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PRELIMINARY ASSESSMENT OF RADIONUCLIDE TRANSPORT VIA STORM-WATER RUNOFF IN LOS ALAMOS CANYON, NEW MEXICO

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Abstract—Observations on streamflow, suspended-sediment concentration and radionuclide activity during a 7-8 September 1995 flow event provide insight into contaminant transport in Los Alamos Canyon. Measurable discharge data from two gaging stations, one above and one below the mouth of DP Canyon, show that flow persisted for 8.8 hrs and at the downstream gage ranged from 651 to 0.28 L/sec. Four storm-water samples, taken at 30-min intervals during the peak flow where NM-4 crosses Los Alamos Canyon below the mouth of DP Canyon, showed suspended-sediment concentration ranged from 40.3 to 4.4 g/L. Mean activity concentrations for the suspended sediments (pCi/g) include 15.4 for gross beta, 2.44 for ^{90}Sr, 1.54 for $^{239/240}$Pu, 0.15 for ^{238}Pu, 1.36 for ^{241}Am and 6.63 for ^{137}Cs. Mean activity concentrations for dissolved radionuclides (pCi/L) include 17.9 for gross beta and 5.05 for ^{90}Sr; ^{238}Pu, ^{241}Am and ^{137}Cs were not detected in the dissolved phase. The radionuclide $^{239/240}$Pu was detected at or near the method or instrument detection limit (0.05 to 0.04 pCi/L). Preliminary estimates of total radionuclide transport during the first 90 min of flow include 41.5 uCi of ^{90}Sr, 26.2 uCi of $^{239/240}$Pu, 2.5 uCi of ^{238}Pu, 23.1 uCi of ^{241}Am and 112.8 uCi of ^{137}Cs. Historical data indicate transport of radionuclides with suspended sediments in Los Alamos Canyon varies from year to year. This variability may be linked to the fluctuation in discharge contributed by DP Canyon. Additional monitoring of flow and transport processes in canyons that contain contaminants is warranted.

INTRODUCTION

Historically, Los Alamos National Laboratory (LANL) has disposed of liquid radioactive waste in several ways. The early years at LANL saw untreated radioactive wastes discharged to canyons, underground storage tanks and absorption beds (Nyhan et al., 1985). More specifically, LANL's initial plutonium and uranium processing facility at Tech Area (TA) 21, located adjacent to DP Canyon, generated and disposed of treated and untreated radioactive wastes to the environment from the early 1940s to 1985 (Anonymous, 1991).

DP Canyon is a tributary to Los Alamos Canyon that extends from Sierra de los Valles downstream to the Rio Grande, and drains portions of the Los Alamos townsite and TA-21. From 1945 through 1951 untreated liquid effluent from TA-21 was discharged into on-site absorption beds. The early waste-disposal records from TA-21 are not clear as to whether untreated wastes were discharged to DP Canyon during that period; however, treated liquid effluent was discharged into DP Canyon from 1952 through 1985 (Nyhan, et al., 1985). The study area (Fig. 1) thus encompasses Los Alamos Canyon between DP Canyon and New Mexico Highway 4 (NM-4).

Previous studies have shown that storm-water runoff from DP Canyon transports radiological contaminants both in suspended sediment and solution (Purtymun, 1974, 1975). However, the relationship between radionuclide transport and the hydrologic system(s), as well as the amount of radionuclides moving off-site, are not well understood. Complete analysis of the modern hydrologic transport of contaminants in both DP and Los Alamos Canyons would be of use in characterizing and/or assessing the impacts of historical contaminant releases. For example, do storm-water data obtained from samples taken at the laboratory boundary reflect drainage from Los Alamos Canyon and/or DP Canyon?

As part of the New Mexico Environment Department's Department of Energy Oversight mission (see Stone, this volume), storm-water transport of radionuclides, especially off-site, is of concern. The purpose of this study was to estimate DP Canyon's surface- water contribution to discharge recorded in Los Alamos Canyon at NM-4, identify radionuclides in a storm-water runoff event and generate preliminary estimates of the amount of contaminants carried off-site.

THE 7-8 SEPTEMBER, 1995 FLOW EVENT

Precipitation

This two-day flow event resulted from a storm occurring in the Los Alamos townsite on 7 September, 1995. As no data are available for the area draining to DP Canyon, I assume that precipitation there was the same as recorded at TA-53 (Fig. 1), located approximately 2.5 km from TA-21. From 17:00 through 21:00 hrs precipitation data were recorded by LANL's Environment, Safety and Health Division (ESH-17) at TA-53 in 15-min increments. Precipitation peaks of 6.86 and 1.02 mm (Fig. 2) occurred during the storm. The total amount measured at TA-53 was 18.8 mm.

Discharge

DP Canyon's runoff contribution and the total runoff exiting Los Alamos Canyon at NM-4 were calculated using provisional discharge records obtained from two gaging stations (Fig. 1) equipped with continuous stage recorders (5-min frequency) installed by the U.S. Geological Survey (USGS). GS-1, operated by LANL's Environment, Safety and Health Division (ESH-18), is located in Los Alamos Canyon approximately 60 m upstream (west) of the mouth of DP Canyon. GS-2, operated by USGS at the time of the flow event, is also located in Los Alamos Canyon, approximately 4 km downstream (east) of GS-1.

At approximately 19:23 the surface-water flow-front or surge was observed in DP Canyon above its confluence with Los Alamos Canyon, while flow at GS-1 was estimated to be <2 L/sec. Approximately 2 min later the instantaneous flow at GS-1 was 227 L/sec (Fig. 2). Therefore, it is assumed that the first recorded instantaneous flow at GS-2 (651 L/sec) was contributed solely by DP Canyon. Flow at GS-1 did not end until several days later. Downstream tributaries between DP Canyon and NM-4 contributed little (< 2 L/sec) or no flow. The duration of surface-water flow at GS-2 was from 20:30 through 05:15. In addition to the initial peak at 20:30 there was a secondary peak from 22:30 to 22:40. The mean discharge for the flow event in Los Alamos Canyon at NM-4 was 106 L/sec and total runoff was 3380 m^3.

DP Canyon's contribution to total discharge was determined by calculating the difference between instantaneous and mean flows recorded at GS-1 beginning at 19:25 and ending at 00:10, and GS-2 beginning at 20:30 and ending at 00:15, assuming a lag time of 65 min and minimal infiltration between the two gages. In other words, the instantaneous flow recorded at GS-1 at 19:30 reached GS-2 at 20:35, or 5 min after DP Canyon runoff reached GS-2. The mean discharge in DP Canyon was estimated at 97 L/sec and the total runoff was estimated at 1688 m^3.

RADIONUCLIDE TRANSPORT

Sample collection

Storm-water samples (LA-I, II, III, IV) were collected at the junction of Los Alamos Canyon and NM-4 (Fig. 1). The first sample was taken at 20:34, and represents the flow-front or surge. The remaining three samples were collected at 30-min intervals after the initial sample was taken. Therefore, the sampling interval spanned 90 min. It was assumed that

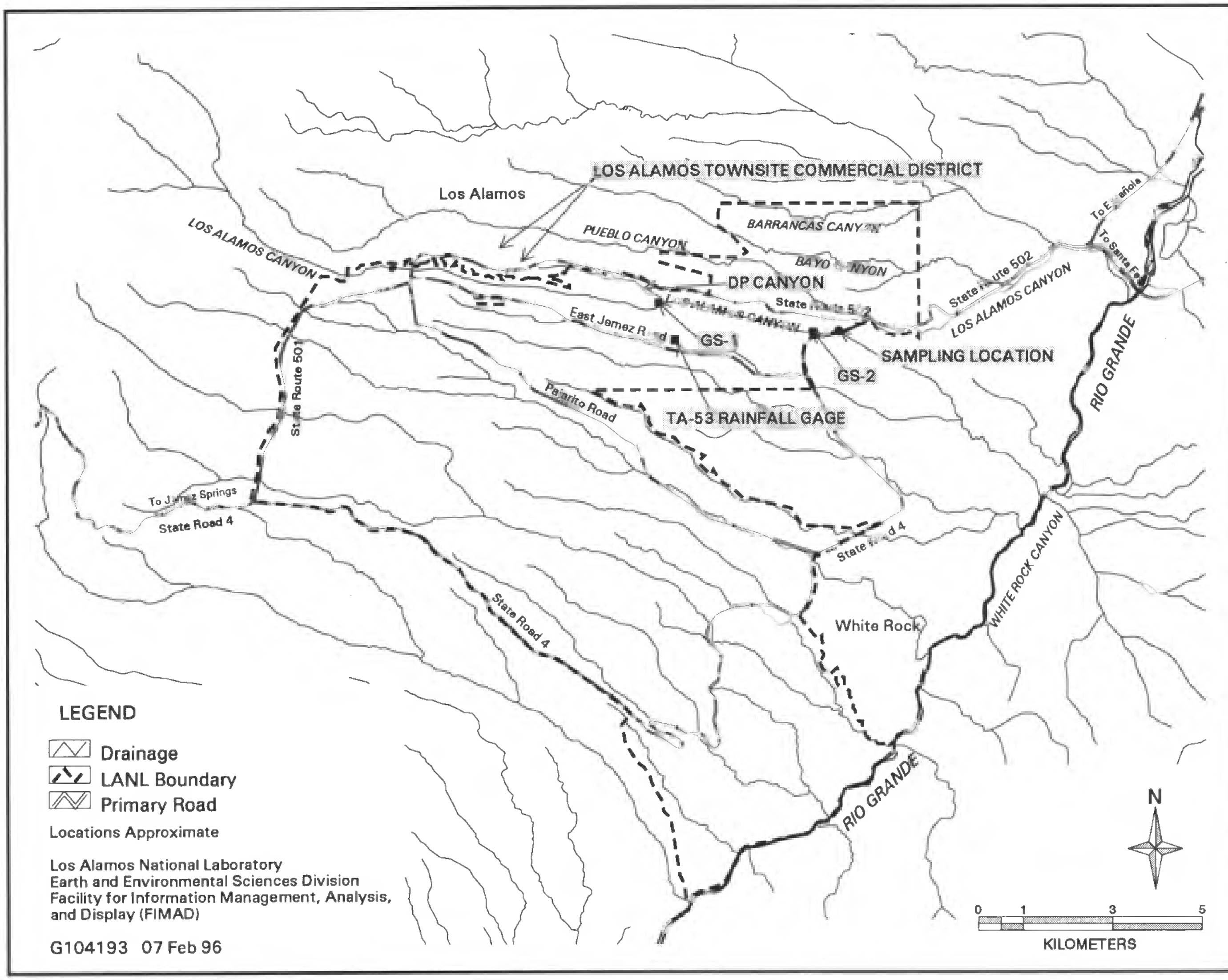

FIGURE 1. Location of streams, gages and sampling stations in the Los Alamos study area.

discharge at the sampling point correlates to discharge recorded approximately 4 min earlier at GS-2. The samples were collected at the approximate center of flow using a 1-L, wide-mouth (6-cm diameter) polyethylene container fastened to a staff (1.2 m in length) with two stainless-steel hose clamps. The opening of the container was submerged approximately 4 cm below the water surface and the container was swept parallel to flow direction in order to decrease the effects of back-washing. Approximately 7.6 L were collected per sample. The sampling container was thoroughly rinsed with deionized water prior to each sample collection. The samples were unpreserved, unfiltered, chilled to approximately 4° C and shipped on September 8, 1995, to a contract analytical laboratory. The samples were analyzed for total suspended solids and radionuclides (with both suspended sediment and dissolved; Tables 1 and 2).

Suspended sediment

Each sample was first decanted through a tared glass-fiber filter until only 1 L of slurry remained. The suspended sediment remaining on the filter was weighed. The remaining slurry was centrifuged in tared 250 ml

TABLE 1. Suspended-sediment radionuclide activity in storm-water samples collected in Los Alamos Canyon at NM-4.

SAMPLE ID	DATE	TIME	DISCHARGE *GS-2 (L/sec)	SUSPENDED SEDIMENT (g/L)	GROSS BETA (pCi/g)	unc	det	Sr-90 (pCi/g)	unc	det	Pu-239/240 (pCi/g)	unc	det	Pu-238 (pCi/g)	unc	det	Am-241 (pCi/g)	unc	det	Cs-137 (pCi/g)	unc	det
LA-I	9/7/95	20:34	651.17	40.3	13.3	1.8	0.74	1.46	0.43	0.47	1.833	0.238	0.01	0.086	0.023	0.02	0.98	0.55	0.03	4.60	0.41	0.21
LA-II	9/7/95	21:04	424.68	5.2	15.9	2.1	0.75	2.81	0.61	0.39	1.42	0.19	0.01	0.14	0.03	0.02	1.58	0.03	0.05	7.33	0.62	0.46
LA-III	9/7/95	21:34	263.30	5.7	16.5	2.2	0.75	2.78	0.62	0.45	1.50	0.19	0.01	0.14	0.03	0.02	1.44	0.03	0.04	6.85	0.54	0.45
LA-IV	9/7/95	22:04	158.55	4.4	15.9	2.1	0.75	2.69	0.60	0.42	1.39	0.19	0.03	0.22	0.05	0.03	1.44	0.05	0.03	7.74	0.93	0.32
		mean		5.1**	15.4	NA	NA	2.44	NA	NA	1.54	NA	NA	0.15	NA	NA	1.36	NA	NA	6.63	NA	NA
		standard deviation		0.54**	1.24	NA	NA	0.56	NA	NA	0.18	NA	NA	0.05	NA	NA	0.23	NA	NA	1.21	NA	NA

* - USGS gaging station # 08313042

unc - estimated total propagated uncertainties (2 sigma)

det - Method detection limit

NA - not analyzed or determined

** - mean and standard deviation values were calculated from LA-II, III and IV

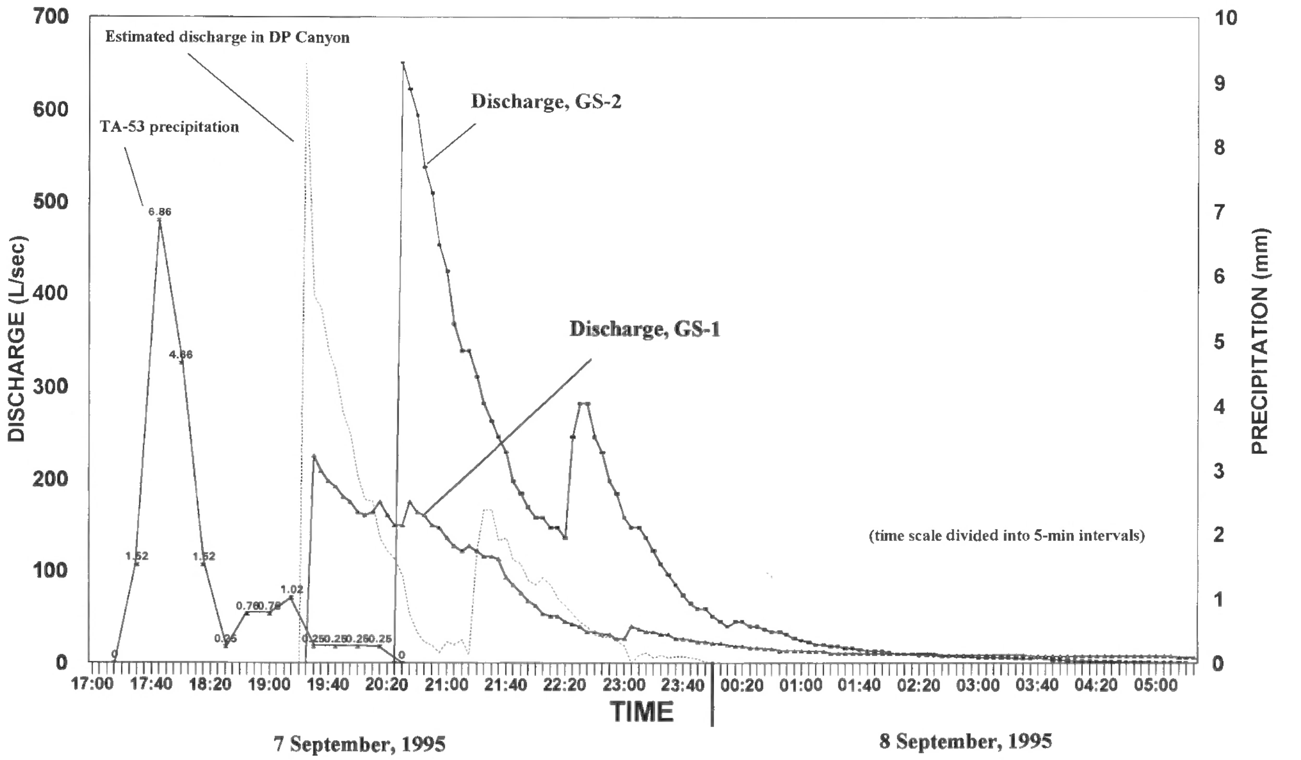

FIGURE 2. Hydrograph illustrating the relationships between precipitation at TA-53, surface-water flow at gaging stations in Los Alamos Canyon (GS-1 and GS-2), and estimated surface-water contribution by DP Canyon.

tubes; the separated water (supernate) was then filtered and added to the filtered liquids. The total volume of water was determined by summing the filtered water and supernatant. The total amount of suspended sediment was then calculated.

As noted at the time of collection, the initial sample (LA-I) contained the highest amount of suspended sediment, 40.3 g/L. The remaining three samples (LA-II, III and IV) contained 5.2, 5.7 and 4.4 g/L, respectively (Table 1). The mean concentration for the last three samples was 5.1 g/L with a standard deviation of 0.54. Due to the high suspended-sediment content of LA-I, the concentrations obtained for the first 90 min of flow were divided into two separate time intervals from 20:30 through 20:40 and from 20:40 through 22:00 in order to determine suspended-sediment transport. The suspended sediment transported during the first 10 min of flow was determined by assuming that its concentration decreased linearly from the initial value (40.3 g/L) to the mean value (5.1 g/L) calculated from the last three samples. The amount of suspended sediment transported during the first 10 min of flow is estimated to be 8676 kg. The amount of suspended sediment transported during the remaining 80 min. of flow, assuming a mean suspended-sediment concentration of 5.1 g/L, is estimated at 8343 kg. Thus, the total amount of suspended sediment transported during the first 90 min. of flow is estimated to be 17,019 kg. An unknown amount of additional suspended sediment would have been transported in flow occurring after 22:00.

Radionuclides in suspended sediment

The radionuclides ^{90}Sr, $^{239/240}$Pu, ^{238}Pu, ^{241}Am, and ^{137}Cs were detected in all suspended-sediment samples, with mean activity concentrations for the first 90 min of flow of 2.44 pCi/g, 1.54 pCi/g, 0.15 pCi/g, 1.36 pCi/g and 6.63 pCi/g, respectively (Table 1). Standard deviation for the radionuclide activity concentrations in suspended sediment ranges from 0.05 to 1.21. The mean activity concentration and standard deviation for gross beta in suspended sediment are 15.4 pCi/g and 1.24, respectively. Transport amounts for the radionuclides were calculated by multiplying their mean activity concentration by the total amount of suspended sedi-

TABLE 2. Dissolved radionuclide activity in storm-water samples collected in Los Alamos Canyon at NM-4.

SAMPLE ID	DATE	TIME	DISCHARGE *GS-2 (L/sec)	GROSS BETA (pCi/L)	unc	det	Sr-90 (pCi/L)	unc	det	Pu-239/240 (pCi/L)	unc	det	Pu-238 (pCi/L)	unc	det	Am-241 (pCi/L)	unc	det	Cs-137 (pCi/L)	unc	det
LA-I	9/7/95	20:34	651.17	24.6	4.0	0.60	7.2	1.4	0.59	0.05	0.02	0.01	ND	-	0.04	ND	-	0.15	ND	-	3.91
LA-II	9/7/95	21:04	424.68	17.3	2.5	0.42	4.8	1.0	0.63	NA	-	-	NA	-	-	NA	-	-	NA	-	-
LA-III	9/7/95	21:34	263.30	14.8	2.1	0.40	4.1	0.91	0.60	0.04	0.02	0.01	ND	-	0.04	ND	-	0.06	ND	-	3.37
LA-IV	9/7/95	22:04	158.55	14.9	2.2	0.42	4.1	0.91	0.61	NA	-	-	NA	-	-	NA	-	-	NA	-	-
		mean values		17.9	NA	NA	5.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		standard deviation		4.00	NA	NA	1.27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

* - USGS gaging station # 08313042
unc - Estimated total propagated uncertainties (2 sigma)
det - Method detection limit
NA - not analyzed or determined
ND - not detected

ment carried during the first 90 min of flow. The estimated amount of ^{90}Sr, $^{239/240}$Pu, ^{238}Pu, ^{241}Am, and ^{137}Cs transported off-site during the run-off event are 41.5 uCi, 26.2 uCi, 2.5 uCi, 23.1 uCi and 112.8 uCi, respectively.

Dissolved radionuclides

An aliquot from each sample was passed through a 0.45 micron filter prior to analysis by the contract analytical laboratory. Following filtration, all samples were analyzed for dissolved ^{90}Sr. In addition, samples LA-I and LA-III were analyzed for dissolved ^{137}Cs, ^{241}Am, $^{239/240}$Pu and ^{238}Pu.

^{90}Sr and $^{239/240}$Pu were detected in the dissolved phase (Table 2); however, the sample analyses showed the activity concentration of $^{239/240}$Pu to be at or near the method or instrument detection limits (0.05-0.04 pCi/L). Consequently, $^{239/240}$Pu transport in the dissolved phase could not be accurately quantified. All samples were found to contain ^{90}Sr in the dissolved phase. The mean activity concentration over the period represented by the four samples was 5.05 pCi/L, with a standard deviation of 1.27. The total amount of ^{90}Sr transported during the storm event in the dissolved phase was calculated by multiplying the total volume of water that was discharged at GS-2 (3380 m^3 or 3.38 X 10^6 L) by the mean ^{90}Sr activity concentration. This assumes that the mean ^{90}Sr activity concentration remained constant throughout the run-off/discharge event. If this assumption is valid, the total amount of ^{90}Sr released in the dissolved phase is estimated to be 17.1 uCi.

Historical trends

Historical data concerning radionuclide transport by storm-water run-off in Los Alamos Canyon at NM-4 has been reported in many of LANL's annual Environmental Surveillance Reports from 1982 through 1991. A careful review of the existing data showed no noticeable trends for radionuclide activity concentration in suspended sediment. The variability may be due to differences in DP Canyon's surface-water contribution. Such differences are in turn related to the intensity and duration of the storm, water velocity, and amount of bank erosion. Few or no data exist for some dissolved constituents, such as ^{90}Sr.

SUMMARY

Discharge measurements and estimates indicate that DP Canyon contributed approximately 50% of the flow that was transmitted off-site during this particular storm event. Therefore, this preliminary study suggests that the amount of surface-water contribution by DP Canyon during a storm event may have direct influence on radionuclide activity concentrations and volumes transported off-site, both absorbed to suspended sediment and in the dissolved phase. Further work is warranted.

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