PNL-2919
UC-11

RADIONUCLIDE CONCENTRATIONS IN RESERVOIRS, STREAMS AND DOMESTIC WATERS NEAR THE ROCKY FLATS INSTALLATION

C W Thomas
D E Robertson

April 1981

Prepared for
Rockwell International
Atomics International Division
under a Related Services Agreement
with the U S Department of Energy
under Contract DE-AC06-76RLO 1830
[formerly USAEC Contract AT(45-1)-1830]

Pacific Northwest Laboratory
Richland, Washington 99352

1/71

RADIONUCLIDE CONCENTRATIONS IN RESERVOIRS, STREAMS AND DOMESTIC WATERS NEAR THE ROCKY FLATS INSTALLATION

SUMMARY

A study of the radionuclide concentrations and distributions in surface waters and sediments of Great Western Reservoir (and the streams feeding it), in Standley Lake, and in domestic tap waters from the cities of Broomfield and Westminster was conducted between April 29 and May 3, 1974 The results of this study show that $^{239-240}$Pu and ^{241}Am concentrations in the waters and sediments of Great Western Reservoir, the streams feeding it, and in Standley Lake were above the fallout background Plutonium-239-240 and ^{241}Am concentrations were below detection limits in Westminster tap water (<0.001 dpm/ℓ), but Broomfield tap water contained measurable but minute quantities of $^{239-240}$Pu (0 0026 ± 0 003) and ^{241}Am (0 006 ± 0 003 dpm/ℓ) These concentrations are orders of magnitude below previously reported values published by other investigators The $^{239-240}$Pu concentration in Broomfield tap water is 1 5 million times below the Concentration Guide for $^{239-240}$Pu in waters applicable to exposure of the general public (3700 dpm/ℓ), and 13,380 times lower than the EPA National Primary Drinking Water Regulation of 33 dpm/ℓ for total long-lived alpha particle activity (exclusive of radon and uranium) Such low levels of transuranic activity should pose no health hazard to area residents

The concentrations of $^{239-240}$Pu in surface sediments (top 5 cm) in Great Western Reservoir ranged from 0 45 to 13 4 dpm/g and averaged 7 8 dpm/g The ^{241}Am ranged from 0 17 to 3 75 dpm/g, and averaged 1 9 dpm/g The depth distribution of both $^{239-240}$Pu and ^{241}Am in age-dated sediment cores (using) ^{137}Cs) from Great Western Reservoir showed two periods of plutonium deposition Highest deposition corresponds to a deposition period of 1968 to 1969 The secondary maximum occurred between 1959 and 1964 Both maxima are thought to be primarily associated with recorded controlled waterborne releases from the plant but the secondary maximum will also have a component from worldwide weapons-testing fallout

Total inventories of $^{239-240}$Pu and ^{241}Am in the sediments of Great Western Reservoir are estimated to be 244 mCi and 73 mCi, respectively Most of this

activity is located in the deep sediment deposits at the eastern end of the reservoir

In Standley Lake, the $^{239-240}Pu$ and ^{241}Am concentrations averaged about 16 times lower than those in Great Western Reservoir Because of its greater area, however, the estimated Standley Lake sediment inventories of transuranics are a factor of only four less than those in Great Western Reservoir, i e , 61 mCi and 18 mCi, respectively, of $^{239-240}Pu$ and ^{241}Am

The ^{137}Cs concentrations in Great Western Reservoir and Standley Lake sediments are typical of the fallout background of ^{137}Cs observed in sediments from numerous waterways in the United States

The naturally occurring ^{226}Ra in surface and domestic waters near the Rocky Flats area represents a much greater relative contribution to the public radiation exposure than do the traces of plutonium The measured activity of ^{226}Ra is 100 to 1000 times that of $^{239-240}Pu$, and its MPC as soluble material is 167 times less than ^{239}Pu Also, ^{226}Ra tends to be more soluble than plutonium and passes through the water treatment plants more efficiently than $^{239-240}Pu$

CONTENTS

4

TABLES

5

TABLES (continued)

6

TABLES (continued)

7

FIGURES

8

INTRODUCTION

The presence of plutonium in soils near the Rocky Flats plant has been well documented [1, 2, 3, 4] However, little data are available which describe the plutonium distribution in the surface waters and sediments in the Rocky Flats vicinity A study was conducted between April 29 to May 3, 1974, to determine the radionuclide input to Great Western Reservoir (GWR) and Standley Lake (SL) during the operation of the Rocky Flats plant It was proposed that this study measure the concentrations of Pu, Am and other radionuclides in waters and sediments of these reservoirs, their inlets, and associated water treatment plants to determine (1) the quantity and origin of radioactivity in the Great Western Reservoir and Standley Lake systems, (2) when the accumulation of radioactivity had occurred, and (3) to what degree the radioactivity had moved through the aqueous environs.

SAMPLING METHODS

Samples of water and sediments were collected in May of 1974 A large volume water sampler was used to collect samples from inlet streams to Great Western Reservoir (see Figure 1, Table 1) Sampling sites were located at the A-3 pond, B-4 pond, and the landfill pond which drain into Walnut Creek, South Walnut Creek and North Walnut Creek, respectively Sampling was also conducted on Walnut Creek at the Indiana Street culvert In addition, Great Western Reservoir and Standley Lake waters and sanitary waters from the water treatment plants for the cities of Broomfield and Westminster were sampled The water sampler used in this study passes water through ten parallel filters (pore size equivalent to 0 5 μm) followed by passage through anion, cation and aluminum oxide sorption beds This sampling technique has several distinct advantages over conventional grab sampling methods 1) it allows for sampling extremely large volumes of water (up to 2000 liters) which greatly enhances the sensitivity for measuring ultratrace quantities of radionuclides, 2) it assures the removal of essentially all chemical forms of the radionuclides which are present in the waterways, and 3) it permits the determination of the particulate (i e , the greater than 0 5 μm fraction), anionic (or negatively charged species), cationic (or positively charged species), and nonionic

9

fractions (or uncharged species of the various radionuclides in the water) This characterization is very important in understanding the behavior, fate and availability of radionuclides in the aquatic environment Anionic forms of radionuclides are much more mobile in aquatic environs compared to cationic forms of the same radionuclides Anionic forms also are more difficult to remove in water treatment plants

Depending upon the turbidity of the water, up to 2000 liters of water were processed Standley Lake, Great Western Reservoir, and especially the creeks which drain into Great Western Reservoir, contained appreciable suspended loads, and plugging of the filters limited the volume of water which could be pumped through the samplers

Sediment samples were collected from Great Western Reservoir, Standley Lake, and from a sedimentation bank consisting of deposits of filter-backwash material from the Broomfield water treatment plant (see Figures 2-4, Table 2). Surface sediments were collected from a boat using a 12-inch by 12-inch Wildro-Eckman (Wildlife Supply Company, Saginaw, Michigan) dredge and using the top 2 inches of sediment for analyses Core samples were obtained using PNL's 6-inch diameter gravity coring device which is capable of sampling sediments to depths of 24 inches Core samples were immediately frozen to prevent mixing of the sediments or migration of the radioactivity, and to thus enhance the integrity of the core The cores were subsequently sectioned into 2-inch thick slices to determine depth profiles for the various radionuclides

ANALYTICAL METHODS

Samples of filters, ion exchange resins, sediments, and water were packaged in a standard geometry configuration and the gamma-ray emitting radionuclides were determined by measuring in a Ge(Li)-NaI(Tl) coincidence-anticoincidence gamma-ray spectrometer This high-sensitivity gamma-ray spectrometer stores coincident and single events in separate halves of the memory The NaI(Tl) well crystal in which the Ge(Li) detector is inserted will accept environmental sample sizes up to 1 1 liter volume

The concentration of the separated plutonium radionuclides was measured by alpha energy analysis Environmental samples were spiked with ^{242}Pu tracer

10

and dried The samples were then leached with a HNO_3-HCl solution The residue was dried and fused with Na_2CO_3 The fused salts were dissolved in acid and combined with the acid leachate. The combined solution was converted to 8M HNO_3 and the plutonium adsorbed on a Dowex 1, 50-100 mesh NO_3^- form anion exchange column The plutonium was eluted by reducing to Pu^{+3} with an HCl-HI acid mixture Nitric acid was added to the eluate and evaporated to dryness The residue was dissolved in nitric acid, the plutonium oxidized in Pu^{+4} with NO_2^- and evaporated to dryness The residue was dissolved in hydrochloric acid and passed through a Dowex 1, 50-100 mesh, Cl^- form anion resin column Plutonium was eluted by reducing to Pu^{+3} with a HCl-HI mixture The eluate was evaporated to dryness, dissolved in sulfuric acid and electroplated The radiochemical yield was determined by the recovery of ^{242}Pu tracer

The concentration of ^{241}Am in sediments and water samples was determined by using the described anticoincidence shielded Ge(Li) diode This instrument lowers the background and Compton interference by an order of magnitude as compared to conventional Ge(Li) diodes of the same size Much lower detection levels could have been attained by chemical separation of the ^{241}Am followed by alpha energy analysis, but the cost of such analyses was prohibitive

ANALYTICAL RESULTS

The radionuclide measurements from water samples associated with the drainage systems of Great Western Reservoir are shown in Tables 5 through 13 and consist of samples taken from A-3 pond, B-4 pond, a landfill pond, the inlet to Great Western Reservoir (Walnut Creek), Great Western Reservoir (near dam site), and sanitary water from the Broomfield water treatment plant The radionuclide measurements in surface sediments and core samples collected in Great Western Reservoir are shown in Tables 14 through 32 and consist of samples taken at Great Western Reservoir and at the Broomfield water treatment plant filter-backwash pond The radionuclide measurements from surface sediments and core samples from Standley Lake are shown in Tables 33 through 36 Water samples associated with Standley Lake are shown in Tables 37 and 38 and consist of samples taken at Standley Lake near the dam site and Westminster water treatment plant Summaries of radionuclide concentrations in surface waters normalized to ^{137}Cs concentrations are shown in Table 3, and comparisons of our $^{239-240}$Pu and ^{241}Am with previously reported data are shown in Table 4

DISCUSSION

Surface Waters

Radionuclide concentrations in surface waters which drain through the Rocky Flats area were extremely low, and frequently near detection limits This sampling was conducted during a period in which fallout from nuclear weapons testing reached its lowest point since the early 1960's Nevertheless, ultratrace quantities of a number of fission products and transuranic radionuclides were detectable in surface waters and in Broomfield city tap water (see Tables 5-13 and Tables 37 and 39) However, there is no evidence that these fission products originated from the Rocky Flats Plant, since their relative concentrations are indistinguishable from fallout.

The drinking waters of the cities of Broomfield (derives water from Great Western Reservoir) and Westminster (derives water from Standley Lake) were analyzed to determine if Pu and Am were present No $^{239-240}$Pu (<0.0003 dpm/ℓ) or ^{241}Am (<0 1 dpm/ℓ) could be detected in Westminster tap water Ultra-trace amounts of $^{239-240}$Pu were detectable in Broomfield tap water, 0 0022 dpm/ℓ being in a soluble species and 0.00029 dpm/ℓ being in a particulate form Americium-241 concentrations were detectable only in the particulate phase, at a concentration of 0 007 dpm/ℓ. The $^{239-240}$Pu concentrations in Broomfield tap water are 500 times lower than that reported in Radiation Data Reports[1] for the 1971 yearly average, and are 15 times lower than measurements made in 1969-70 by Poet and Martell[3] (see Table 4) Also in Radiation Data Reports,[1] a $^{239-240}$Pu concentration of 0 89 dpm/ℓ was reported as a yearly average for Westminster tap water. The value reported in RDR is about 3000 times higher than the "less than" concentrations measured in this study The sampling and analyses methods were not described in the studies reported in RDR[1] and Poet and Martell,[3] so no comparison can be made with the methods described here However, 1600 liters and 2000 liters, respectively, of Broomfield and Westminster tap waters were sampled in this study The particulate and soluble forms of $^{239-240}Pu$ (and other radionuclides) were removed and concentrated on filters, resins and activated aluminum oxide adsorbents during the sampling process, so handling, storage and contamination problems were greatly minimized. It is felt that the extreme sensitivity and care afforded by this large-volume sampling technique have provided the most accurate ultratrace measurements of $^{239-240}Pu$ ever made in these tap waters.

The $^{239-240}Pu$ concentrations which were measured in Broomfield tap water (0.0025 dpm/ℓ total $^{239-240}Pu$) and Westminster tap water (<0.0003 dpm/ℓ total $^{239-240}Pu$) were 1.5 x 10^6 and 1.2 x 10^7 times, respectively, below the maximum permissible concentration in waters applicable to exposure of the general public, which is 3667 dpm/ℓ.[3] These concentrations are also 13,300 and 110,000 times lower, respectively, then the EPA National Interim Primary Drinking Water Regulations for total long-lived alpha activity (exclusive of radon and uranium) which is 33 dpm/ℓ.[10] Whereas the RDR[1] report showed that Standley Lake water and Westminster tap water contained about the same $^{239-240}Pu$ concentrations, the data here show that at least a 10-fold reduction of the $^{239-240}Pu$ levels occurs during the water treatment process. This is accomplished primarily by removal of the particulate forms of $^{239-240}Pu$.

The sampling method used in this study partitions the radionuclides into particulate, cationic, anionic and nonionic chemical forms. Such information on the chemical forms is useful in assessing the environmental behavior and fate of radionuclides in aquatic environments. Plutonium-239-240 in Standley Lake appears to be predominantly associated with the particulate matter. The majority of the $^{239-240}Pu$ in Broomfield tap water is in a soluble anionic form. The ^{7}Be, ^{95}Zr-^{95}Nb, ^{141}Ce, ^{144}Ce and ^{241}Am were usually associated with the suspended particulates, whereas the ^{40}K, $^{103-106}Ru$, ^{124}Sb and ^{226}Ra were predominantly present as soluble species. The soluble $^{103-106}Ru$ shows a unique behavior, being present in anionic, cationic and nonionic forms. The chemistry of ruthenium is complex, and numerous chemical forms are known to simultaneously exist in natural waters. During the water treatment process at the Broomfield and Westminster water works the cationic ^{106}Ru is efficiently removed, but the anionic ^{106}Ru is only slightly reduced in concentration. It is interesting to note that about 60% of the filterable Pu in Broomfield tap water was collected by the anion resin.

In some of the surface waters, a small fraction (5-30%) of the ^{40}K and/or ^{137}Cs was collected by either the anion resin or Al_2O_3, and in the Broomfield tap water as much as 69% of the ^{137}Cs was collected on the Al_2O_3 The most plausible explanation for this anomaly could be the presence of negatively charged colloids which contain adsorbed radioactivity, and which may have a high affinity for the anion resin or activated aluminum oxide

Sediments

Great Western Reservoir

Great Western Reservoir sampling locations are shown in Figure 2 The perimeter of the reservoir, except for the deep eastern end, appears to be rather well scoured of fine-grain sediments The near-shoreline stations B-5, D-1, D-2, D-5 and E-4 were characterized by gravel or partial rock bottoms and no sediment cores could be obtained at these locations The bottom of the western half of the reservoir, and also near the center, contained a layer of flocculent sediments several inches thick which overlay a hard, compact clay layer, believed to be the original bottom of the reservoir The compact clay bottoms of these cores had undetectable amounts of ^{137}Cs, which suggests penetration of the coring device into the original clay bottom where no fallout ^{137}Cs had reached (see Tables 26 and 28) In the deep eastern end of the reservoir, at Stations A-2, A-3 and B-3, up to 16-22 inches of fine-textured, soft sediments overlay the compact clay bottom layer At these locations cores of 20 to 24 inches in length were collected, the bottom several inches containing the original hard clay bottom of the reservoir. The low ^{137}Cs concentrations in the compact clay bottom of these cores indicate that penetration through the sediments deposited since the dam was constructed in 1955 was achieved. Based on these observations and using ^{137}Cs to age date the deep cores, sedimentation rates for various locations in the reservoir could be estimated and are shown in Figure 9 Sedimentation rates in the eastern end of the reservoir appear to range from about 0 82 to 1 45 incher per year, and in the center of the reservoir range from about 0 1 to 0 46 inches per year Sedimentation rates around the perimeter of the reservoir appear to be less than 0 1 inches per year

The distribution of ^{40}K, ^{137}Cs, ^{226}Ra and ^{241}Am in surface sediments of the reservoir are shown in Figures 5 to 8 The concentrations of ^{137}Cs, ^{226}Ra and ^{241}Am are two- to threefold higher in the sediments located in the center of the reservoir compared to the sediments accumulating around the perimeter of the reservoir This may be due to erosion of the edges of the reservoir, resulting in a dilution of the contaminated sediments by the input of relatively uncontaminated clay soil The ^{137}Cs concentrations in the reservoir sediments are typical of the fallout background levels observed at other locations in the United States [5, 6, 7, 8]

It should be pointed out that the radionuclide concentrations in the surface grab samples do not exactly correspond with the concentrations measured in the top 2 inches of the gravity cores, especially at stations along Transect A We believe that this is due to small differences in distance (tens of feet) between the actual locations where the grabs and core samples were taken The reservoir bank at the eastern end is steep So that deep gravity cores along the side of this bank could be obtained, it was necessary to back off toward the center of the reservoir several tens of feet It was subsequently found from the sediment data that radionuclide concentrations decrease in the near-shore sediments compared to those in the middle of the reservoir, and it is believed that this is the reason for the observed differences between surface grabs and the tops of the gravity cores

A comparison of the $^{239-240}Pu$ and ^{241}Am data in this report with earlier studies reported in Radiation Data Reports[1] and by Poet and Martell[3] is shown in Table 4 The average $^{239-240}Pu$ concentrations in surface sediments measured here were 3 2 and 25 times higher, respectively, than that reported in RDR[1] and by Poet and Martell,[3] while the average ^{241}Am concentrations are 30 times higher than that reported by Poet and Martell [3] Since the distribution of radioactivity in the reservoir shows low levels near the shoreline, the samples analyzed in the RDR report and by Poet and Martell may have been obtained near the shore Such samples do not give a representative picture of the areal and depth distribution of radionuclides in the reservoir

In Figure 10 the depth distribution of the ^{137}Cs in several cores is plotted It has been demonstrated by other investigators [5, 6, 7, 8] that

15

^{137}Cs can be used to age date certain types of sediment cores, and that the subsurface maxima are due to abnormally high levels of fallout ^{137}Cs which had been deposited in 1963. Cesium-137 becomes strongly attached to sediment particles and becomes a tracer of sediment deposition. Post-depositional diffusion or chemical exchange of the attached ^{137}Cs has been shown to be practically negligible. Thus, ^{137}Cs can be used to age data sediment cores if the sedimentation rate is fairly constant and of the appropriate magnitude to be compatible with the 30-year half-life of ^{137}Cs. These conditions appear to be optimum for Great Western Reservoir, and the ^{137}Cs depth profile in Figure 10 can be age dated with the ^{137}Cs maxima corresponding to sediments laid down in 1963.

The distribution of $^{239-240}Pu$ in the A-2 core is shown in Figure 11, with the age vs. depth scale on the right margin. Two subsurface maxima in the $^{239-240}Pu$ depth distribution may be identified. The larger $^{239-240}Pu$ maxima occurs at a depth of 6 inches, and corresponds to sediments deposited between 1968 and 1969. The smaller maxima occurs at a depth of 16 inches, and corresponds to sediments deposited around 1959.

A similar dating procedure may be done for the ^{241}Am distribution observed in the A-2, A-3, and B-3 cores (cf. Tables 20, 21, 22, 23, 25, and 26) because of the relative constancy of the plutonium to americium ratio (Pu/Am = 3.3 ± .79 in the A-2 core). This analysis likewise indicates a primary maximum in the 1968 to 1969 period but shows the secondary peaks to range from 1959 to 1964.

These transuranic sediment distributions in Great Western Reservoir are thought to be primarily associated with controlled, recorded waterborne releases from the plant but the secondary (early 1960's) maximum will also have a component from worldwide weapons testing.(9)

The amount of $^{239-240}Pu$ incorporated in Great Western Reservoir sediments in excess of that derived from fallout can be estimated by dividing the ratio of $^{239-240}Pu/^{137}Cs$ in the sediments by the $^{239-240}Pu/^{137}Cs$ ratio in fallout. The $^{239-240}Pu/^{137}Cs$ ratio in fallout has been reasonably constant at about 0.01 since the early 1960's. The $^{239-240}Pu/^{137}Cs$ ratios in Sacramento, California soils (top cm) and in Columbia River sediment cores upstream from the Hanford project were 0.013 and 0 012, respectively, and are thus not much different than the fallout ratio The average $^{239-240}Pu/^{137}Cs$ ratio in surface sediments of Great Western Reservoir was 2 75. Thus, the apparent plutonium contribution to the surface sediments from Rocky Flats averaged about 275 times that contributed from fallout The apparent Rocky Flats plutonium contribution relative to that derived from fallout in the subsurface sediments in the A-2 core ranged from about 260 at the surface to 80 at a depth of 12 inches

The inventory of $^{239-240}Pu$ in Great Western Reservoir sediments can be estimated as follows the reservoir can be divided into three zones of plutonium activity and sediment thickness (see Figures 12 and 13) Zone A is the deepest layer of sediments (40 to 50 cm) containing the highest plutonium activity, and is located at the eastern end of the reservoir Zone B is a region approximately 3 times larger in area than Zone A and of intermediate sediment thickness (estimated to average about 20 cm deep) and plutonium activity, and extends to the west from Zone A The average $^{239-240}Pu$ activity in Zone B was estimated to be about 5 dpm/g, and was obtained by using a slightly lower plutonium concentration than the average surface value, which was 6 dpm/g This reasoning was used since the average $^{239-240}Pu$ concentration in Core A-2 (0-50 cm) was 75% lower than the surface plutonium concentration in the core Only surface plutonium concentrations were measured in Zone B Zone C is the remaining area of the reservoir which is characterized by a thin deposit of sediments (estimated to average about 5 cm deep) of relatively low activity The average plutonium activity in this area is the most difficult to estimate, since only one $^{239-240}Pu$ measurement was made Since the ^{137}Cs and ^{241}Am concentrations in the sediments from the shallow areas represented by Zone C are 1/3 to 1/2 of the concentrations in the center and east end of the reservoir, a plutonium concentration of about 1/3 to 1/2 of the maximum surface concentrations in the east end was estimated and 3 dpm/g was used A tabulation using these considerations may then be made

17

	Surface Area (m^2)	Est Avg Sediment Depth (m)	Sediment Vol (cm^3)	Sediment Wt (g)*	$^{239-240}Pu$ Avg Activity (dpm/g)
Zone A	45,000	0 5	$2\ 3 \times 10^{10}$	$3\ 2 \times 10^{10}$	9
Zone B	120,000	0.2	2.4×10^{10}	$3\ 4 \times 10^{10}$	5
Zone C	400,000	0 05	2.0×10^{10}	$2\ 8 \times 10^{10}$	3

*Assuming a bulk density of 1.4 g/cm^3 for the sediments This is a typical value for fine grained lake and river sediments

Upon multiplying the sediment masses (g) by the average $^{239-240}Pu$ concentrations in each zone, these three sediment zones contain the following estimated inventories of $^{239-240}Pu$

	dpm	mCi
Zone A	29×10^{10}	131
Zone B	17×10^{10}	77
Zone C	8×10^{10}	36
Total	54×10^{10}	244

Thus, a total of approximately 244 mCi (or 3 9 g) of $^{239-240}Pu$ is present in the reservoir sediments Over 50% of this inventory is located in the deep sediment deposits at the east end of the reservoir which represent only about 8% of the total surface area of the reservoir

The average $^{241}Am/^{239-240}Pu$ ratio in surface and subsurface sediments is about 0 30 Thus, an ^{241}Am inventory of about (244 mCi)(0 30) = 73 mCi is also present in the reservoir

Two 18-inch sediment cores were collected from a sedimentation bank consisting of deposits of filter-backwash material (alum floc) from the Broomfield water treatment plant (see Table 2 and Figure 4) The radionuclide analyses of these cores (see Tables 2, 31, 32, and Figure 4) showed ^{137}Cs and ^{241}Am concentrations which were typical of the surface sediments in Great Western Reservoir The $^{239-240}Pu$ concentration in these cores, based on extrapolations from the $^{241}Am/^{239-240}Pu$ ratio in the reservoir sediments, was estimated to average 4 5 dpm/g This sedimentary material appeared to consist primarily of processed alum floc Since the radionuclide concentrations in this material were similar to those observed in surface sediments of the reservoir, it would indicate that scavenging by the alum floc of soluble forms or very small suspended particles (containing relatively high concentrations of adsorbed radionuclides) was occurring during the water treatment process

Standley Lake

Although Standley Lake is about four times larger than Great Western Reservoir, the sedimentation characteristics of the two water bodies appear to be quite similar The area of high sedimentation in Standley Lake is located in the deep water at the eastern end of the lake adjacent to the dam At this location (SL-5G) a 17-inch long gravity core was obtained which showed a ^{137}Cs depth distribution quite similar to those observed at stations A-2, A-3 and B-3 at Great Western Reservoir A sedimentation rate of about 1 0 inches/year was estimated for this area of relatively fast sediment deposition. The western 2/3 of the lake has a sediment bottom characterized by a 1- to 6-inch layer of flocculent sediments which overlay a layer of hard, compact clay which appears to be the original lake bottom

The average $^{239-240}Pu$ concentation in Standley Lake surface sediments was 0 49 dpm/g, which is about 16 times lower than in Great Western Reservoir (see Table 3) The ^{241}Am concentrations were near the detection limit of the direct counting method used, but an average concentration of 0 28 ± 14 dpm/g was measured in four samples. Based on the relative sizes and radionuclide contents of Standley Lake and Great Western Reservoir, it is estimated that the $^{239-240}Pu$ and ^{241}Am inventories in Standley Lake are about 1/4 of those in Great Western Reservoir, or about 61 mCi of $^{239-240}Pu$ and 18 mCi of ^{241}Am

19

REFERENCES

1 Anonymous, Radiation Data Reports 15, 281-296, May, 1974

2. Krey, P W and E. P. Hardy, HASL-235, U S Atomic Energy Commission Health and Safety Laboratory, New York, August 1, 1970

3 Poet, S E and E A Martell, Health Phys 23, 537-548, October, 1972

4 Krey, P. W , Health Phys. 30, 209-214, February, 1976

5 Pennington, W , R S Cambray and E M Fisher, Nature 242, 324-326, March 30, 1973

6 Ritchie, J. C , J R. McHenry and A. C Gill, Limnol Oceanog 18, 254-263, March 1973

7 McHenry, J R , Water Res Bull 10, 329-337, April, 1974

8 Robbins, J A and D N Edgington, Geochem Cosmochem Acta, 39, 285, 1975

9 Koide, M , E O Goldberg, M. M Herron and C C. Langway, Jr , Nature 269, 137-139, September, 1977

20

Table 1

LARGE VOLUME WATER SAMPLES

Location	Date	Volume Sampled (liters)	No. of Samples
Westminster City Water Supply	4-29-74	2006	1
Standley Lake	4-29-74	710	1
Broomfield City Water Supply	4-30-74	1665; 1514	2
Great Western Reservoir	4-30-74	297, 212	2
Walnut Creek & Inlet to GWR	4-30-74	70.8, 58.3	2
B-4 Pond	4-30-74	153	1
A-3 Pond	5-01-74	97.4	1
North Walnut Creek Below Rocky Flats Landfill	5-01-74	136	1

21

Table 2

SEDIMENT CORES

Great Western Reservoir and Standley Lake

Station	Core Length (inches)
A-1	8
A-2	24
A-3	20
A-4	6
B-3	20
C-2	6
C-3	6
C-4	10
E-4	6
*HC-1	18
*HC-2	18
**SL-5	20

*Broomfield Water Treatment Plant Effluent Basin

**Standley Lake

Table 3

COMPARISON OF $^{239-240}Pu$ AND ^{241}Am CONCENTRATIONS IN

SURFACE WATERS AND LAKE SEDIMENTS

Water	$^{239-240}Pu$ (dpm/ℓ) Battelle*	Radiation Data Reports**	Poet & Martell***	^{241}Am (dpm/ℓ) Battelle*	Radiation Data Reports**	Poet *** & Marte
A-3 Pond	--	1 5	1 8	0.51 (partic <4 2 (sol)	--	0 42
B-4 Pond	--	4 2	--	0 42 (partic) <2.22 (sol)	2.49	--
Walnut Creek	--	5.0	--	1.5 (partic.) <8.2 (sol)	1.33	--
Great Western Reservoir	--	0 44	--	0.13 (partic.) <0.67 (sol)	0.64	--
Broomfield tapwater	0 00029 (partic) 0 00220 (sol) †	1 2	0 037	0 007 (partic) <0.16 (sol)	--	--
Standley Lake	0 00170 (partic) < 0 00110 (sol.) †	0 87	--	<0 04 (partic.) <0 60 (sol.)	0.16	--
Westminster tapwater	< 0 0002 (partic) < 0 0001 (sol) †	0.89	--	<0.004 (partic) <0 12 (sol)	--	--
Sediments	$^{239-240}$ Pu (dpm/gm)			^{241}Am (dpm/gm)		
Great Western Reservoir	7.75 (avg of 8 surface sed)	2 40 (avg of 2)	0 3 (avg. of 2)	1.91 (avg of 10 surface sed)	--	0 064 (avg o 2)
Standley Lake	0 49 (avg of 3 surface sed)	0 64 (avg of 2)	--	0 28 (avg of 4 surface sed)	--	--

† The $^{239-240}Pu$ concentrations in Broomfield and Westminster tap waters is compared to a maximum permissible concentration of ^{239}Pu in water applicable to exposure of the general public of 3667 dpm/ℓ.
* April, 1973
** 1971 yearly avg
*** 8/69 to 2/70

23

Table 4

RADIONUCLIDE CONCENTRATIONS IN SOUTH WALNUT CREEK WATER AT RETENTION POND B-4

dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	12.8± 42	3.53±.68	<1.88	.263±.135
^{40}K	<1 56	<5.32	<3.81	<1.28
^{54}Mn	.204±.023	.160± 054	<.192	<.036
^{60}Co	.006±.003	.012±.007	<.007	<.003
^{90}Sr	*	*	*	*
^{95}Zr	7.54±.139	2.35±.245	.736±.238	.412±.056
^{95}Nb	14.1±.12	4.29±.232	2.27±.182	.484±.045
^{103}Ru	.768±.040	.512±.092	.529±.129	.198±.026
^{106}Ru	8.41±.111	4.87±.169	13.4±.252	2.24±.080
^{125}Sb	1.18±.103	< 329	<.614	6.66±.734
^{137}Cs	.759±.039	.402± 093	<.244	<.037
^{141}Ce	.333±.053	<.155	<.267	<.035
^{144}Ce	13.7±.270	2.85±.392	<1.18	<.174
^{226}Ra	1.14±.472	13.2±1.37	<3.89	2.55±.352
^{228}Ac	.464±.114	1.71±.427	<1.22	.362±.115
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	419±.234	<.405	< 690	<.106

* Not measured

24

Table 5

RADIONUCLIDE CONCENTRATIONS IN WALNUT CREEK WATER AT RETENTION POND A-3

dpm/liter

Isotope	Filter	Cation	Anion
^{7}Be	6.38±1.07	<1.98	<1.90
^{40}K	2.24±.88	15.9±2.33	14.2±2.33
^{54}Mn	<.019	<.234	<.232
^{60}Co	.007±.004	.014±.011	<.012
^{90}Sr	*	*	*
^{95}Zr	.202±.031	<.393	<.396
^{95}Nb	.413±.028	<.231	<.230
^{103}Ru	.051±.010	<.237	<.231
^{106}Ru	.295±.066	<.136	.705±.172
^{125}Sb	<.047	<.643	<.640
^{137}Cs	.205±.023	<.238	<.239
^{141}Ce	<.022	<.308	<.300
^{144}Ce	.674±.060	<1.25	<1.21
^{226}Ra	1.08±.181	4.68±2.27	<1
^{228}Ac	.284±.084	<1.23	<1.37
^{238}Pu	*	*	*
^{239}Pu	*	<.0033	*
^{241}Am	.511±.068	<1 58	<1 55

*Not measured

25

Table 6

RADIONUCLIDE CONCENTRATIONS IN NORTH WALNUT CREEK WATER AT LANDFILL POND

dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	.870±.098	<2.72	<2.97	<0 5
^{40}K	<.913	<6.86	<6.52	<1 0
^{54}Mn	.032±.009	<.323	< 290	<0 05
^{60}Co	< 003	<.008	<0 007	<.002
^{90}Sr	*	*	*	*
^{95}Zr	.322±.026	<.591	.662± 289	<0 2
^{95}Nb	.590±.020	<.352	.921±.205	.884±.015
^{103}Ru	.036±.010	<.304	<.345	<0 1
^{106}Ru	.917±.051	1.11±.128	2.52±.161	.928±.051
^{125}Sb	.070±.026	<.842	<.874	<0 3
^{137}Cs	.223±.014	<.354	<.364	.045±.008
^{141}Ce	<.027	<.405	<.424	<0 2
^{144}Ce	.794± 056	<1.68	<1.79	<0 5
^{226}Ra	<.161	<6.07	<5.93	<.027
^{228}Ac	.160± 060	<1.77	<1.28	.010±.007
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	<.220	<2.80	<2.83	*

*Not measured

Table 7
RADIONUCLIDE CONCENTRATIONS IN WALNUT CREEK
AT THE POINT OF ENTRANCE TO THE GREAT WESTERN RESERVOIR

dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	3.50±.644	<4.06	<5.30	<2
^{40}K	11.1±4.5	<25.8	<22.6	<7
^{54}Mn	<.104	<.508	<1.06	<0 3
^{60}Co	< 006	039± 019	<.018	.036± 010
^{90}Sr	*	*	*	*
^{95}Zr	1.01±.172	<.887	<2.02	<0 5
^{95}Nb	2.24±.154	<.617	<1.05	<0 3
^{103}Ru	.204±.055	<.434	<1.17	<0 3
^{106}Ru	.450± 115	.472± 224	.699±.248	<.112
^{125}Sb	<.298	<1.11	<3.09	<0 5
^{137}Cs	.804±.098	<.563	<1.22	<.024
^{141}Ce	.159± 065	<.587	<1.45	<0 3
^{144}Ce	3.76±.374	<2.26	<6.06	<1
^{226}Ra	11.9±1.12	30.6±5.16	21.1	<10
^{228}Ac	3.96±.486	<3.53	<6 34	.049±.025
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	2.17±.261	<1.84	<9.75	*

*Not measured

27

Table 8

RADIONUCLIDE CONCENTRATIONS IN WALNUT CREEK WATER AT INDIANA STREET

dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	2.10±.27	<1.89	<1.81	<0 5
^{40}K	4.4 ±1.75	8.26±2.80	<5.49	<2
^{54}Mn	<.054	<.183	<.195	<0 05
^{60}Co	<.005	<0 02	<0 02	<.01
^{90}Sr	*	*	*	*
^{95}Zr	.608±.064	<.381	<.427	<0 1
^{95}Nb	1.22±.072	<.189	<.196	<.22
^{103}Ru	.138±.024	<.193	<.182	<0 5
^{106}Ru	.743±.017	.349±.210	1.22±.210	<0 3
^{125}Sb	.165±.051	.864±.257	.480±.259	<0 3
^{137}Cs	.492±.049	.324±.113	.396±.114	<0 1
^{141}Ce	.090±.027	<.317	<.322	<0 1
^{144}Ce	2 21±.166	1.05±.11	<1.17	<0 3
^{226}Ra	4.82±.45	6.89±3.65	8.70±1.90	<2
^{228}Ac	1.20±.20	1.67±.56	<1.27	<0 3
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	848±.111	<2.49	<2.54	*

*Not measured

Table 9

RADIONUCLIDE CONCENTRATIONS IN GREAT WESTERN RESERVOIR WATER NEAR DAM

Water Sample #1

dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	1.94±.110	<.687	<.262	<.079
^{40}K	<.694	9 11±1.15	<1.39	.959±.243
^{54}Mn	.022± 007	<.062	<.030	<.010
^{60}Co	<0 005	<0 02	<0.02	<0 007
^{90}Sr	*	*	*	*
^{95}Zr	.540±.031	<.026	<.093	<.025
^{95}Nb	1.24±.041	.280±.005	.139±.030	.056±.009
^{103}Ru	.082±.009	<.082	.065±.019	<.009
^{106}Ru	945 ±.025	.358±.130	.626±.142	.088±.015
^{125}Sb	.066±.018	<.183	<.085	.048± 013
^{137}Cs	.19 ± 003	.130±.055	<.042	.010±.003
^{141}Ce	<0 1	<.065	<.034	<.010
^{144}Ce	<0 1	<.260	<.176	.046±.021
^{226}Ra	.531± 087	2.55±.603	1.52±.261	.637±.089
^{228}Ac	.114± 040	< 363	<.262	<.056
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	121± 029	<.360	<.171	<.051

*Not measured

Table 10

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR WATER NEAR DAM

Water Sample #2

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	2.07±.107	<.352	<.635	<.263
^{40}K	<.761	10.5±1.34	<1.95	<2.59
^{54}Mn	.023±.006	<.047	<.064	<.026
^{60}Co	<.002	.006± 005	< 005	< 002
^{90}Sr	*	*	*	*
^{95}Zr	.520±.033	<.122	<.125	<.056
^{95}Nb	1.18±.031	.297± 045	<.074	.078±.015
^{103}Ru	.079±.008	<.042	<.064	<.025
^{106}Ru	.919±.038	.535± 068	.680±.077	.339±.081
^{125}Sb	.063±.017	<.113	<.182	.104±.037
^{137}Cs	.159±.013	.064± 014	<.080	.082±.011
^{141}Ce	.040±.006	< 049	<.114	<.046
^{144}Ce	1.95±.055	<.204	<.376	<.162
^{226}Ra	.533±.086	4.09± 451	<.132	<.54
^{228}Ac	.131±.040	.472± 064	<.42	.019±.012
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	.127±.032	<.280	<.509	<.398

*Not measured

30

Table 11

RADIONUCLIDE CONCENTRATION IN WATER FROM BROOMFIELD WATER TREATMENT PLANT MORNING SHIFT

dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	< 0088	<.061	<.068	< 02
^{40}K	< 092	.268±.016	<.410	< 1
^{54}Mn	< 001	<.010	<.0087	< 003
^{60}Co	< 0002	<.0006	<.0006	< 0002
^{90}Sr	*	*	*	*
^{95}Zr	.0043±.0016	<.015	<.015	<.015
^{95}Nb	.0117±.0012	<.010	<.015	<.015
^{103}Ru	<.0011	<.009	.042±.007	
^{106}Ru	.018± 003	.057±.011	.352±.013	.018± 003
^{125}Sb	<.0024	<.020	<.026	
^{137}Cs	.0025± 0007	.032±.002	<.0091	<.003
^{141}Ce	<.0010	<.011	<.012	< 004
^{144}Ce	.022± 003	<.043	<.043	< 01
^{226}Ra	.042±.004	.873±.002	1.32±.123	< 03
^{228}Ac	.0074± 0018	.171±.044	<.075	<.0006
^{238}Pu	*	00021*	.00014*	<.00018
^{239}Pu	*	.00095 *	.0017±.0002	<.00018
^{241}Am	<.0060	<.033	<.035	*

* Error bar limits are between 20-50%.

* Not measured

31

Table 12

RADIONUCLIDE CONCENTRATION IN WATER FROM BROOMFIELD WATER TREATMENT PLANT AFTERNOON SHIFT

dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	<.015	<.131	<.201	< 05
^{40}K	1.53±.078	.706±.133	<.441	<0 2
^{54}Mn	<.0014	<.013	<.024	< 005
^{60}Co	< 0002	<.0007	< 0007	< 0002
^{90}Sr	*	*	*	*
^{95}Zr	.0077± 0022	<.022	<.042	< 01
^{95}Nb	.019±.0021	.0158±.0059	<.271	.195±.070
^{103}Ru	.0028±.0009	<.013	<.241	< 01
^{106}Ru	.024±.004	.061±.012	.311±.129	.019±.003
^{125}Sb	<.0043	<.035	<.066	< 02
^{137}Cs	.0023±.0011	.034±.0076	<.028	.082±.011
^{141}Ce	.0023±.0012	<.019	<.031	< 01
^{144}Ce	.029±.0057	<.082	<.128	< 05
^{226}Ra	.160±.019	682±.129	.533±.231	<0 2
^{228}Ac	.0143± 007	248±.049	<.142	<0 1
^{238}Pu	<.00029	00020± 00016	.00019± 00016	<.00016
^{239}Pu	.00028 ± 00014	00099±.00015	.0013±.00020	<.00016
^{241}Am	.006±.003	<.112	<.203	*

*Not measured

32

Table 13

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Surface**Sediments - Transect A

dpm/gram

Isotope	A-1	A-2	A-3	A-4	A-5
^{7}Be	.258± 101	345± 072	<.19	.272±.072	<.15
^{40}K	28.8±1.04	36.4±.494	26.7±1.06	37.4±.516	22.9±.927
^{54}Mn	<.026	<.016	<.016	.025±.008	<.019
^{60}Co	<.01	< 01	< 01	< 01	< 01
^{90}Sr	*	*	*	*	*
^{95}Zr	074±.028	.089±.018	.081±.030	.085±.018	<.042
^{95}Nb	.102±.018	.113±.011	.161±.023	.118±.111	.069±.016
^{103}Ru	<.02	<.014	<.023	.021±.007	<.018
^{106}Ru	237±.098	.320±.073	.281±.198	.191±.074	<.340
^{125}Sb	<.061	.077±.022	.048±.033	.123±.021	<.047
^{137}Cs	636±.039	1.14±.014	1.20±.053	.905±.018	.620± 036
^{141}Ce	<.029	<.027	<.019	.027±.013	<.033
^{144}Ce	.268±.086	.224±.051	.393±.085	.209±.050	.094±.074
^{226}Ra	4.68±.327	3 80±.166	3.63±.309	3.07±.164	3.79±.276
^{228}Ac	1.57±.166	1.85±.072	1.65±.167	1.93±.073	1.11±.137
^{238}Pu	*	*	*	*	*
^{239}Pu	*	*	*	*	*
^{241}Am	.286±.110	1.28±.125	1.62±.134	1.24±.122	.532±.098

**Depth of surface sample is 5 cm
*Not measured

33

Table 14

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR NEAR ROCKY FLATS

Surface**Sediments - Transect B
dpm/gram

Isotope	B-1	B-2	B-3	B-4
^{7}Be	.450± 144	.288± 150	.374±.075	.723±.140
^{40}K	29.9±1.20	31 8±1.02	30.4±.695	33.0±.602
^{54}Mn	<.033	<.030	<.017	.036± 015
^{60}Co	< 0.01	<0 01	<0.01	<0 01
^{90}Sr	*	*	*	*
^{95}Zr	.097±.028	.165±.036	.100±.018	.163±.028
^{95}Nb	.156±.025	.150± 023	.204±.015	.209±.020
^{103}Ru	<.019	<.030	<.014	.017±.014
^{106}Ru	.332±.261	<.319	.325±.138	.404±.136
^{125}Sb	.221±.040	.114± 043	.151±.022	.108±.041
^{137}Cs	1.79±.072	1.24± 042	1.67±.038	1 92±.037
^{141}Ce	.028±.020	.079± 027	.044±.011	.021±.021
^{144}Ce	.353±.097	.234± 102	.498±.056	.494±.095
^{226}Ra	5.10±.381	3.59± 335	4.92±.204	5 78±.299
^{228}Ac	1.64±.205	1.42±.146	1.75±.107	2.55±.134
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	1.90±.153	1.74±.246	1.64±.084	1.51±.143

** Depth of surface sample is 5 cm.

* Not measured.

Table 15

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Surface**Sediments - Transect C
dpm/gram

Isotope	C-1	C-2	C-3	C-4	C-5
^{7}Be	363±.145	.665± 123	1.01±.130	.990±.136	<.17
^{40}K	34.5±.618	41.6±1.00	42.9±1.02	43.8±1.03	41.3±1.01
^{54}Mn	.043±.016	<.028	.038±.013	<.027	<.026
^{60}Co	<0.01	<0.01	<0.01	<0.01	<0.01
^{90}Sr	*	*	*	*	*
^{95}Zr	099±.028	.195±.025	.330±.032	.279±.030	<.03
^{95}Nb	296±.019	.270±.023	.579±.030	.441±.028	.080±.014
^{103}Ru	016±.015	<.022	.056±.013	.030±.012	<.018
^{106}Ru	.615±.142	.836±.228	.675±.235	.611±.229	<.41
^{125}Sb	133±.044	.294± 038	.313±.040	.287±.037	<.05
^{137}Cs	2.59±.043	2.96±.063	3.19±.066	2 94±.064	.491±.028
^{141}Ce	.042±.022	.048±.023	.040±.022	<.046	.127±.021
^{144}Ce	508±.101	.993±.106	1.39± 110	1.21±.111	.195± 084
^{226}Ra	6.31±.317	9.37± 390	8.57±.393	9.91± 398	9.85±.378
^{228}Ac	2.83± 144	2.91± 180	2.76±.181	2.29± 192	2.12±.154
^{238}Pu	*	*	*	*	*
^{239}Pu	*	*	*	*	*
^{241}Am	2.01±.152	2.12± 092	2.45±.095	1.89±.092	.328±.066

** Depth of surface sample is 5 cm.
 * Not measured.

Table 16

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Surface**Sediments - Transect D

dpm/gram

Isotope	D-1	D-2	D-3	D-4
^{7}Be	< 377	<.381	<.444	.626± 121
^{40}K	37 4±1.74	35.9±1 72	33.4±.969	40.6±.989
^{54}Mn	<.046	< 044	<.048	<.024
^{60}Co	<0.01	<0.01	<0 01	<0.01
^{90}Sr	*	*	*	*
^{95}Zr	<.068	<.079	.118±.043	.172±.026
^{95}Nb	.119± 031	<.061	.190±.030	.279±.022
^{103}Ru	<.032	<.037	<.047	<.022
^{106}Ru	<.718	<.821	<.476	.911± 222
^{125}Sb	<.102	<.102	.244±.070	.205±.036
^{137}Cs	1.30±.078	2.24±.102	1.51±.057	2.74± 061
^{141}Ce	.078±.039	<.078	<.066	.090±.021
^{144}Ce	353±.169	<.345	<.291	.877±.100
^{226}Ra	7.68±.655	7 28±.652	5.46±.533	8 72± 389
^{228}Ac	2.99±.314	3.67±.345	2.36±.208	2.89±.174
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	.510±.130	.491± 128	1.81±.265	2.14± 090

* Not measured.

**Depth of surface sample is 5 cm.

Table 17

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Surface**Sediments - Transect E

dpm/gram

Isotope	E-1	E-2	E-3	E-4
^{7}Be	<.377	<.350	<.516	<.398
^{40}K	34.9±.846	39.4±1.75	34.6±1.06	33.4± 827
^{54}Mn	.079±.023	<.042	<.053	<.044
^{60}Co	< 0.01	<0.01	< 0.01	<0 01
^{90}Sr	*	*	*	*
^{95}Zr	.132±.041	<.076	<.096	.160±.039
^{95}Nb	.115±.024	.183±.034	<.070	.181±.029
^{103}Ru	<.041	<.037	<.056	<.044
^{106}Ru	<.414	<.414	<.528	.513± 212
^{125}Sb	<.123	<.112	<.158	<.205
^{137}Cs	1.35±.047	1.77±.090	2.19±.070	2.39±.059
^{141}Ce	<.060	<.068	.099±.037	<.061
^{144}Ce	<.258	.490±.169	.329±.165	<.271
^{226}Ra	5 59±.460	5.97±.619	5.41±.590	5.16±.465
^{228}Ac	3.58±.203	2.23± 280	2.87±.225	2.53±.190
^{238}Pu	*	*	*	*
^{239}Pu	*	*	*	*
^{241}Am	<.079	2.00±.156	1.35±.285	811±.224

* Not measured.

** Depth of surface sample is 5 cm.

37

Table 18

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Surface* Sediments - Transect F

dpm/gram

Isotope	F-1	F-2
^{7}Be	<.389	<.367
^{40}K	33 7±.833	32.1± 818
^{54}Mn	<.042	<.043
^{60}Co	<0.01	<0 01
^{90}Sr	**	**
^{95}Zr	096±.039	.174±.038
^{95}Nb	<.053	<.051
^{103}Ru	<.042	<.042
^{106}Ru	<.416	<.388
^{125}Sb	<.121	<.115
^{137}Cs	2.10±.056	1.09± 043
^{141}Ce	<.059	<.059
^{144}Ce	<.254	<.247
^{226}Ra	5.56±.450	5.34±.452
^{228}Ac	2.59±.180	2.93±.196
^{238}Pu	**	**
^{239}Pu	**	**
^{241}Am	1.39± 224	.666±.211

* Depth of surface sample is 5 cm thick.

** Not measured.

Table 19

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESIRVOIR

Core* Sediments - Transect A-1

dpm/gram

Isotope	A-1-1	A-1-2	A-1-3
^{7}Be	<.131	<.184	<.317
^{40}K	40.4±.99	39.0±.98	34.9±1.69
^{54}Mn	<.028	<.025	<.044
^{60}Co	<0 01	<0 01	<0 01
^{90}Sr	1.21±.312	**	1.49±.361
^{95}Zr	<.042	<.035	<.061
^{95}Nb	.048±.013	.034±.012	<.043
^{103}Ru	<.015	<.020	<.016
^{106}Ru	<.302	<.413	<.352
^{125}Sb	.283±.037	.107±.021	<.085
^{137}Cs	3.44±.069	3.19±.066	.234±.036
^{141}Ce	<.044	<.044	<.072
^{144}Ce	.624±.096	<.173	<.294
^{226}Ra	8.84±.379	12.0±.380	7 97±.75
^{228}Ac	2.99± 215	2.52±.17	2.45±.30
^{238}Pu	.129±.013	**	<.011
^{239}Pu	6.21±.079	**	.11 ±.005
^{241}Am	2.16±.091	1.04±.079	< 086

* Core sections are 5 cm thick

** Not measured.

39

Table 20

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect A-2

dpm/gram

Isotope	A-2-1	A-2-2	A-2-3	A-2-4	A-2-5	A-2-6
^{7}Be	<.247	<.841	<.448	<.263	<.406	<.314
^{40}K	34.5±1.53	44.3±2.40	35.5±1.41	30.9±1.70	37.0±1.27	35.7±1.07
^{54}Mn	.026±.016	<.090	<.051	<.041	<.046	<.035
^{60}Co	<0 01	<0 01	<0 01	<0 01	<0 01	<0 01
^{90}Sr	1.05±.303	1.75±.391	1.05±.300	2.04±.416	1.21±.312	1.77±.377
^{95}Zr	<.072	<.182	<.100	<.061	<.089	<.073
^{95}Nb	.099±.023	<.099	<.044	<.033	<.044	<.039
^{103}Ru	<.028	<.083	<.042	<.030	<.040	<.032
^{106}Ru	.610±.305	<.789	.58 ±.240	<.711	<.365	<.312
^{125}Sb	.23 ±.045	.19 ±.126	.28 ±.072	.23 ±.064	.132±.060	190± 100
^{137}Cs	2.14±.088	2.81±.12	2.05±.072	3.55±.132	2.58±.067	2.46±.056
^{141}Ce	<.045	<.149	<.077	<.028	<.087	<.053
^{144}Ce	.52 ±.111	.49 ±.278	.33 ±.146	<.239	<.253	<.208
^{226}Ra	5.06 .420	5 22±.898	5.85±.491	6.52±.526	4.26±.444	3.97±.360
^{228}Ac	2.18±.244	2.40±.406	2.07±.221	1.97±.258	1.60±.199	1.74±.158
^{238}Pu	.281±.019	.352±.021	.249±.017	.336±.022	.290±.019	.082±.011
^{239}Pu	12.0±.041	11.4± 055	7.51±.072	18.23+.091	9.97±.058	2.36±.021
^{241}Am	3.75±.214	4.28±.698	2.42±.361	4.13±.254	2.11±.326	710± 245

* Core sections are 5 cm thick

Table 21

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect A-2 (cont.)

dpm/gram

Isotope	A-2-7	A-2-8	A-2-9	A-2-10	A-2-11
^{7}Be	<.276	<.221	<.108	<.362	<.153
^{40}K	31.6±1.36	34.8±.673	31.0±.692	38.8±1.26	30.6±1.09
^{54}Mn	<.036	<.023	<.017	<.042	<.026
^{60}Co	<0 01	<0 01	<0 01	<0 01	<0 01
^{90}Sr	2.69±.538	2.15±.430	1.72±.385	1.16±.310	0.95±.286
^{95}Zr	<.130	<.163	<.025	<.085	<.049
^{95}Nb	<.026	<.077	<.012	<.040	<.022
^{103}Ru	<.030	<.022	<.013	<.043	<.019
^{106}Ru	<.506	<.204	<.257	<.190	<.314
^{125}Sb	.380±.058	220± 036	<.047	.130±.059	<.043
^{137}Cs	5.28±.130	4.12±.046	3.10±.051	2.57±.065	.690±.018
^{141}Ce	<.048	072±.038	<.051	<.070	<.039
^{144}Ce	<.209	<.139	<.102	<.249	<.170
^{226}Ra	4.76±.416	4.85±.244	5.16± 215	4.10±.431	4.26±.317
^{228}Ac	1.86±.219	1.82±.105	1.88±.111	2.08±.194	1.57±.163
^{238}Pu	.124±.014	154± 015	.235±.018	.142±.015	.008±.010
^{239}Pu	4.28±.028	5.71±.043	11.3±.054	7.68±.029	.032±.007
^{241}Am	1.87±.166	2.42±.182	3.31±.101	2.16±.318	.195±.099

* Core sections are 5 cm thick

41

Table 22

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect A-3

dpm/gram

Isotope	A-3-1	A-3-2	A-3-3	A-3-4	A-3-5
^{7}Be	<.334	<.189	<.391	<.199	< 453
^{40}K	47.0±1 36	40.6±.998	46.9±2.04	41.7±1.00	49.6±2.06
^{54}Mn	<.034	<.026	<.047	<.026	<.050
^{60}Co	<0 01	<0 01	<0 01	<0 01	<0 01
^{90}Sr	1.29±.322	**	**	**	**
^{95}Zr	.138±.037	<.039	<.072	<.038	<.069
^{95}Nb	.272±.033	<.025	<.045	<.024	<.039
^{103}Ru	<.034	<.021	<.047	<.022	< 045
^{106}Ru	.874±.338	<.448	1.39±.535	.868±.237	<.887
^{125}Sb	.349±.054	.287±.038	.516±.092	.469±.046	<.337
^{137}Cs	3 49±.097	3.67±.071	5.15±.163	4.36±.077	5.62±.167
^{141}Ce	<.059	<.043	<.096	<.062	< 186
^{144}Ce	1.19±.137	.863±.101	1.65±.220	.824±.106	<.372
^{226}Ra	10.3±.553	8.47±.381	10.5±.809	10.3±.404	10.6±.820
^{228}Ac	2.99±.243	2.91± 179	3.67±.420	2.82±.172	3.29±.362
^{238}Pu	.195±.015	**	**	**	**
^{239}Pu	13.4±.041	**	**	**	**
^{241}Am	3.22±.140	3.15±.103	2.55±.190	2.20±.093	5.02± 223

* Core sections are 5 cm thick

** Not measured

Table 23

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect A-3 (cont.)

dpm/gram

Isotope	A-3-6	A-3-7	A-3-8	A-3-9	A-3-10
^{7}Be	<.197	<.384	<.232	<.391	< 225
^{40}K	44.2±1.03	42.8±1.85	45.2±1 04	47.9±1.93	43.3±1.03
^{54}Mn	<.025	<.047	< 030	<.049	<.027
^{60}Co	<0 01	<0.01	<0 01	<0 01	<0 01
^{90}Sr	**	**	**	**	1.80±.393
^{95}Zr	<.037	<.068	<.037	<.059	<.037
^{95}Nb	<.024	<.050	<.023	<.043	<.047
^{103}Ru	<.023	<.041	<.025	<.191	<.023
^{106}Ru	<.434	<.805	<.450	<.842	<.424
^{125}Sb	.245±.039	.358±.071	.560±.050	.724±.093	.231±.037
^{137}Cs	5 61± 088	6.40±.172	9 65±.114	9.68±.210	5.94±.091
^{141}Ce	<.066	<.083	<.076	<.080	<.046
^{144}Ce	<.227	<.337	<.199	<.351	<.188
^{226}Ra	9 64±.405	9.10±.747	9.67±.421	11.4±.784	10.9±4.14
^{228}Ac	2.90± 184	3.37±.335	2.83± 176	2.67±.342	2.74+.176
^{238}Pu	**	**	**	**	<.011
^{239}Pu	**	**	**	**	.11 ± 005
^{241}Am	1.92± 092	1.24±.157	1.58±.089	2.17±.170	4.70±.116

* Core sections are 5 cm thick

** Not measured

Table 24

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect A-4

dpm/gram

Isotope	A-4-1	A-4-2	A-4-3
^{7}Be	<.391	<.174	<.103
^{40}K	48.6±1.98	41.2±1.01	41.7±1.83
^{54}Mn	<.044	<.026	< 047
^{60}Co	<0 01	<0 01	<0 01
^{90}Sr	<.425	**	**
^{95}Zr	<.057	<.034	<.075
^{95}Nb	< 051	<.024	<.041
^{103}Ru	<.045	<.018	<.038
^{106}Ru	<.827	**	<.818
^{125}Sb	<.126	<.103	<.120
^{137}Cs	2 66±.111	1.58± 047	.940± 068
^{141}Ce	<.084	<.069	< 085
^{144}Ce	<.361	<.182	<.340
^{226}Ra	9.62±.745	8.44±.375	9.10±.745
^{228}Ac	3.16±.344	2.93±.171	3.10±.310
^{238}Pu	.099± 011	**	**
^{239}Pu	3.97±.021	**	**
^{241}Am	1.38±.153	.566±.073	.558±.140

* Core sections are 5 cm thick

** Not measured

44

Table 25

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect B

dpm/gram

Isotope	B-3-1	B-3-2	B-3-3	B-3-4	B-3-5
^{7}Be	<.441	<.609	<.426	<.362	<.243
^{40}K	36.0±.912	36 6±1.22	39.2±.890	44.4±1.89	43.1±1.09
^{54}Mn	.077±.024	<.061	<.047	<.052	<.031
^{60}Co	<0 01	<0 01	<0.01	<0 01	<0 01
^{90}Sr	1.45±.363	**	**	**	**
^{95}Zr	<.118	<.117	<.081	<.070	<.040
^{95}Nb	<.046	<.073	<.052	<.041	<.026
^{103}Ru	<.047	<.065	<.046	<.045	<.026
^{106}Ru	.542±.232	<.637	<.433	<.783	<.464
^{125}Sb	.396±.073	.311± 106	.435±.073	<.144	.519±.049
^{137}Cs	2.49±.064	3.48±.098	4.41±.077	5.66±.161	8.53±.114
^{141}Ce	<.066	<.092	<.065	<.082	<.048
^{144}Ce	.692±.146	.705±.202	<.275	<.346	<.198
^{226}Ra	6.21±.516	6.51±.730	7.38±.519	10.6±.743	9.92±.431
^{228}Ac	2 95±.208	3.32± 293	3.17±.201	3.18±.316	3.02±.190
^{238}Pu	.241±.019	**	**	**	**
^{239}Pu	11.8±.044	**	**	**	**
^{241}Am	2.41±.267	2.09±.352	3.09±.265	1.23±.156	1.89±.096

* Core sections are 5 cm thick

** Not measured

Table 26

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect B(cont.)

dpm/gram

Isotope	B-3-6	B-3-7	B-3-8	B-3-9	B-3-10
^{7}Be	<.326	<.539	<.273	<.472	<.262
^{40}K	38.0±.631	36.0±1.12	39.9±.640	38.4±1.15	36.7±.618
^{54}Mn	<.033	< 059	<.033	<.058	< 050
^{60}Co	<0.01	<0 01	<0 01	<0 01	<0 01
^{90}Sr	**	**	**	**	.850±.283
^{95}Zr	< 054	<.098	<.054	<.102	<.056
^{95}Nb	<.037	< 065	<.038	<.066	<.036
^{103}Ru	<.035	<.064	<.030	<.053	<.029
^{106}Ru	< 311	<.566	<.291	<.490	<.290
^{125}Sb	.367±.056	<.178	<.087	<.141	<.083
^{137}Cs	6.49±.066	4.61±.102	1.06±.031	<.067	<.047
^{141}Ce	< 048	<.085	<.085	<.077	<.042
^{144}Ce	< 197	<.353	<.186	<.326	<.178
^{226}Ra	6.28±.372	5.55±.652	6.44±.346	5.68±.601	6.22±.334
^{228}Ac	2.67±.146	3.50±.264	3.00±.142	2.65±.247	2.91±.137
^{238}Pu	**	**	**	**	<.007
^{239}Pu	**	**	**	**	.083±.007
^{241}Am	3.34±.191	3.34±.339	<.170	0 107	<.313

* Core sections are 5 cm thick

** Not measured

46

Table 27

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect C-1,2,3

dpm/gram

Isotope	C-1-1	C-2-1	C-2-2	C-3-1	C-3-2	C-3-3
^{7}Be	2.44± 337	<.325	<.173	<.366	<.165	<.274
^{40}K	24 6±1.54	39 8±1.80	46.6±1.06	42.0±1.84	39.1±.982	37.9±1.76
^{54}Mn	<.057	<.045	<.034	< 053	<.027	<.045
^{60}Co	<0 01	<0 01	<0 01	<0 01	<0 01	< 0 01
^{90}Sr	**	.830±.314	**	1.30±.347	**	**
^{95}Zr	.699±.093	<.061	<.035	<.067	<.032	<.062
^{95}Nb	1.58±.091	<.039	<.023	<.055	.036±.012	<.033
^{103}Ru	.094±.031	<.035	<.019	<.030	<.019	<.035
^{106}Ru	3.55±.551	<.769	<.458	1.00±.362	<.414	<1.04
^{125}Sb	.440±.080	<.087	<.048	.257±.065	<.055	<.087
^{137}Cs	1.70±.077	.507±	<.027	3.06±.118	1.12±.040	< 042
^{141}Ce	.421±.053	<.075	<.047	< 081	<.042	< 070
^{144}Ce	2.91±.255	<.325	<.199	< 353	<.175	<.294
^{226}Ra	33.6±1.18	7.54±.658	8.73±.397	8.96±.693	7.64± 365	7.14±.594
^{228}Ac	2.70±.304	3 02± 316	3.66±.188	2.72±.303	3.10±.175	2.37±.279
^{238}Pu	**	.030± 010	**	.103±.011	**	**
^{239}Pu	**	.450±.010	**	5.99±.028	**	**
^{241}Am	1.45±.201	<.172	<.099	1.43±.156	.426±.070	<.215

* Core sections are 5 cm thick

** Not measured.

Table 28

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect C-4

dpm/gram

Isotope	C-4-1	C-4-2	C-4-3	C-4-4	C-4-5
^{7}Be	<.216	<.180	< 386	<.168	< 180
^{40}K	40.6±.984	40 9±1.01	46.3±1.90	43.5±.873	42 3±1.01
^{54}Mn	<.027	<.026	<.036	<.022	<.026
^{60}Co	<0 01	< 0 01	< 0 01	< 0 01	<0 01
^{90}Sr	2.13±.444	**	**	**	1.14±.316
^{95}Zr	.064±.021	<.042	<.051	<.031	<.034
^{95}Nb	.112±.016	<.026	<.055	<.020	<.023
^{103}Ru	<.022	<.022	<.043	<.017	<.019
^{106}Ru	.782±.243	<.440	<.780	<.372	<.409
^{125}Sb	.304±.038	.355±.041	.329± 073	<.095	<.049
^{137}Cs	3.53±.069	5.06±.083	7.08±.179	3.76±.060	.363±.024
^{141}Ce	083±.023	<.046	<.085	<.060	<.042
^{144}Ce	.882±.101	<.198	<.336	<.155	<.179
^{226}Ra	7.00±.383	10.5± 407	9.55±.744	9.07±.336	8 06± 370
^{228}Ac	2.97± 167	3 52± 179	3.03±.312	2.85±.149	2.93±.171
^{238}Pu	.182±.012	**	**	**	.017±.010
^{239}Pu	8.16± 037	**	**	**	.344±.009
^{241}Am	2.41±.094	2.58±.096	1.58±.169	2.17±.068	<.168

* Core sections are 5 cm thick

** Not measured.

48

Table 29

RADIONUCLIDE CONCENTRATION IN GREAT WESTERN RESERVOIR

Core* Sediments - Transect E-2

dpm/gram

Isotope	E-2-1	E-2-2	E-2-3
^{7}Be	< 257	<.239	<.450
^{40}K	37 2±.617	36.2±.607	34.2±1.08
^{54}Mn	<.030	<.033	<.056
^{60}Co	<0 01	<0 01	<0 01
^{90}Sr	**	**	**
^{95}Zr	<.052	<.051	<.091
^{95}Nb	<.037	<.032	<.064
^{103}Ru	<.028	<.024	<.051
^{106}Ru	<.271	<.266	<.491
^{125}Sb	<.083	< 076	<.136
^{137}Cs	580±.025	<.034	<.060
^{141}Ce	<.041	<.040	<.073
^{144}Ce	<.176	<.168	<.305
^{226}Ra	5.14±.321	5.34±.315	4.66±.573
^{228}Ac	2.69±.133	2.48±.126	2.75±.234
^{238}Pu	**	**	**
^{239}Pu	**	**	**
^{241}Am	.786±.157	.483±.147	< 280

* Core sections are 5 cm thick

** Not measured

49

Table 30

RADIONUCLIDE CONCENTRATION IN SEDIMENTS FROM THE BROOMFIELD WATER TREATMENT PLANT

dpm/gram

Isotope	HC-1-1	HC-1-2	HC-1-3	HC-1-4	HC-1-5	HC-1-6
^{7}Be	2 38±.339	< 263	<.893	<.377	<.481	<.285
^{40}K	26 0±1.57	30 8± 567	19.1±1.35	25.9±.677	26.5±.831	21.7±.509
^{54}Mn	<.053	<.031	< 103	<.043	<.055	<.032
^{60}Co	<0 01	<0 01	<0 01	<0.01	<0 01	<0 01
^{90}Sr	**	**	**	**	**	**
^{95}Zr	.587±.081	<.053	<.174	<.072	<.094	<.053
^{95}Nb	1.39±.087	<.036	<.109	.088±.027	.136±.033	.060±.020
^{103}Ru	<.065	<.030	< 100	<.041	<.053	<.031
^{106}Ru	2.30±.499	<.059	2.20±.528	1.81±.231	1.05±.279	.574±.153
^{125}Sb	.300±.079	.186±.045	<.307	.494±.066	.449±.087	.236±.049
^{137}Cs	1.85±.094	2.03±.039	2.05±.112	2.31±.053	2.59±.067	1.98±.040
^{141}Ce	.543±.055	.155± 022	.449±.075	.427±.034	.437±.042	.374±.026
^{144}Ce	3.18±.256	.283±.092	<.590	.866±.138	.752±.176	<.205
^{226}Ra	35.3±1.20	13.7±.381	28.7±1.37	37.4±.662	37.2±.809	29 8±.488
^{228}Ac	2.31±.316	2.45±.128	2.10±.364	2.40±.167	10.6±.339	2.78±.130
^{238}Pu	**	**	**	**	**	**
^{239}Pu	**	**	**	**	**	**
^{241}Am	1.09±.196	1.23±.173	<1.15	1.20±.267	.684±.323	.954±.205

* Core sections are 5 cm thick

** Not measured

Table 31

RADIONUCLIDE CONCENTRATION IN SEDIMENTS FROM THE BROOMFIELD WATER TREATMENT PLANT

Core* Sediments dpm/gram

Isotope	HC-2-1	HC-2-2	HC-2-3	HC-2-4	HC-2-5	HC-2-6
^{7}Be	< 805	<.269	< 546	<.702	<.300	<.844
^{40}K	20.8±1.31	29 7± 561	19.2± 878	24.5±1.16	21.4±.536	23 9±1.39
^{54}Mn	<.092	<.031	<.063	<.072	<.033	<.087
^{60}Co	<0 01	<0 01	<0 01	<0 01	<0 01	<0 01
^{90}Sr	**	**	**	**	**	**
^{95}Zr	<.163	<.052	<.107	.331±.071	<.058	<.154
^{95}Nb	<.116	<.035	.133±.037	.691±.061	.124±.022	<.129
^{103}Ru	<.091	<.029	<.063	<.075	<.033	<.091
^{106}Ru	2.59±.536	911± 150	2.05±.346	1.80±.380	.663±.168	<.868
^{125}Sb	<.274	212± 045	.268±.091	.339±.106	.120±.055	<.314
^{137}Cs	2.02±.104	2.05± 039	1.78±.066	1.81±.083	2.12±.044	2.39±.116
^{141}Ce	.519±.071	.172± 023	.434±.046	.215±.052	.441±.028	.355±.072
^{144}Ce	.880±.033	< 191	<.378	1.53± 228	.295±.110	<.566
^{226}Ra	38.2±1.40	14.2±.383	29.5±.853	20.7±.952	34.5±.540	33.1±1.35
^{228}Ac	2.27±.379	2.73± 129	2.35±.238	2.21±.018	2.13±.138	2.96±.388
^{238}Pu	**	**	**	**	**	**
^{239}Pu	**	**	**	**	**	**
^{241}Am	1.21±.545	1 39±.175	<.695	2.19±.411	2.09±.228	2.30± 581

* Core sections are 5 cm thick

** Not measured

51

Table 32

RADIONUCLIDE CONCENTRATION IN STANDLEY LAKE

Surface* Sediments - Grab Samples

dpm/gram

Isotope	1	2	3	4
^{7}Be	.255±.090	<.190	<.175	831±.132
^{40}K	36 9±.625	43 6±1.03	30.1±.87	46.7± 231
^{54}Mn	<.034	<.028	< 022	<.030
^{60}Co	<0 01	<0 01	<0 01	<0 01
^{90}Sr	**	**	**	**
^{95}Zr	<.059	<.039	.060±.019	.220±.029
^{95}Nb	.199±.020	.077± 016	.064±.014	.445±.028
^{103}Ru	<.031	<.021	<.016	.028±.013
^{106}Ru	.801±.156	< 450	<.376	.879±.250
^{125}Sb	.306±.049	<.070	<.048	.355±.038
^{137}Cs	2 72±.017	2.08±.054	.931± 037	2.95±.064
^{141}Ce	<.047	<.045	<.050	.108±.025
^{144}Ce	.898±.102	<.136	.328±.083	1.52±.116
^{226}Ra	7.30±.389	7.84± 378	5.87±.338	12.2±.428
^{228}Ac	2.91±.139	3 50±.193	2.48±.160	3.64±.179
^{238}Pu	.023±.009	**	.020±.010	**
^{239}Pu	.512±.028	**	.636±.031	**
^{241}Am	.291±.169	.182± 071	<.054	149±.075

* Depth of surface sediment is 5 cm

** Not measured

52

Table 33

RADIONUCLIDE CONCENTRATION IN STANDLEY LAKE

Surface* Sediments - Grab Samples (cont)

dpm/gram

Isotope	5	6	7	8
^{7}Be	<.254	< 272	<.262	<.524
^{40}K	26.3±.530	35 8± 608	29.2± 550	48 6±1.3
^{54}Mn	<.178	<.032	<.031	<.063
^{60}Co	<0 01	<0 01	<0 01	<0 01
^{90}Sr	**	**	**	**
^{95}Zr	.098±.025	<.057	<.054	<.111
^{95}Nb	<.033	<.038	<.034	<.073
^{103}Ru	<.027	<.029	.047±.014	<.058
^{106}Ru	.580±.138	.384±.144	<.283	<.575
^{125}Sb	.120± 042	.165±.045	.127±.042	<.162
^{137}Cs	1.79± 037	1.25± 033	1.43± 034	.112±.039
^{141}Ce	<.037	<.043	<.042	<.087
^{144}Ce	.278±.086	< 187	<.179	<.371
^{226}Ra	5 19± 454	6.18± 13	5.02± 324	10.1±.722
^{228}Ac	2 31±.127	2.74± 142	2.95± 134	3.56± 162
^{238}Pu	**	**	< 007	**
^{239}Pu	**	**	.329±.021	**
^{241}Am	<.162	<.317	<.150	485±.325

* Depth of surface sediment is 5 cm

** Not measured

Table 34

RADIONUCLIDE CONCENTRATION IN STANDLEY LAKE

Core* Sediments

dpm/gram

Isotope	5-1	5-2	5-3	5-4
^{7}Be	<.412	<.265	<.260	<.542
^{40}K	35.2±1.68	47.6±1.29	45.9±1.31	50.2±2.46
^{54}Mn	<.042	<.032	<.036	<.071
^{60}Co	0 01	0 01	0 01	0 01
^{90}Sr	**	**	**	**
^{95}Zr	<.078	<.053	<.051	<.101
^{95}Nb	.102±.031	<.034	<.032	<.068
^{103}Ru	<.034	<.028	<.029	<.053
^{106}Ru	<.786	<.624	1.21±.310	<.485
^{125}Sb	.358± 072	.569±.059	.411±.053	<.205
^{137}Cs	2.44±.106	4.31±.092	4.72±.099	6.10±.203
^{141}Ce	<.073	<.056	<.057	<.105
^{144}Ce	.795± 170	1.05±.134	.573±.124	<.448
^{226}Ra	8.76±.633	12.2±.532	11.7±.538	12.6±1.02
^{228}Ac	2.34±.300	3.83± 251	3.87±.243	3.67±.466
^{238}Pu	**	**	**	**
^{239}Pu	**	**	**	**
^{241}Am	<.112	<.186	<.190	.374±.182

* Core sections are 5 cm thick

** Not measured.

Table 35

RADIONUCLIDE CONCENTRATION IN STANDLEY LAKE

Core* Sediments (cont)

dpm/gram

Isotope	5-5	5-6	5-7	5-8
^{7}Be	<.262	<.278	<.212	<.292
^{40}K	47 6±1.19	52.2±1.22	56.3±1.14	39.2±.638
^{54}Mn	<.031	<.031	<.028	<.035
^{60}Co	0 01	0 01	0 01	0 01
^{90}Sr	**	**	**	**
^{95}Zr	<.042	<.049	<.041	<.062
^{95}Nb	<.030	<.031	<.029	<.040
^{103}Ru	<.026	<.028	<.023	<.032
^{106}Ru	<.530	<.522	<.471	<.308
^{125}Sb	.315±.046	.677±.058	<.074	<.095
^{137}Cs	6.49±.102	10.8± 131	4.65±.058	1.66±.037
^{141}Ce	<.055	<.057	<.051	<.047
^{144}Ce	<.222	<.235	<.210	< 203
^{226}Ra	14.4±.508	17.2+.570	17.2±.496	6.81±.369
^{228}Ac	3.82±.224	4.01±.230	4.02±.194	4.58±.160
^{238}Pu	**	**	**	**
^{239}Pu	**	**	**	**
^{241}Am	.186±.086	.351± 089	<.080	.391±.174

* Core sections are 5 cm thick

** Not measured

55

Table 36

RADIONUCLIDE CONCENTRATION IN STANDLEY LAKE WATER NEAR DAM

Isotope	Water Samples - dpm/liter			
	Filter	Cation	Anion	Al_2O_3
^{7}Be	.864±.030	<.287	<.302	<0 1
^{40}K	<.170	7.70±.436	<.686	<0 2
^{54}Mn	.0116±.0019	<.030	<.034	<0 01
^{60}Co	.001±.0005	.006±.002	<.002	<0 001
^{90}Sr	**	**	**	**
^{95}Zr	.224±.0085	.090±.029	.077±.033	<0 03
^{95}Nb	.385± 0068	.138±.020	.293±.024	.117±.003
^{103}Ru	.275± 025	<.031	<.035	<0 01
^{106}Ru	.153±.022	.231±.025	.549±.109	.119± 011
^{125}Sb	.066±.0066	<0 1	<.095	<0 03
^{137}Cs	.030± 003	.063±.020	<.039	.010± 002
^{141}Ce	.020±.003	<.0412	<.044	<0 02
^{144}Ce	.947± 018	.299±.089	<.189	<0 07
^{226}Ra	.052±.034	2.11± 316	2.27±.340	<1
^{228}Ac	<.022	<.162	<.182	<.002
^{238}Pu	<.00028	<.00062	<.00044	<.00052
^{239}Pu	.0017±.0002	<.00062	<.00044	<.00052
^{241}Am	< 049	< 282	<.302	**

* Not measured

56

Table 37

RADIONUCLIDE CONCENTRATION IN WATER FROM THE WESTMINSTER WATER TREATMENT PLANT

Water Samples - dpm/liter

Isotope	Filter	Cation	Anion	Al_2O_3
^{7}Be	.012± 004	<.091	<.139	<0 03
^{40}K	<.076	1.24±.119	<.627	<0 2
^{54}Mn	< 0009	<.011	<.014	<0 04
^{60}Co	< 0002	<.0005	< 0005	<0 0002
^{90}Sr	*	*	*	*
^{95}Zr	<.0024	<.018	<.025	<0 01
^{95}Nb	.0087±.0009	<.010	.040±.011	<0 01
^{103}Ru	.0027±.0006	<.010	<.021	<0 05
^{106}Ru	025± 003	.064±.009	.363±.013	.022±.003
^{125}Sb	.0022±.0010	<.029	<.044	<0 01
^{137}Cs	<.0012	<.012	<.014	<0 005
^{141}Ce	<.001	<.013	<.016	<0 005
^{144}Ce	.012± 002	<.056	<.068	<0 02
^{226}Ra	<.014	2.47±.148	.482 ±.151	<0 4
^{228}Ac	< 0056	<.061	<.111	<0 02
^{238}Pu	<.00029	<.00006	<.00007	<.00013
^{239}Pu	<.00029	<.00006	<.00007	<.00013
^{241}Am	<.0046	<.092	<.050	*

* Not measured

57

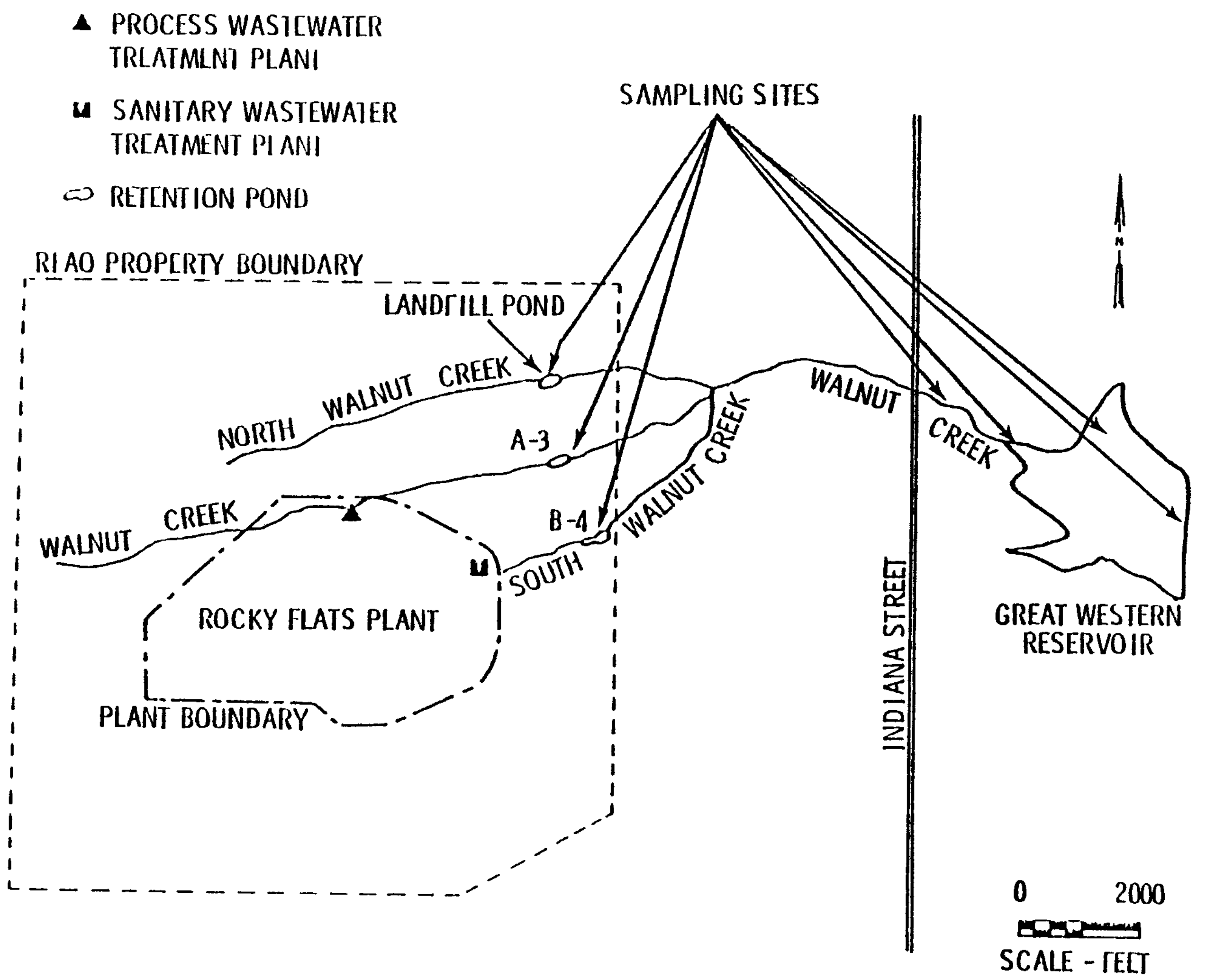

Figure 1 Water Sampling Sites at Great Western Reservoir and Associated Waterways

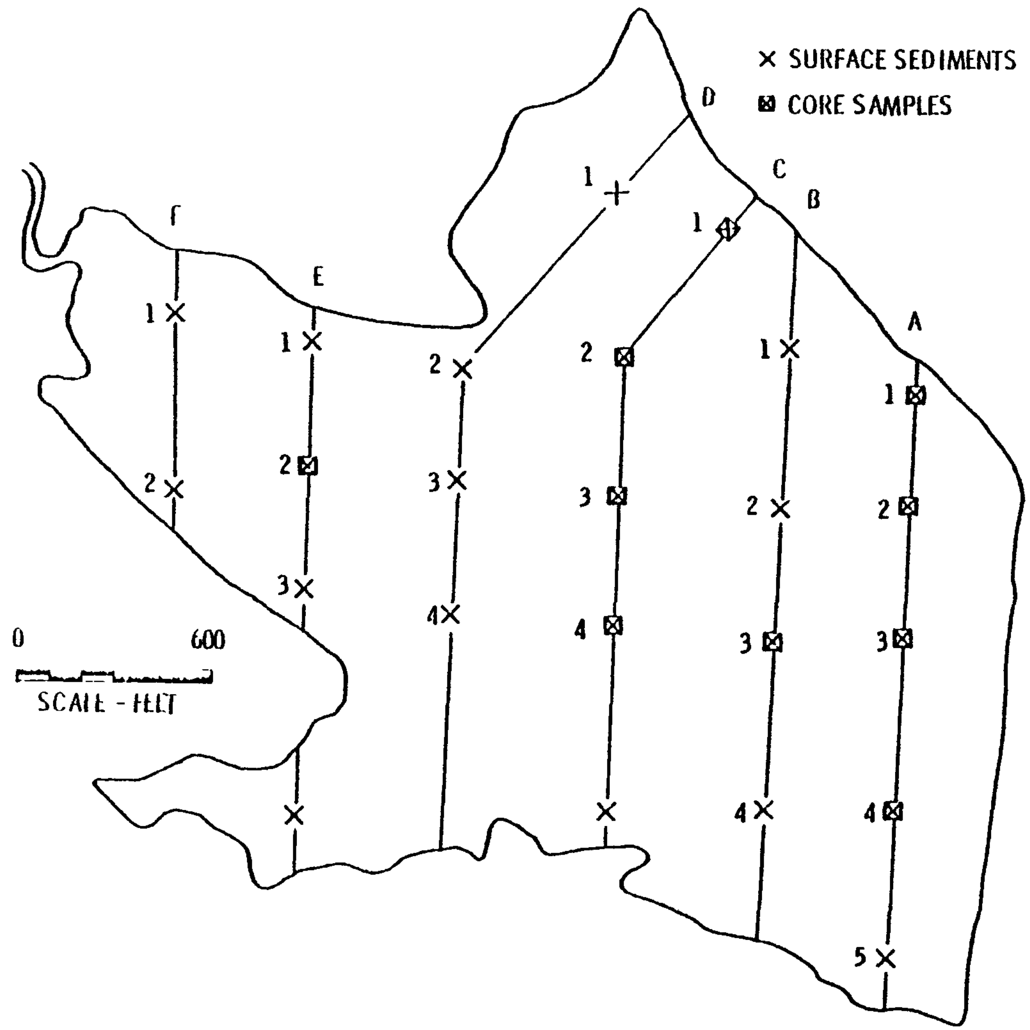

Figure 2. Sediment Sampling Stations at Great Western Reservoir

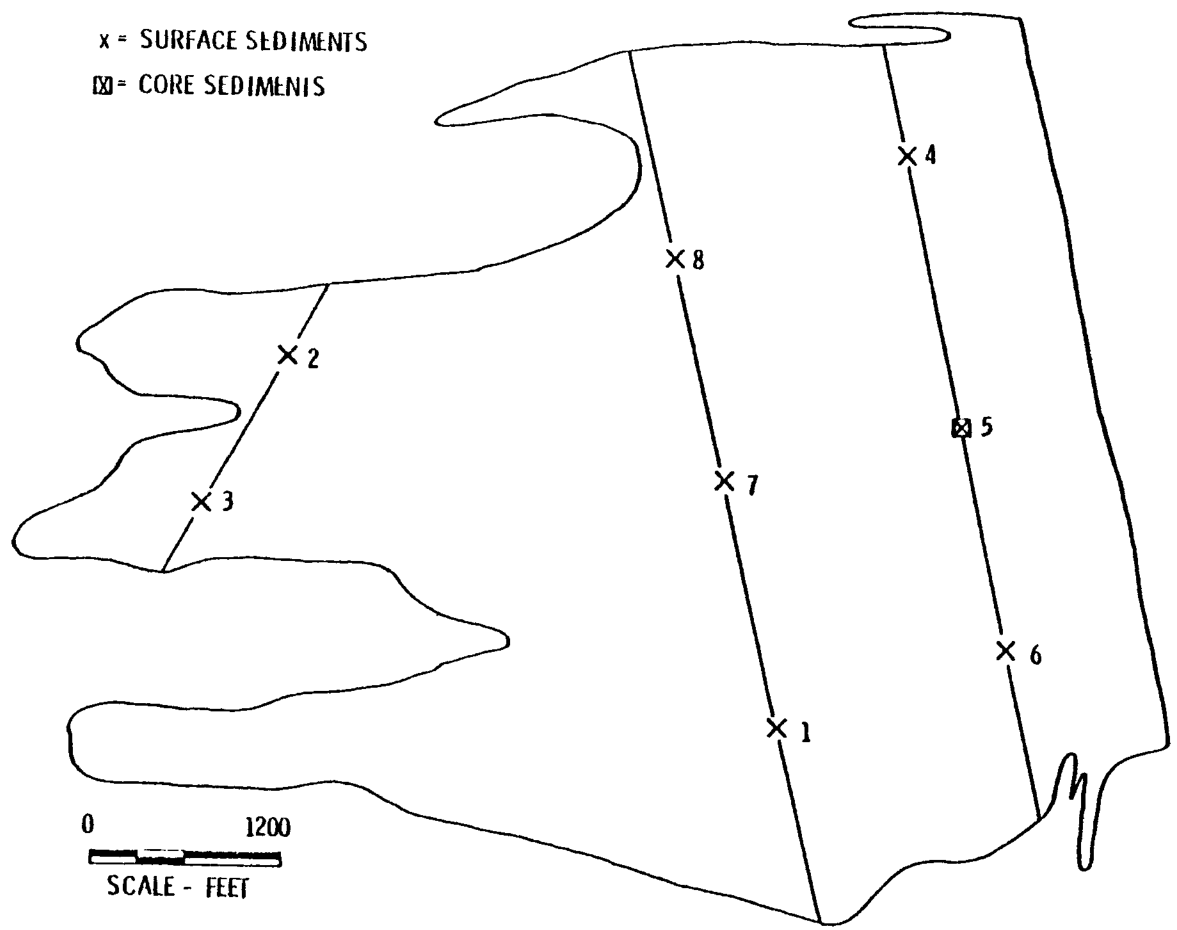

Figure 3 Sediment Sampling Stations at Standley Lake Reservoir

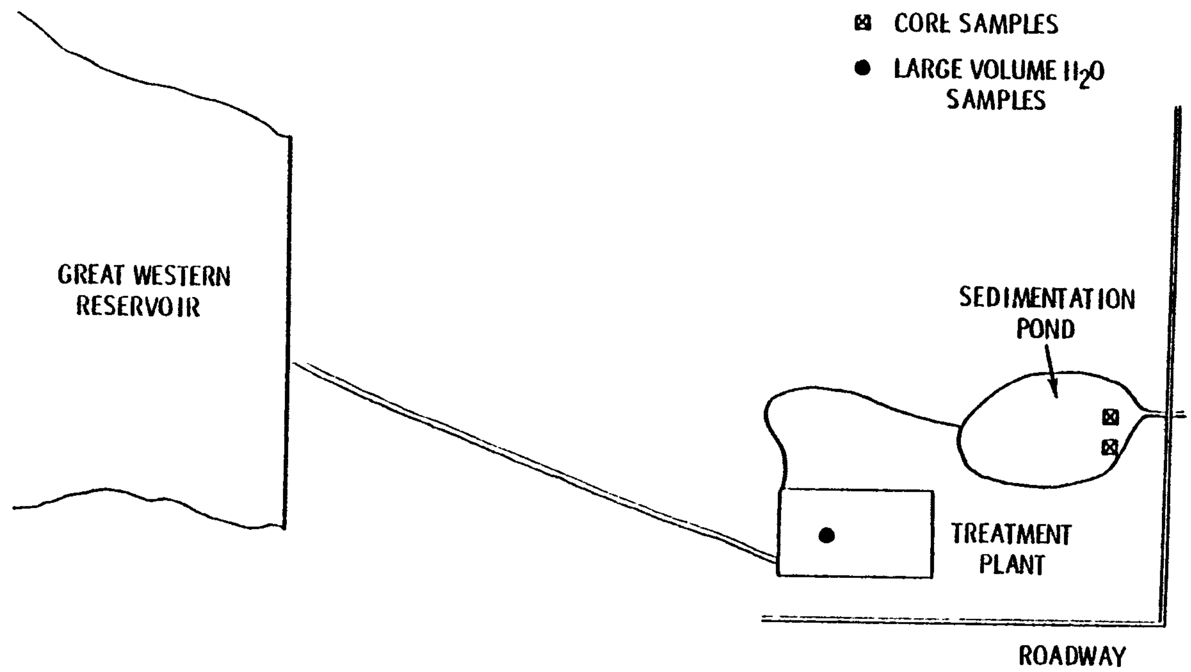

Figure 4 Large Volume Water and Sediment Sampling Location in the Vicinity of Broomfield Water Treatment Plant

61

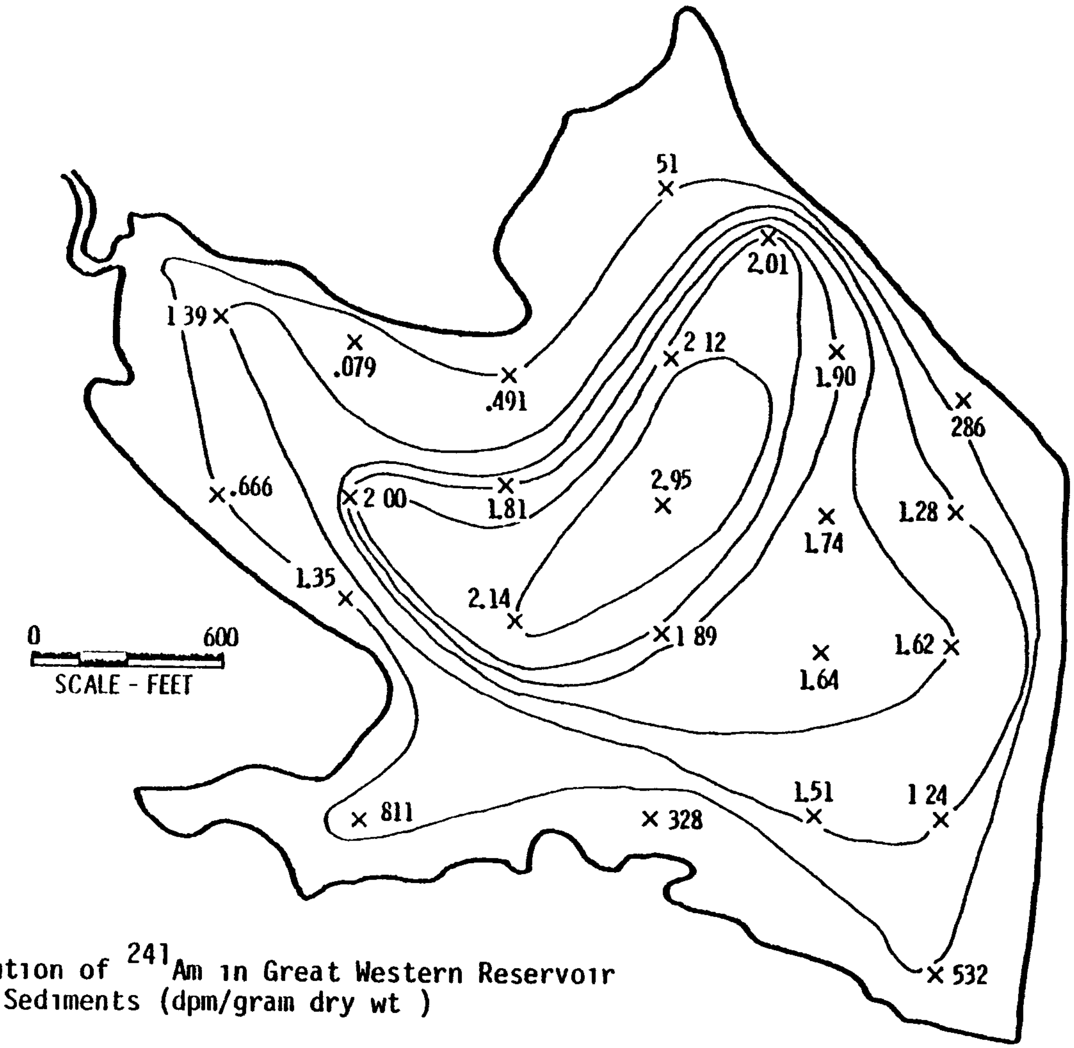

Figure 5 Distribution of ^{241}Am in Great Western Reservoir Surface Sediments (dpm/gram dry wt)

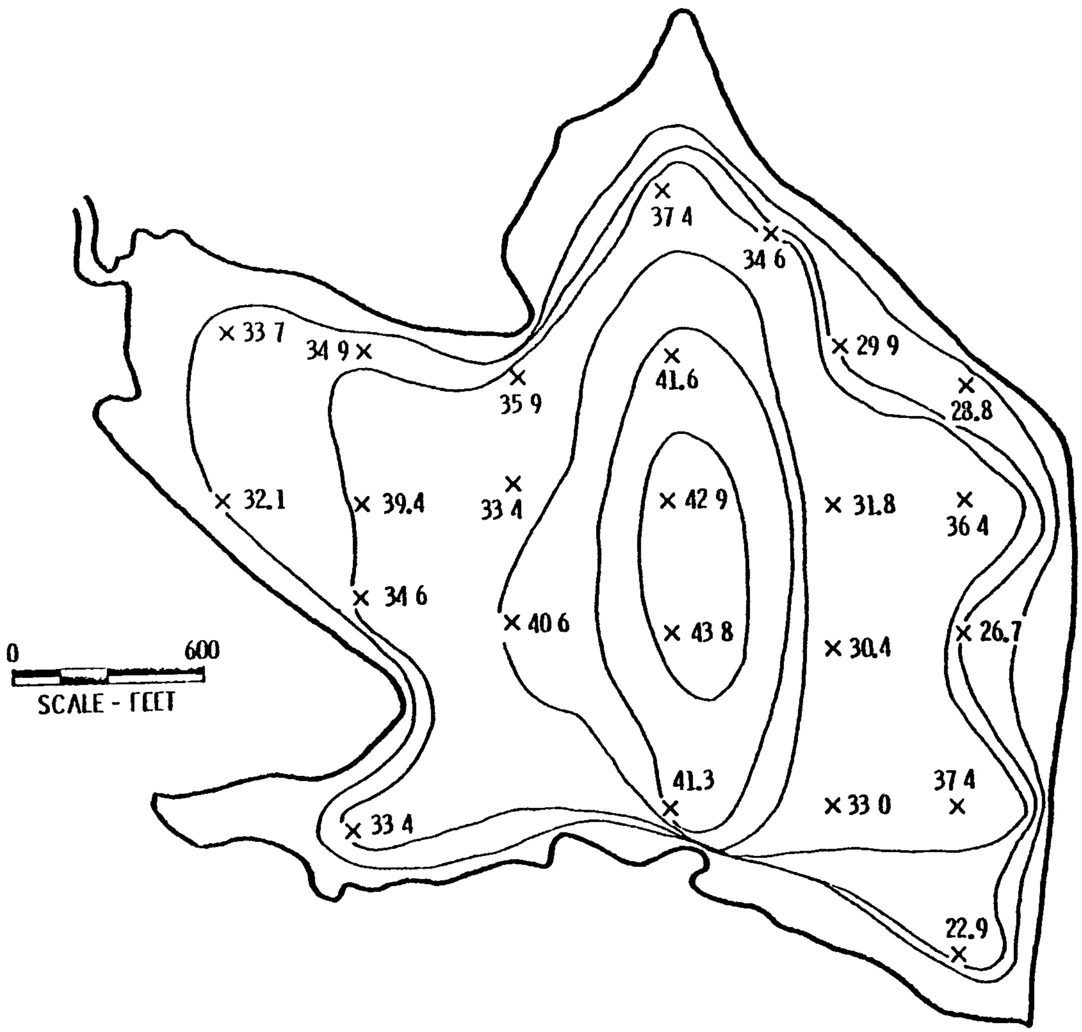

Figure 6 Distribution of ^{40}K in Great Western Reservoir Surface Sediments (dpm/g)

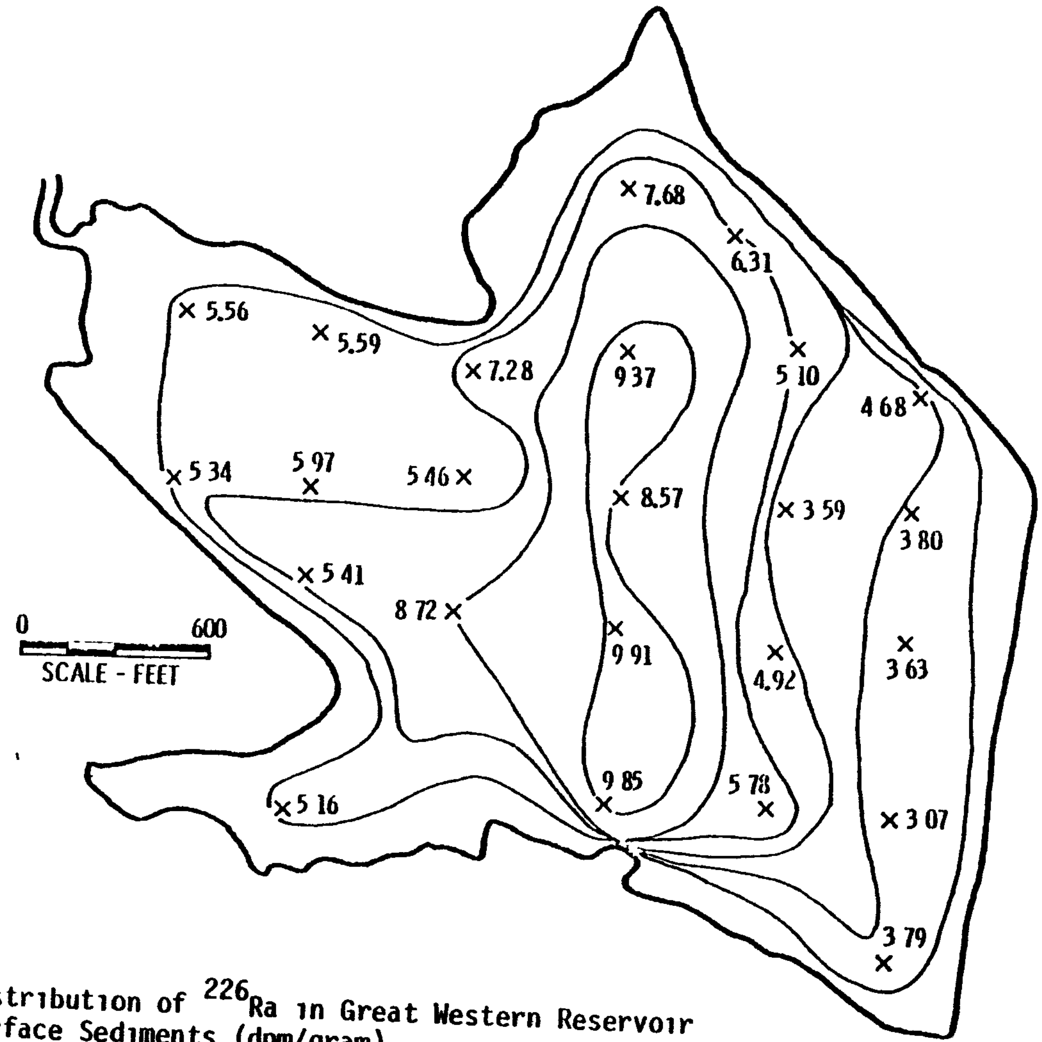

Figure 7. Distribution of ^{226}Ra in Great Western Reservoir Surface Sediments (dpm/gram)

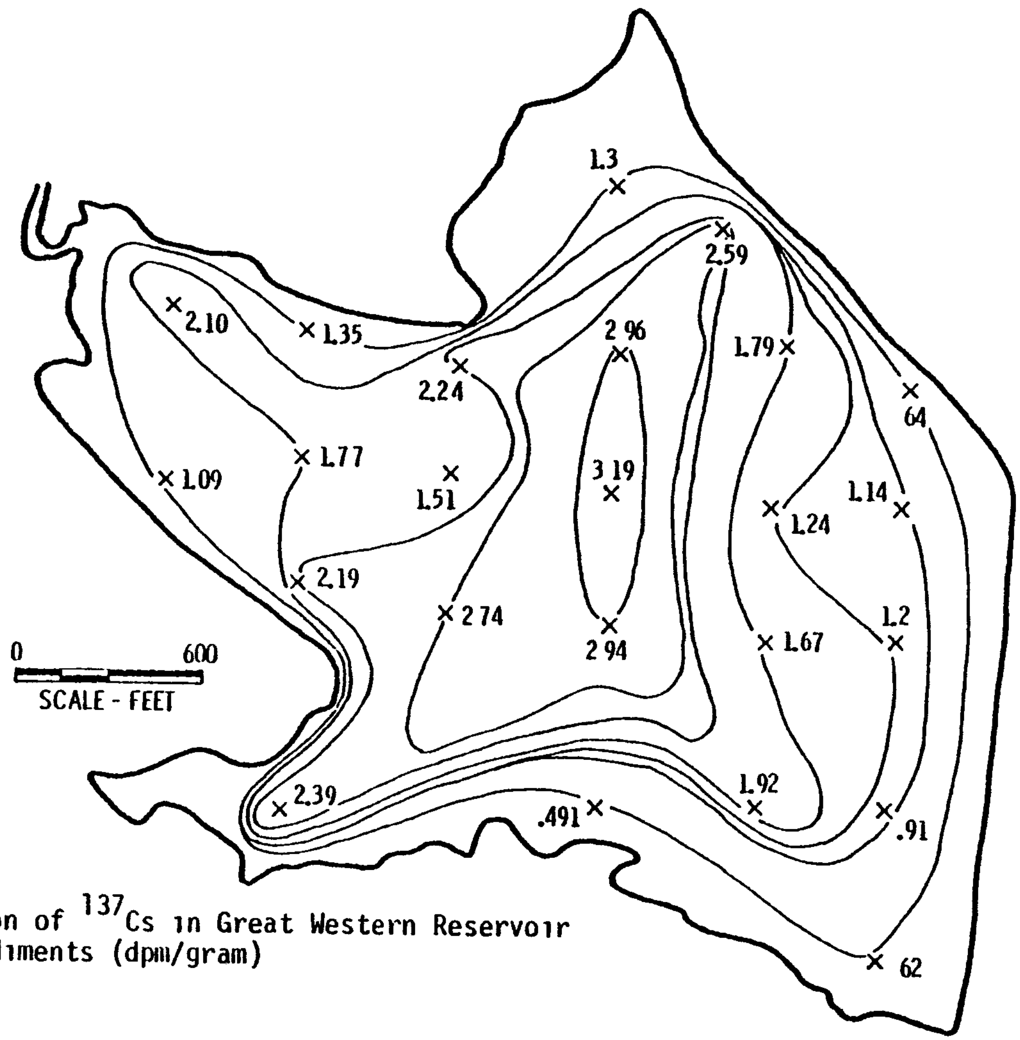

Figure 8 Distribution of ^{137}Cs in Great Western Reservoir Surface Sediments (dpm/gram)

65

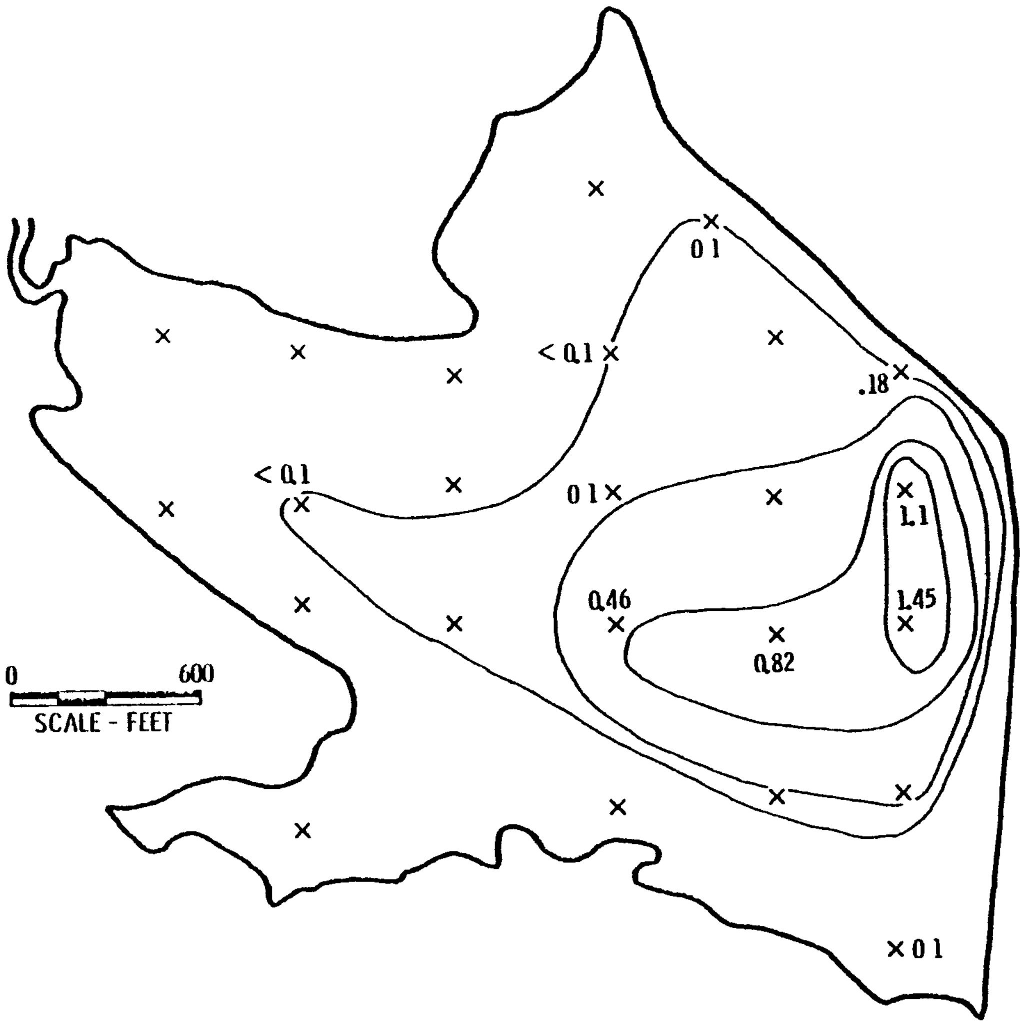

Figure 9 Deposition Rate of Sediments in Great Western Reservoir (inches/year)

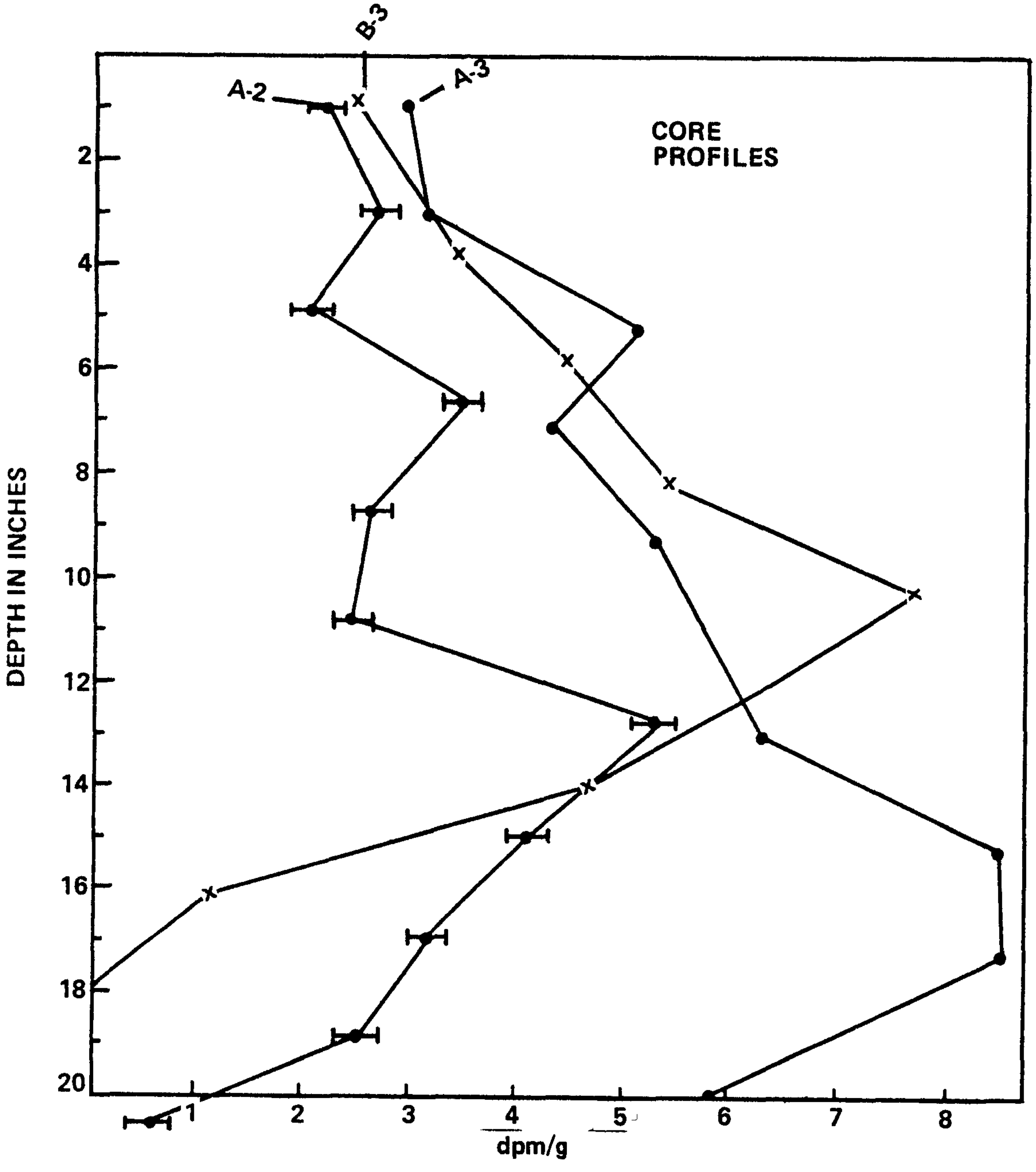

Figure 10 Depth Distribution of ^{137}Cs in Great Western Reservoir Sediments

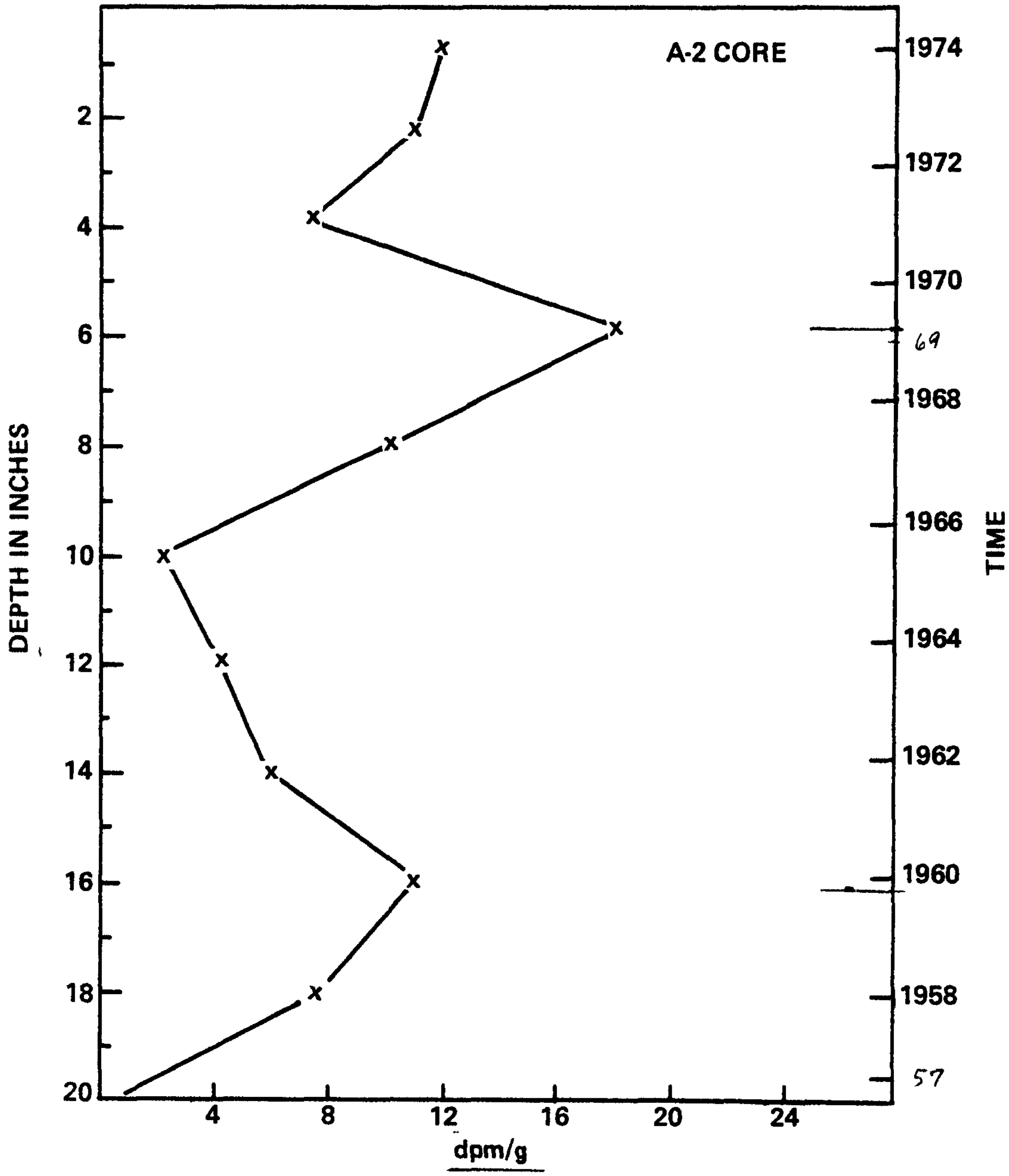

Figure 11 Depth Distribution of $^{239-240}Pu$ in Great Western Reservoir Sediments

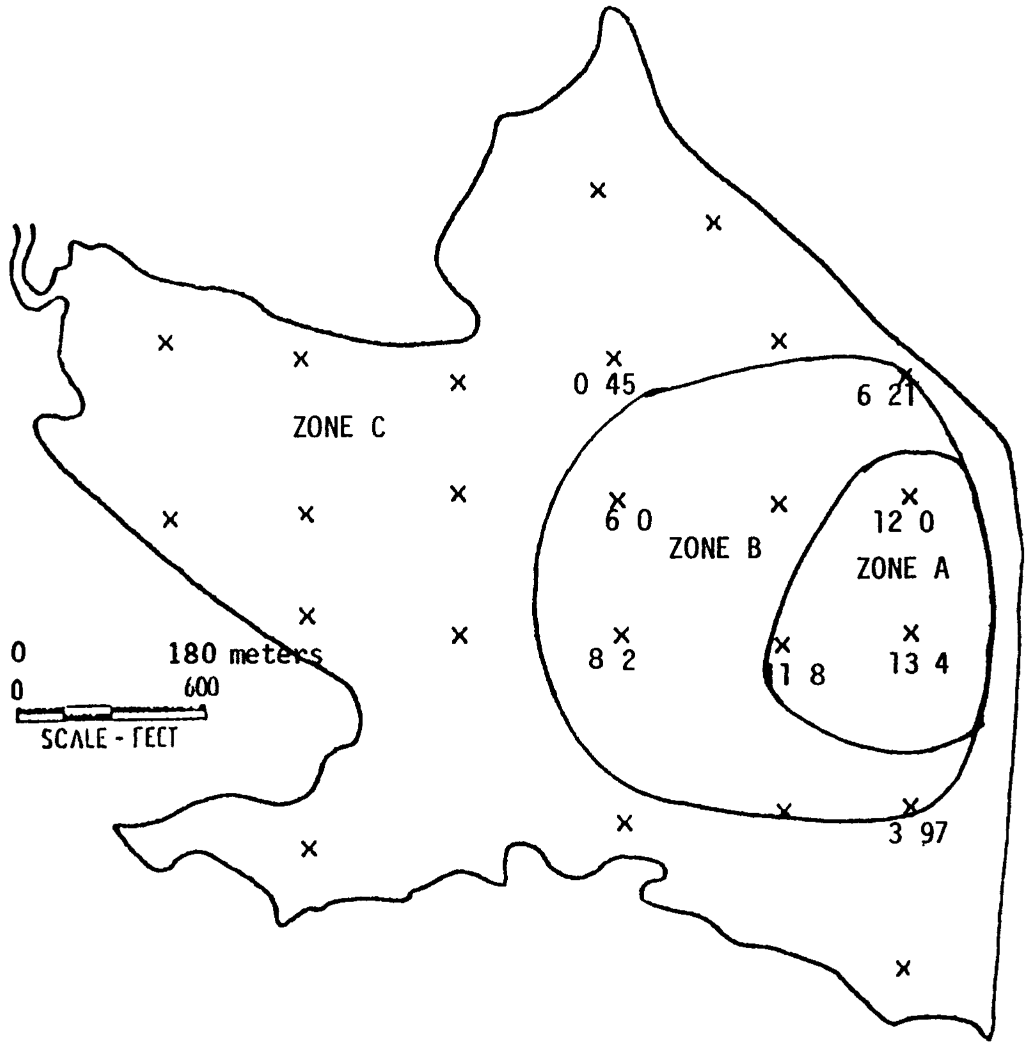

Figure 12 $^{239-240}$Pu Distribution in Surface (0-5 cm) Sediments in Great Western Reservoir and Zones Used for Estimating $^{239-240}$Pu Inventory in Sediments

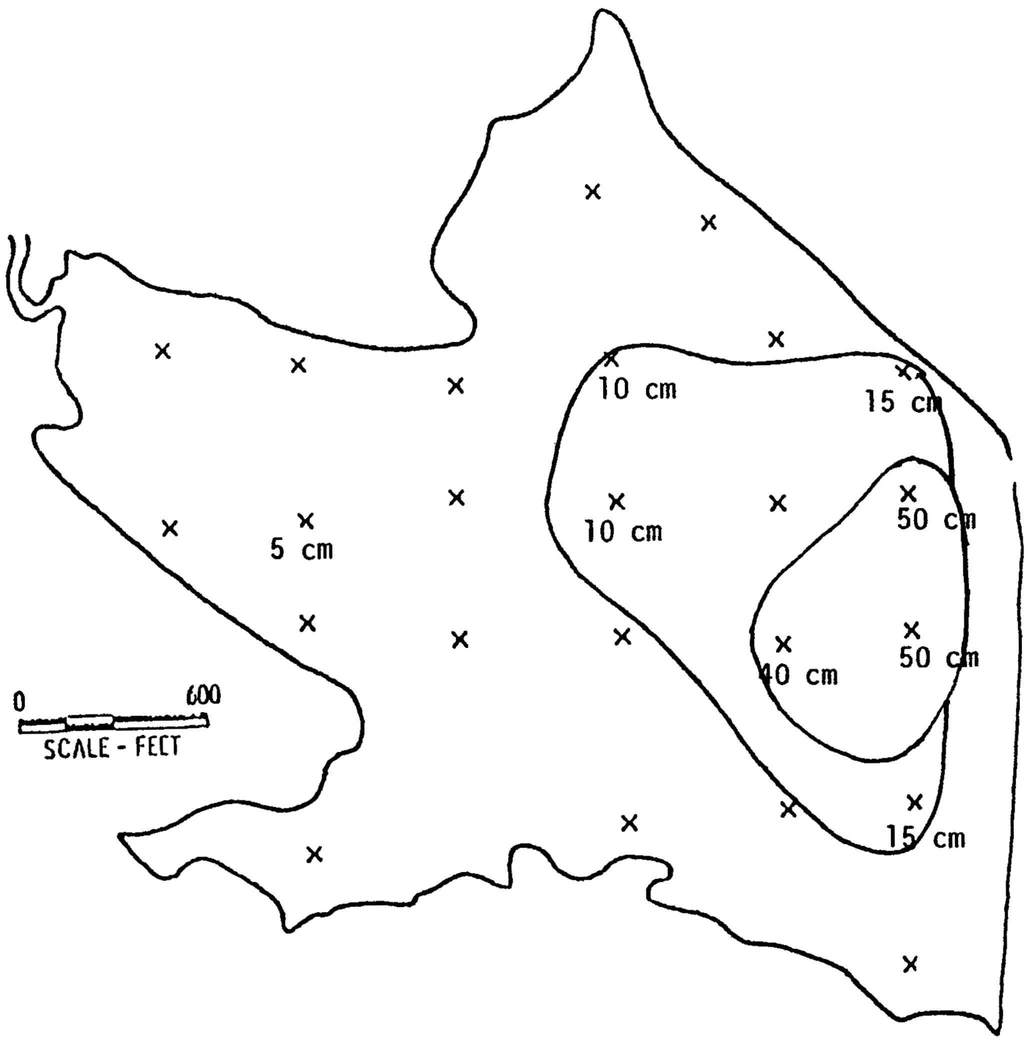

Figure 13   Approximate Depth of Sediments Deposited in Great Western Reservoir

DISTRIBUTION

No of Copies	
OFFSITE	
	A A Churm DOE Patent Division 9800 South Cass Avenue Argonne, IL 60439
2	DOE Technical Information Center
20	Douglas Hunt Health, Safety and Environmental Studies Rockwell International Atomics International Division Rocky Flats Plant P O Box 464 Golden, CO 80401
	M V Werkema, Manager Environmental Sciences Rockwell International Atomics International Division Rocky Flats Plant P O Box 464 Golden, CO 80401
ONSITE	
28	R W Perkins D E Robertson (10) C W Thomas (10) Technical Information (5) Publishing Coordination (2)

71/71