been based only on the concentrations of ^{134}Cs and ^{137}Cs associated with edible flesh of fish and other aquatic organisms. If this procedure is questioned or challenged, based on new or other dietary information, the data in Table 4, along with the radionuclide concentrations associated with the respective tissues, can be used to construct mean concentrations in any assemblage of fish tissue. However, it is evident from the data in Table 4 that the concentrations of ^{134}Cs or ^{137}Cs in flesh only, will exceed the level for the reconstructed whole body of these 3 species of fish.

A weighted mean concentration for both ^{134}Cs and ^{137}Cs in the flesh of fish during the month collected is computed using equation 1 from the sum of the product of the concentration (C_i), number of fish in the sample (n_i), and the whole body fresh weight (w_i). This sum is divided by the sum of the product of the whole body fresh weight and number of fish in the respective sample.

$$C \text{ (pCi/g wet)} = \Sigma C_i w_i n_i \; / \; \Sigma W_i n_i \qquad (1)$$

Mean concentrations of ^{137}Cs and ^{134}Cs in the flesh of bluegill, bass, and catfish collected at downstream stations during 1985 are shown in Tables 5-7. Also shown for comparison are the mean concentration of ^{134}Cs and ^{137}Cs in fish from the respective stations collected in 1984 (3,5). Reading across these tables, left to right, shows the change in the concentration of ^{134}Cs and ^{137}Cs in the flesh of the respective fish with distance downstream from Rancho Seco. Reading the tables from top to bottom shows the trend for the change in concentration with time.

Table 3. Concentrations of ^{90}Sr and ^{137}Cs in the flesh of fish caught between July and October 1984, 0.5 km from the plant outfall.

Sample ID	Common name	Mean wt whole fish (g)	pCi/g wet wt[a]	
			^{90}Sr	^{137}Cs
J140	Bluegill	48	<0.04	7.6 (1)
J138	Bluegill	67	<0.01	8.8 (2)
J208	Bluegill	71	<0.01	10.9 (1)
J210	Bluegill	77	<0.01	13.6 (1)
J206	Bluegill	80	<0.01	10.4 (1)
J399	Largemouth bass	121	<0.01	14.3 (2)
J393	Largemouth bass	141	<0.01	8.2 (2)
J391	Largemouth bass	203	<0.004	9.0 (1)
J389	Largemouth bass	556	<0.002	14.5 (1)

a Detection limit for ^{90}Sr is 0.4 pCi/sample. ^{137}Cs values are shown for comparison.

Table 4. Concentrations of ^{134}Cs and ^{137}Cs in tissues and organs of fish caught at station RS-17 on July 10, 1985, and the percentage the tissue or organ is of the whole body weight of the fish.

Tissue or organ	Concentrations of ^{134}Cs and ^{137}Cs pCi/g wet wt[a]						Percentage of whole fish weight[d]		
	Bluegill		Bass		Catfish		Bluegill	Bass	Catfish
	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs			
Muscle	1.77(2)	5.20(1)	0.82(4)	2.40(2)	0.83(3)	2.44(2)	52.0	62.0	56.0
GIC[b]	0.66(12)	1.68(5)	1.1(16)	3.17(5)	1.47(6)	4.54(6)	8.4	7.5	4.5
Skin	0.85(6)	2.41(3)	0.46(16)	1.56(5)	0.47(15)	1.41(5)	7.7	7.4	4.6
Viscera[c]	0.6(14)	1.78(5)	bd	bd	0.60(18)	.4(11)	5.4	6.1	5.9
Liver	0.8(22)	2.3(9)	bd	0.6(44)	bd	1.1(16)	0.4	.3	3.6
Bone	0.12(20)	0.23(13)	0.13(39)	0.18(22)	bd	0.08(30)	11.0	9.3	9.4
Gonad	0.8(25)	2.5(9)	bd	bd	bd	bd	1.3	0.5	0.9
Fins		NA		NA		NA	2.8	1.5	1.5
Eyes & Brain		NA		NA		NA	1.3	1.3	0.7
Gill-filaments		NA		NA		NA	2.3	0.9	2.5
Heart		f		f		f	0.7	1.0	0.7
Kidney		f		f		f	0.9	1.2	1.2
Remains[e]		f		f		f	7.9	3.7	11.0
GIT		f		f		f	3.8	3.9	4.0

[a] Number in parentnesis is the 1σ counting error expressed as % of the value listed.

[b] Contents of GI tract.

[c] Viscera sample includes heart, kidney, and GIT (stomach lining, intestinal lining, spleen).

[d] Mean % from the dissection of 2 fish.

[e] Consists of pieces of flesh, connective tissue, skin fragments, etc.

[f] Components of viscera sample described above.

bd below detection.

NA no analysis because of small sample size.

Table 5. Mean concentration of ^{137}Cs and ^{134}Cs in flesh of bluegill collected from downstream locations during 1984 and 1985[a].

Downstream location distance (km)[b]	RS-17 0.5	T-1 3.0	R-5 4.6	T-2 7.5	T-3 10.2	R-8 12.6	T-4 17.2	R-11 19.5
				^{137}Cs (pCi/g wet)				
Date sampled								
4-26-84	11.1							
5-18-84	10.4							
7-18-84	8.9		5.8			0.57		0.15
8-14-84	13.1		4.5			0.54		0.10
10-18-84	15.2		3.1			0.43		
3-19-85	9.3	4.6	2.6	0.97	0.36	0.18	0.14	0.08
4-26-85	4.1	5.2	4.7	0.84	0.33	0.18	0.10	0.05
5-23-85	6.1	2.7	2.5	0.58	0.18	0.18	0.08	0.06
7-11-85	5.2	2.4	2.2	0.32	0.22	0.11	0.07	bd
8-30-85	2.7	2.4	1.04	0.27	0.20	0.10	0.05	bd
10-16-85	2.2	1.4	1.7	0.33	0.15	0.09	0.05	bd
				^{134}Cs (pCi/g wet)				
4-26-84	5.7							
5-18-84	5.1							
7-18-84	4.1		2.8			0.28		0.07
8-14-84	5.7		2.1			0.26		0.05
10-18-84	6.4		1.3			0.27		
3-19-85	3.5	1.7	1.0	0.36	0.16	0.08	bd	bd
4-26-85	1.5	1.8	1.8	0.33	0.13	0.07	0.04	bd
5-23-85	2.1	1.0	0.92	0.20	0.07	0.06	bd	bd
7-11-85	1.8	0.87	0.73	0.16	0.07	0.05	0.03	bd
8-30-85	0.86	0.73	0.33	0.08	0.08	0.03	bd	bd
10-16-85	0.76	0.44	0.56	0.09	bd	bd	bd	bd

[a] 1984 data from reference 4 and 5.

[b] Downstream distance from Rancho Seco.

bd below detection.

Table 6. Mean concentration of ^{137}Cs and ^{134}Cs in flesh of large mouth bass collected from downstream locations during 1984 and 1985[a].

Downstream location distance (km)[b]	RS-17 0.5	T-1 3.0	R-5 4.6	T-2 7.5	T-3 10.2	R-8 12.6	T-4 17.2	R-11 19.5
				^{137}Cs (pCi/g wet)				
Date sampled								
4-26-84	7.0							
5-18-84								
7-18-84	2.8					0.57		0.06
8-14-84	4.4		2.8			0.57		0.14
10-18-84	11.8					0.46		
3-19-85	8.0		7.6	0.88	1.3	5.1	0.26	0.15
4-26-85	10.4		7.7			1.0	0.29	bd
5-23-85	1.8			4.5	1.3	0.83	0.16	0.10
7-11-85	2.4	1.1	1.2	0.62	bd	0.17	0.15	bd
8-30-85	0.90	1.2	0.90		0.24	0.17	0.11	0.10
10-16-85	1.4				0.37	0.27	0.04	bd
				^{134}Cs (pCi/g wet)				
4-26-84	3.3							
5-18-84								
7-18-84	1.3					0.25		bd
8-14-84	1.9		1.2			0.26		0.07
10-18-84	5.0					0.20		
3-19-85	3.0		2.8	0.34	0.51	1.8	0.10	0.07
4-26-85	3.7		2.8			0.37	0.12	bd
5-23-85	0.7			1.5	0.49	0.30	0.07	0.03
7-11-85	0.8	0.36	0.36	0.23	bd	bd	0.06	bd
8-30-85	0.30	0.39	0.30		bd	0.06	0.04	0.04
10-16-85	0.45				0.13	0.08	bd	bd

[a] 1984 data from reference 4 and 5.

[b] Downstream distance from Rancho Seco.

bd *below detection.*

Table 7. Mean concentration of ^{137}Cs and ^{134}Cs in flesh of catfish collected from downstream locations during 1984 and 1985[a]

Downstream location	RS-17	T-1	R-5	R-52	T-2	T-3	R-8	T-4	R-11
distance (km)[b]	0.5	3.0	4.6		7.5	10.2	12.6	17.2	19.5
				^{137}Cs (pCi/g wet)					
Date sampled									
7-18-84									0.08
10-17-84				5.1					
2-7-85			11.4						
3-19-85	6.3	4.5	4.9	1.6	2.0				
4-26-85	6.7	5.1	4.5		2.0				
5-23-85	2.6	3.8	2.6		2.0	0.38	0.32		0.04
7-10-85	2.4	1.2	2.2		0.97		0.35		0.18
8-30-85	2.1	1.5			0.44		0.20		bd
10-15-85		0.86			1.04		0.10		
				^{134}Cs (pCi/g wet)					
7-18-84									0.03
10-17-84				2.2					
2-7-85			4.5						
3-19-85	2.3	1.7	1.9	0.56	0.75				
4-26-85	2.4	1.9	1.6		0.71				
5-23-85	0.93	1.4	0.91		0.72	0.14	0.14		bd
7-10-85	0.83	0.41	0.77		0.34		0.11		0.07
8-30-85	0.69	0.49			0.14		0.07		bd
10-15-85		0.34			0.33		bd		

[a] 1984 data from reference 4 and 5.

[b] Downstream distance from Rancho Seco.

bd below detection.

The mean concentration of ^{137}Cs in the flesh of bluegill decreased between March and October 1985 more or less uniformly with both downstream distance and time (Table 5). This trend is also seen in the results shown in Tables 6 and 7 for bass and catfish but with some anomalies that will be discussed. Levels of ^{134}Cs in the fish, during the year, were 35 $\pm$ 5% of the ^{137}Cs concentration.

By October 1985, the mean concentration of ^{137}Cs in the flesh of the three species of fish had fallen to 28% of the concentration measured in the respective fish collected from comparable stations during this period in 1984.

The values given in Table 5 were used to develop a relationship between mean bluegill flesh concentration, downstream distance, and time. This relationship is described by:

$$C(pCi/g\ wet) = 7.8\ e^{-(0.255D + 0.00338t)} \qquad (2)$$

where D is the distance in km of the station (given in Table 5) downstream from the plant and t is the time in days after March 19, 1985. The coefficients for D and t were obtained from a least-square analyses of the data. The concentrations of ^{137}Cs in the flesh of bluegill decreased during the period with an effective half life of 205 days. By the end of 1986, the calculated levels of ^{137}Cs in the flesh of bluegill from any location downstream of Rancho Seco will be less than 1 pCi/g providing the concentrations continue to decrease at the present rate. Concentrations of ^{134}Cs in bluegill will decrease somewhat more rapidly than ^{137}Cs because of its shorter radiological half-life.

Changes in the mean concentration of ^{137}Cs in the flesh of bass and catfish with distance and time during 1985 were not as uniform as the changes noted in bluegill (Tables 6 and 7). For example, the mean concentrations of ^{137}Cs (and ^{134}Cs) in bass caught at station R-B (12.6 km downstream) in March 1985 and at T-2 (7.5 km downstream) in May are higher than those in fish caught at stations closer to the plant on the respective sampling dates. The higher body burdens of these fish were probably derived from more contaminated locations nearer the plant outfall. It appears that the bass, possibly in search of food, may have swam downstream shortly before being caught. This suggests that bass may be somewhat more migratory in the local creeks than previously assumed (5). However, by neglecting these two data points a

reasonably good exponential relationship can also be developed that relates concentrations of ^{137}Cs in the flesh of bass (and also in catfish) with downstream distance and time.

$$C(pCi/g \text{ wet bass flesh}) = 11\ e^{-(0.190 + 0.0081t)} \quad (3)$$

$$C(pCi/g \text{ wet catfish flesh}) = 9\ e^{-(0.190 + 0.0082t)} \quad (4)$$

The definition and units of D and t are those described with equation 2. The values of the regression coefficient of 0.26, 0.19 and 0.19, relating the change in concentration in bluegill, bass, and catfish with downstream distance, are essentially identical to the values determined for these fish from an assessment of the results generated in 1984 (3,5).

There are certain differences between the results from last year and this year for which reasonable interpretations cannot yet be made. In 1984 (see reference 5 or compare values in Tables 5, 6, and 7) the mean concentration of ^{137}Cs in the flesh of bluegill was always greater than (or at least equivalent to) the concentration in the flesh of bass and catfish collected on the same date at downstream locations. For this reason we concentrated on bluegill collections in 1985 because these earlier findings confirmed the usefulness of bluegill as indicators of maximum flesh concentrations (8) among edible fish collected from the creeks. This year, most notably in the spring and early summer, the mean concentrations of ^{37}Cs in the flesh of bass and catfish (compare data in Tables 5, 6, and 7) were greater than the levels in bluegill at many of the downstream stations sampled. Examination of the gut contents revealed there was no obvious differences in the monthly diets between the two year collections. The trend developed from the 1984 data was not repeated in 1985, and we presently lack an explanation for this change.

In Appendix II and III are presented measured concentrations of ^{137}Cs and ^{134}Cs in edible frog legs and flesh of crayfish collected from downstream locations during 1985. No other gamma-emitting radionuclide associated with the releases from Rancho Seco was detected in the edible flesh of these organisms. From the data presented in Table 8, comparisons can be made of the concentration of ^{137}Cs in the flesh of frogs and crayfish to that in bluegill flesh from the stations sampled during different periods of 1985. With very few exceptions, the concentration of ^{137}Cs in bluegill flesh was either equivalent to or greater than the concentration in flesh of

frogs or crayfish from the respective station. In the absence of downstream site specific data for concentrations in frogs or crayfish, the levels in bluegill may be substituted with some certainty to estimate conservative values for mean concentrations during 1985 in these organisms from any downstream location.

Concentrations of Radionuclides in Sediment and Soil Samples

Concentrations of radionuclides determined in creek sediment and in selected soil sampled during 1985 are given in Appendices IV and V. From the data presented in Figure 3, a comparison can be made of the concentrations for ^{137}Cs measured in the 0-12 cm surface sediment sections collected in 1984 and 1985 from different downstream regions of Clay, Hadselville, and Laguna creeks. Concentrations associated with the bed sediments decrease more or less uniformly with increasing distance downstream of Rancho Seco, and there is no obvious difference in the downstream distribution observed over the 2 y. There has been no substantial net addition or loss of ^{137}Cs in the sediments from any downstream region over the two-year period. The change in concentration is best expressed by equation 5 where D is the distance in km downstream of Rancho Seco.

$$^{137}Cs\ (pCi/g\ 0\text{-}12\ cm) = 22\ e^{-0.28D} \qquad (5)$$

There was also little change in the concentrations of the longer lived radionuclides measured in the retention basin sediments that were collected in August 1984 (see reference 4) and July 1985. However, the concentration ratio of $^{58}Co/^{60}Co$, for example, in sediments collected in July 1985 did not relate to the quantities measured in 1984. The mean 1985 ratio of $^{58}Co/^{60}Co$ in the sediments was 0.022 while the measured value in August 1984 was 0.056. The half life of ^{58}Co is 70.8 d and 11 months elapsed between the two collections of sediment. Between August 1984 and July 1985, the ratio should have decreased from 0.056 to 0.003 by radioactive decay. Hence, there must have been some additional source of ^{58}Co to the basin sediments to account for a concentration ratio ten times the expected value.

Table 8. Comparison of the mean concentrations of ^{137}Cs in flesh of bluegill, frogs, and crayfish collected from downstream locations in 1985[a].

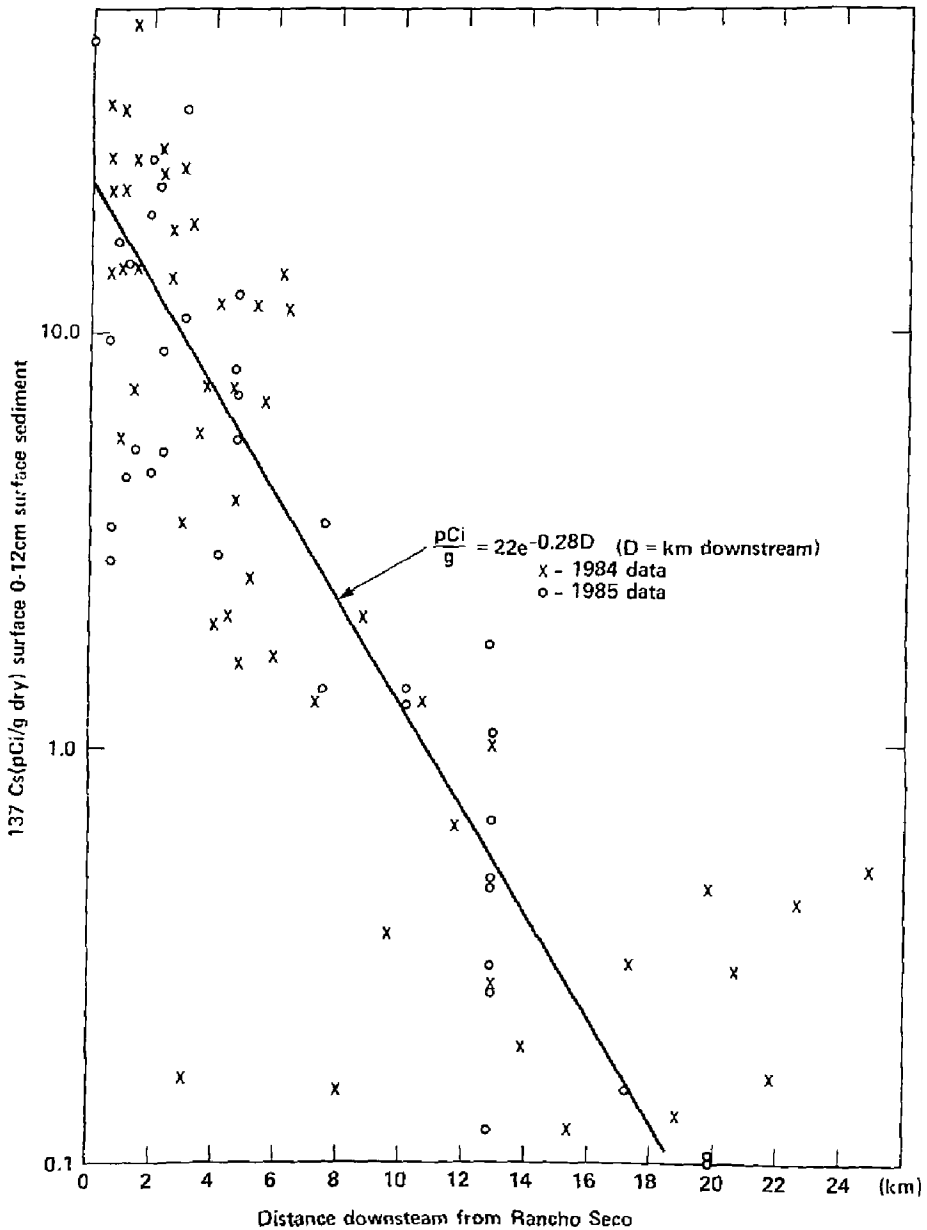
ate sampled	Station ID	Downstream distance (km)	^{137}Cs (pCi/g wet) Bluegill	Frogs	Crayfish
3/19-21/85	RS-30[b]	0.5	5.4	4.9	
	R-5	4.6	2.6	2.5	
	T-2	7.5	0.97	0.64	bd
4/24-26/85	R-5	4.6	4.7	3.5	
	T-2	7.5	0.84	0.73	
	R-8	12.6	0.18	0.09	
5/22-23/85	RS-17	0.5	6.1		7.5
	R-5	4.6	2.5	3.1	1.8
	R-8	12.6	0.18		bd
7/10/85	RS-17	0.5	5.2	0.71	
	R-5	4.6	2.6	3.1	
	R-8	12.6	0.11	0.09	
8/28-30/85	RS-17	0.5	2.7	2.6	3.1
	R-5	4.6	1.04	1.08	0.8
	T-2	7.5	0.27	0.16	bd
	R-8	12.6	0.10	bd	

a Mean values computed from equation 1.

b Sump next to Station RS-17.

bd below detection.

Figure 3. Concentrations of ^{137}Cs in creek surface sediments collected in 1984 and 1985.


137 Cs(pCi/g dry) surface 0-12cm surface sediment
10.0
1.0
0.1
0
2
4
6
8
10
12
14
16
18
20
22
24
(km)
Distance downsteam from Rancho Seco
pCi/g = 22e^-0.28D (D = km downstream)
x - 1984 data
o - 1985 data

Soils were collected at locations near irrigation pumps or fishing sites used by local ranchers. It is recommended that the measured concentrations be used with appropriate usage factors (time spent in the region) to compute the radiological dose to individuals from shore-line exposure at the downstream locations sampled.

Concentrations of Radionuclides in Different Water Samples

Appendix VI contains tables of concentrations for different radionuclides measured in various samples of water collected during 1984 and 1985.

a. Groundwater Samples

Several local ranchers requested that SMUD assess the concentrations of any man-made radionuclides in domestic groundwater samples. We fulfilled these requests by analyzing 15 gal of unfiltered water from the well locations shown in Fig. 2 and described in Appendix VI. Cesium radionuclides and ^{3}H were below our detection limits in all the samples that we analyzed. It appears that no measureable radionuc ides discharged by Rancho Seco have migrated to the local groundwater reservoirs.

b. Creek Water Samples

Concentrations of ^{134}Cs and ^{137}Cs in filtered creek water samples and in the separated particulate material from downstream locations are shown in Appendix VI. During February 1985, the amount of particulate material was measured in the water both before and after a heavy rain. These measurements were made to assess the magnitude of the distribution coefficient (K_d) for ^{137}Cs. The quantities of filtered particles in the water and computed K_d values are shown in Table 9. Note that the amount of filtered particles (along with associated ^{134}Cs and ^{137}Cs) moving with the water during the heavy rain, increased at all downstream locations by 1 to 2 orders of magnitude above the ambient amounts measured prior to the rainstorm. Transport of contaminated sediment downstream, especially in the rainy season, may increase the chance of exposing fish to higher concentrations of ^{137}Cs at the more remote downstream locations.

Table 9. Amount of suspended particles in water sampled and K_d values for ^{137}Cs.

Station ID	Date sampled	Suspended particles concentration g dry/l	^{137}Cs K_d [a] values
RS-17	4-26-84	0.0052	3.7×10^4
RS-17	2-7-85	0.0084	6.0×10^4
RS-17[b]	2-8-85	0.138	4.3×10^4
R-5	2-7-85	0.0062	9.4×10^4
R-5[b]	2-8-85	0.404	5.1×10^4
R-8	2-7-85	0.0029	10.6×10^4
R-8[b]	2-8-85	0.223	1.6×10^4
R-11	2-7-85	0.0087	17.8×10^4
		mean	$7.3 \pm 5.1 \times 10^4$

a $K_d = \frac{\text{pCi/L prefilter} \times 1000}{\text{pCi/L water} \times \text{g/L particles}}$

Respective values for pCi/L prefilter and pCi/L water for ^{137}Cs shown in Appendix VI.

b Samples collected after a heavy rain.

Table 10. Median value for concentration factors (CF) for ^{137}Cs in bluegill, bass, and catfish and stable potassium concentration in creek water.

	Clay Creek		Hadselville Creek		Laguna Creek	
	Number	Median CF	Number	Median CF	Number	Median CF
Bluegill	10	11.4×10^3	10	3.0×10^3	17	1.3×10^3
Bass	10	5.7×10^3	5	2.5×10^3	17	2.7×10^3
Catfish	5	11.2×10^3	6	5.3×10^3	6	1.1×10^3
Potassium[a] (ppm)	1	0.9	1	1.1	2	6.7

[a] Potassium measured on October 10, 1985.

During February 1985, the computed K_d values were not constant but were variable and increased in value with downstream distance. This could be caused by one of many complex factors that govern the uptake of radionuclides by suspended material including differences in water quality that may exist between Clay, Hadselville, and Laguna Creeks. This latter possibility will be discussed in more detail in a subsequent section.

All downstream concentrations of ^{137}Cs, both in solution and associated with particles, were greater than the global fallout background levels (0.008-0.012 pCi/L) measured in the Mokelumne River and Rancho Seco Lake. The concentrations of ^{137}Cs measured in solution during the periods sampled in 1985 (during periods of no reported releases) generally increased between the plant outfall and station R-5 (4.8 km downstream) and then decreased exponentially to near fallout background concentrations at station R-11, which is 19.5 km from the plant. The mean concentration of ^{134}Cs was 36±3% of the ^{137}Cs concentration. Still unexplained is the difference consistently found in 1984 (5) and 1985 between the $^{134}Cs/^{137}Cs$ activity ratios in filtered water and in the particulate material. The activity ratio of the cesium isotopes in solution has been consistently less than the ratio of the isotopes associated with the material filtered from water at all stations downstream of the plant.

We performed a regression analysis to show that during 1985 the change in the concentration of soluble ^{137}Cs with distance (km) downstream of station R-5 is best represented with a mean regression coefficient of -0.13±0.02. Concentrations in the water at some stations also appeared to be decreasing with time during 1985. Not evident in the sediment results, discussed in the preceeding section, the water concentration data show there must be some net loss of ^{137}Cs from upstream sediment with subsequent adsorption onto material at downstream locations. No difference would be observed in the concentration of dissolved ^{137}Cs with distance downstream if there were no interactions between dissolved ^{137}Cs and sedimentary material. Because discharges of radioactivity stopped in the fall of 1984, it was unexpected to find ^{137}Cs in solution everywhere downstream, our first assumption was that the quantities measured represented the amounts mobilized or leached from the bottom sediments of the creek. However, we were unable to account for all of the ^{137}Cs moving past station RS-17 (0.5 km downstream from Rancho Seco) by remobilization alone. The mean concentration of ^{137}Cs moving past station

RS-17 between October 1984 and October 1985 was 0.66 pCi/L in solution and 0.48 pCi/L with particles. Flow rates measured at RS-17 were in agreement with the rates measured at the station outfall. Monthly flow rates were available from SMUD. It is estimated that from 8-13 mCi of ^{137}Cs flowed past station RS-17 between October 1984 and October 1985 from the concentration and flow rate data. However, this amount of ^{137}Cs is slightly greater than the total inventory measured in the sediments (including the on-site retention basin sediment) upstream of RS-17. The total upstream inventory was not mobilized during the year. Recall from the previous section that the amount of ^{137}Cs in the retention basin sediments measured in 1985 was equivalent to the amount measured in 1984. Therefore, possibly another non-sedimentary source was contributing to the radioactivity moving past RS-17 during 1985.

The last 2 tables in Appendix VI show concentrations of ^{137}Cs and other radionuclides in water samples collected in October 1985 from the on-site retention basins and regenerate hold-up tanks. Levels of ^{137}Cs were below the SMUD operational detection limits that are required to comply with USNRC regulations. There may have been small levels of ^{137}Cs (and other radionuclides) in the retention basin water (below the SMUD detection limit) released to Clay Creek over the year that contributed to the inventory estimated passing station RS-17.

One other purpose for the continuous collection of water samples is to strengthen our data base on concentration factors for ^{137}Cs in the species of fish from the creek. Last year it was determined that the concentration factors for ^{137}Cs in the flesh of fish caught nearest the plant were larger than the concentration factors measured further downstream (5). The concentration factor is the ratio of radionuclide concentration in the organism or tissue to that in the water. Concentration factors were computed from the mean concentrations of ^{137}Cs in fish muscle given in Tables 5, 6, and 7 and the appropriate filtered water concentration measured in 1985 at the stations shown in Appendix VI. Median concentration factors were computed for ^{137}Cs for fish from Clay, Hadselville, and Laguna Creek. There are clearly significant differences in the median value of the concentration factor, especially between Clay and Laguna Creeks. Vanderploeg et. al. (6) had previously reported that the concentration factor for ^{137}Cs is influenced by the stable potassium in water, that highest values were found in lake waters having a potassium concentration of 1 ppm or less, and that concentration

factors decreased with increasing levels of potassium. During October 1985, water samples were collected for the analysis of stable potassium. The levels of potassium in Clay and Hadselville Creeks, shown in Table 10, are significantly lower than the mean concentration in Laguna Creek. These results were unexpected but clearly show that the levels of potassium in the water from the creeks are variable and may change during different growing seasons of the year. This could result from natural causes or changes in water quality caused by runoff from downstream fields where high potassium fertilizers were applied. Whatever the reason, it is possible that variations in the potassium content of the water may be one reason for the differences in the concentration factors for ^{137}Cs.

Concentrations of Radionuclides in parts of Water Hyacinth

Collections of water hyacinth (Eichhornia crassipies) were initiated in 1985 to evaluate the usefulness of the plant as an indicator species for future monitoring of the waterway. Concentrations of the radionuclides detected by gamma spectrometry in the roots and stem-leaf sections of the plants collected from different downstream stations are shown in Appendix VII. The data indicate that these plants may obtain a significant fraction of the measured radionuclides by root uptake from interstitial water of bottom sediments. There are no clear trends noted for the changes in concentrations with distance or time. In August, for example, the concentration of ^{137}Cs was highest in the leaf-stem sample from station R-5, 4.6 km downstream, but in October the highest concentration in the plant leaf was from station T-3, 10.2 km downstream. The levels of ^{137}Cs in the plant do not appear to follow the changes in concentration measured in both fish and sediment.

Although the plant accumulates most radionuclides found in past releases from Rancho Seco, its general usefulness as a reliable indicator species has yet to be adequately demonstrated.

Concentration of Radionuclide in Beef Samples

During the year, requests were made (1) to evaluate the levels of ^{134}Cs and ^{137}Cs in the flesh of beef cattle from a ranch downstream of Ranch Seco. In Appendix VIII are listed the concentrations measured in samples of beef obtained from slaughtered ranch animals and from local markets.

In March 1985, two cows were slaughtered for analysis. The cows had grazed on pasture grass irrigated with water from Clay Creek but were removed to a feed lot several months prior to slaughter. The concentrations of ^{137}Cs in the flesh were no greater than the fallout background levels in the market samples. Any ^{134}Cs and ^{137}Cs accumulated by the cows while feeding in the pasture was eliminated with a biological half life of about 30 d during the months at the feed lot.

In June 1985, two additional cows, which were taken directly from a downstream pasture, were slaughtered for analysis. The concentrations of ^{134}Cs and ^{137}Cs in samples from the hindquarter of each cow are shown in Appendix VIII. The mean concentration of ^{137}Cs in the flesh was not significantly different from the average value of 0.066 pCi/g measured in sirloin and hamburger samples from a cow sampled from the grazing area on November 1, 1984 (5). Based on an annual consumption rate of 95 kg/y for beef and a mean concentration of 63 pCi/kg, we calculated the average daily intake rate of ^{137}Cs from consumption of meat from these grazing cows would be 16 pCi/d. This intake rate of ^{137}Cs is within the range of ^{137}Cs daily intake from a survey of California diets in 1971, 1972, and 1973 conducted by the Radiological Health Section, California State Department of Health (9). It is stated in this report "that levels of radioactivity were observed to be far below those levels for which consideration should be given to protective health action."

CONCLUSIONS

Since mid-October 1984, the levels of ^{134}Cs and ^{137}Cs (the two radionuclides contributing the major fraction of the estimated dose to individuals in 1983 and 1984) and other gamma-emitting radionuclides in water discharged to Clay Creek from Rancho Seco have been reduced below detectable quantities (1). However, results from our sampling program in 1985 indicate that radionuclides previously released persist in the downstream environment and are present in many of the aquatic dietary components. As with the results generated in 1984 (3,5), ^{134}Cs and ^{137}Cs were the primary gamma-emitting radionuclides detected in the edible flesh of different fish, crayfish, and frog legs sampled for analysis in 1985. No ^{90}Sr was detected in the flesh of fish caught downstream of Rancho Seco. Concentrations of ^{137}Cs in fish from downstream regions began to decrease at the time the decision was made and implemented to minimize the amount of cesium radionuclides in aqueous discharges. The mean concentration of ^{137}Cs in bluegill, for example, caught 0.5 km from the plant was 15.2 pCi/g in October 1984 and 9.3 pCi/g in March 1985. The mean concentration of ^{137}Cs in the flesh of all fish during October 1985 was, on the average, 28% of the concentration measured in fish during October 1984 from comparable downstream locations. No such decrease was evident in the concentration of ^{137}Cs in the surface sediments collected from comparable locations during 1984 and 1985. Because the sediments are now the principal source of radioactivity, it is presently difficult to explain these conflicting results. One might have expected to observe the same fractional decrease in concentration with time in both fish and sediment. This does not appear to be the case.

Concentrations in the flesh of fish decreased with both time and distance from the plant outfall in 1985. These changes in concentrations were described by exponential equations, the coefficients of which were obtained from the least square analysis of the data obtained between March and October 1985. The concentration of ^{134}Cs during this period was 35±5% of the concentration of ^{137}Cs in fish from any downstream location. During this period the effective biological half-life (the time for the measured concentration to be reduced to one-half its original value) of ^{137}Cs was 205 d in bluegill and 85 d in bass and catfish. If the concentrations in fish continue to decline at these rates, concentrations of ^{137}Cs in all species will be less than 1 pCi/g by the end of 1986. Changes in the concentration

of ^{137}Cs in crayfish and frogs closely follow the changes in concentration measured in the flesh of bluegill.

Stable potassium levels in the water sampled from different downstream creeks are not the same. Levels are lowest in the water of Clay Creek and highest in Laguna Creek. This could result from natural causes or from changes in water quality caused by runoff from downstream fields where high potassium fertilizers were applied. The values computed for the ^{137}Cs concentration factors are highest for fish from Clay Creek and lowest for fish from Laguna Creek. This trend was also evident in the 1984 data (5). The stable potassium level in the water may play a role in regulating both the magnitude of the ^{137}Cs concentration factor for the different species of fish found in the creeks and K_d values between the particles and the creek water. Concentrations of dissolved ^{137}Cs were measurable in all water samples collected from downstream locations in 1985. Some of the levels result from mobilization of radiocesium at the sediment-water interface. However, there may have been small amounts of ^{137}Cs and other radionuclides released to the creek from the retention basins during the year; this would explain the levels measured in the downstream water samples.

^{137}Cs, ^{134}Cs, and ^{3}H were below detection limits in all downstream domestic groundwater samples collected in 1985. No activity was found in samples of honey from hives 0.5 km from the plant, and the levels of ^{137}Cs in the flesh samples of cattle taken directly from pasture in 1985 were comparable to the levels detected in the flesh of beef collected in 1984 (5).

RECOMMENDATIONS FOR FUTURE STUDIES

This was the second year of study of the aquatic and terrestrial environment downstream of Rancho Seco Nuclear Power Generating Station. Based on our studies conducted during 1984, a number of recommendations for future studies in 1985 were developed and described (5). Many of these studies have been accomplished and the results presented in this report. We are now recommending a further scientific study through the end of 1986 to better understand the distribution and fate of radionuclides in the ecosystem to insure that no major environmental factors related to the radionuclides previously discharged in aqueous releases from Rancho Seco are overlooked.

Because the releases of ^{137}Cs and ^{134}Cs to the aquatic environment were significantly reduced in October 1984, the levels of radionuclides in the edible aquatic organisms from all downstream areas have generally decreased well below the levels observed in 1984. Between the spring and fall of 1985, the levels of ^{137}Cs decreased in bluegill with an effective biological half-life of 205 d. Concentrations in bass and catfish decreased with an effective biological half-life of 85 d. However, there was no difference in the concentration of ^{137}Cs in downstream surface sediments from comparable locations sampled in 1984 and 1985. One might have expected the same decrease in concentration with time in both fish and sediment. This does not appear to be the case. Because the sediments now appear to be the principal source of radioactivity, further study will be required to explain these conflicting results.

If the concentrations of ^{137}Cs continue to decline in fishes at the above rates, by the end of 1986 the levels of ^{137}Cs in the flesh of fish from any location downstream of Rancho Seco will be less than 1 pCi/g. At these low concentrations, serious consideration should then be given to lifting all fishing restrictions on the creeks.

Before the models describing the change in fish concentrations with time can be used with confidence, they should be validated during 1986 with additional field data. The lack of corresponding changes in sediment concentrations over the year is cause for concern. Originally it appeared, from the 1984 data, that sediment and fish concentrations decreased in a

similar manner with downstream distance from the station. The observed behavior may be attributed to the cesium associated with the creek sediments becoming more firmly fixed and less biological available with time. Changes brought about in the major chemical composition of the discharged water and/or alterations in downstream agricultural practices may influence the chemical-biochemical behavior of cesium radionuclides. We find ome evidence for this effect in the variations of ^{137}Cs concentration factors and K_d values. An assessment of the biological availability of radiocesium associated with bottom sediments and the factors affecting the availability should be key elements for study in the 1986 aquatic program.

ACKNOWLEDGMENT

We wish to thank Mr. Jack Dawson and Mr. Gary Floyd for assisting in the sample collection and processing phases of this program. This work was performed under the auspices of the U.S Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48, with support from the Sacramento Municipal Utility District under contract A087.

REFERENCES

1). E.W. Bradley, Sacramento Municipal Utility District, Sacramento, CA., private communication (1985).

2). R.J. Eagle, K.M. Wong, and V.E. Noshkin, Ranch Seco Liquid Effluent Pathway--Aquatic and Terrestrial Dietary Survey Report, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20267 (1984).

3). V.E. Noshkin, R.J. Eagle, J.M. Dawson, J.L. Brunk, and K.M. Wong, Concentration of Radionuclides in Fresh Water Fish Downstream of Rancho Seco Nuclear Power Generating Plant, Lawrence Livermore National Laboratory, CA, UCID-20295 (1984).

4). K.M. Wong, R.J. Eagle, J.M. Dawson, J.L. Brunk, and V.E. Noshkin, Radionuclides in Sediments Collected Downstream from the Rancho Seco Nuclear Power Generating Station, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20298 (1985).

5.) V.E. Noshkin, K.M. Wong, R.J. Eagle, J.W. Dawson, J.L. Brunk, T.A. Jokela, Environmental Radiological Studies Downstream from Rancho Seco Nuclear Power Generating Station, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20367 (1985).

6.) H.A. Vanderploeg, D.C.Parzyak, W.H. Wilcox, J.R. Kercher, and S.V. Kaye, Bioaccumulation Factors for Radionuclides in Freshwater Biota, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-5002 (1975).

7.) R. Gunnik and J.B. Niday, Computer Quantitative Analysis by Gamma-Ray Spectrometry, Vol. 1 Description of the General Program, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-51061 (1972).

8.) R.S. Harvey, "Uptake of Radionuclides by Fresh Water Algae and Fish," Health Phys. 10, 243-247 (1964).

9.) Radiation Data Reports, U.S. Environmental Protection Agency, Office of Radiation Programs, RDDRA 4, 15 (2) (1974).

DISCLAIMER

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $; Microfiche $4.50

Page Range	Domestic Price	Page Range	Domestic Price
001-025	$ 7.00	326-350	$ 26.50
026-050	8.50	351-375	28.00
051-075	10.00	376-400	29.50
076-100	11.50	401-426	31.00
101-125	13.00	427-450	32.50
126-150	14.50	451-475	34.00
151-175	16.00	476-500	35.50
176-200	17.50	501-525	37.00
201-225	19.00	526-550	38.50
226-250	20.50	551-575	40.00
251-275	22.00	576-600	41.50
276-300	23.50	601-up[1]	
301-325	25.00		

[1]Add 1.50 for each additional 25 page increment, or portion thereof from 601 pages up.