PROBABILISTIC RISK ASSESSMENT FOR THE SANDIA NATIONAL LABORATORIES TECHNICAL AREA V LIQUID WASTE DISPOSAL SYSTEM SURFACE IMPOUNDMENTS

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ABSTRACT

A probabilistic risk assessment was completed for a former radioactive waste disposal site. The site, two unlined surface impoundments, was designed as part of the Liquid Waste Disposal System (LWDS) to receive radioactive effluent from nuclear reactors in Technical Area-V (TA-V) at Sandia National Laboratories/New Mexico (SNL/NM). First, a statistical comparison of site sampling results to natural background, using EPA methods, and a spatial distribution analysis were performed. Risk assessment was conducted with SNL/NM's Probabilistic Risk Evaluation and Characterization Investigation System (*Précis*) model.[1] The risk assessment indicated that contamination from several constituents might have been high enough to require remediation. However, further analysis based on expected site closure activities and recent EPA guidance indicated that No Further Action (NFA) was acceptable.

I. INTRODUCTION

In 1953, TA-V was established at SNL/NM to research nuclear reactor safety and to test the effects of radiation on weapons components and other equipment. It is one of five Technical Areas at SNL/NM and is located approximately eight miles southeast of downtown Albuquerque, New Mexico, within the boundaries of Kirtland Air Force Base. The SNL/NM Environmental Restoration (ER) Project has been characterizing and remediating inactive waste sites as part of the requirements under the Resource Conservation and Recovery Act (RCRA). The SNL/NM ER Project has completed a RCRA Facility Investigation (RFI) at the LWDS.

The LWDS was designed to receive, monitor, and discharge radioactive effluent from the Sandia Experimental Reactor Facility (SERF) in TA-V. The LWDS consisted of three holding tanks and an associated pumping system, a drainfield, and two surface impoundments (Figure 1). This discussion is focused on the evaluation of the LWDS Surface Impoundments (ER Site 4). Contaminants included radionuclides from reactor cooling water and metals from various industrial processes.

II. SITE HISTORY

The LWDS Surface Impoundments (Impoundments 1 and 2) were constructed in June 1967 and June 1970. Impoundment 1, the eastern impoundment, covers 8100 ft^2 (65 ft by 125 ft) and is 12 ft deep. Impoundment 2 covers approximately 9400 ft^2 (102 ft by 92 ft) and is 20 ft deep. Neither impoundment is lined. The impoundments were used for the disposal of the SERF's primary cooling water, and potentially contaminated waste water from experiments and operations in the SERF. In addition, waste oil and resin beads were disposed of in the surface impoundments on at least one occasion. The volume and radionuclide content of the discharges to Impoundments 1 and 2 between 1967 and 1971 were monitored and recorded. During those 5 years, approximately 12 million gallons of waste water containing approximately 14 Curies of measured radioactivity were discharged. It is assumed that the majority of these radionuclides were deposited in Impoundment 1, because Impoundment 2 was installed later, near the end of the time in which radioactive discharges occurred.

The last discharge of radioactive waste water from reactor operations occurred in April 1970. SERF waste water discharges to the impoundments were tracked and recorded until July 1971, when the Atomic Energy Commission relaxed this reporting

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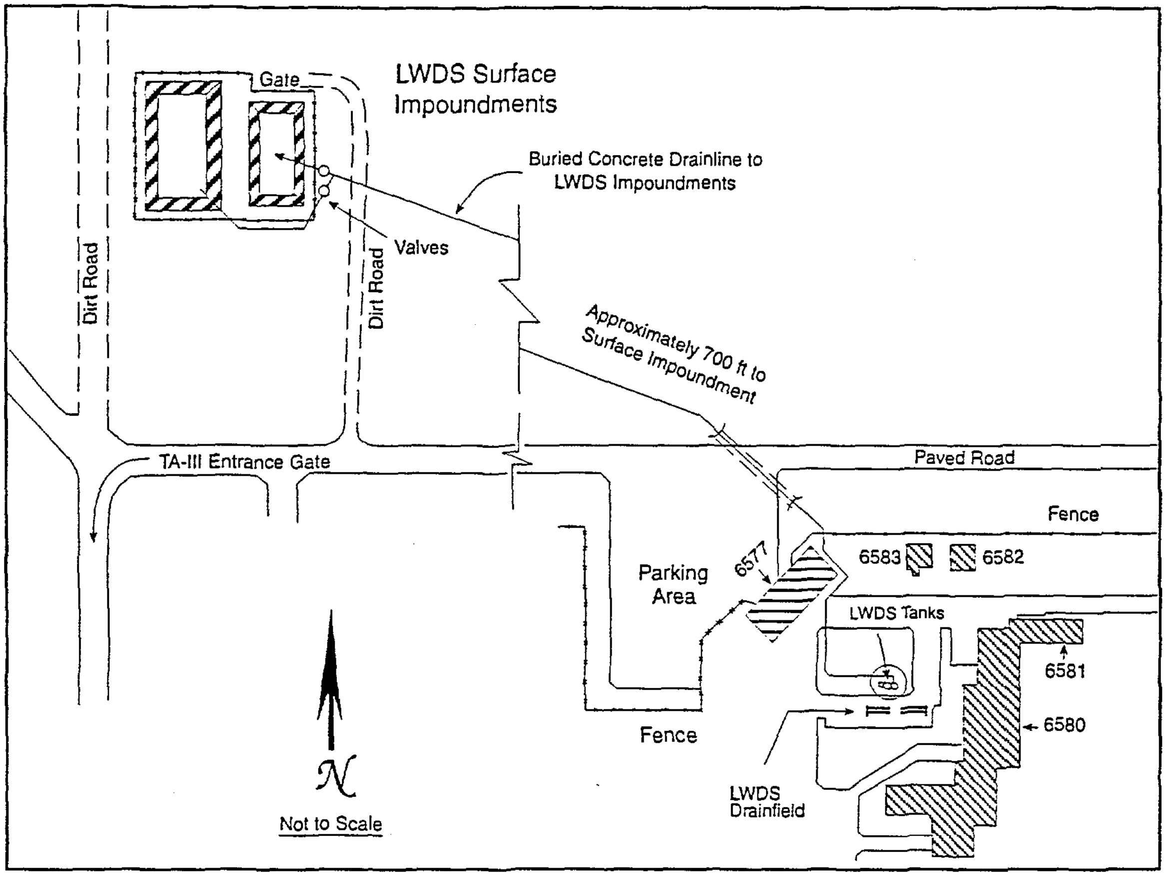

Figure 1. Liquid Waste Disposal System Site Map

requirement because the reactor was no longer in operation. Since that time, however, the impoundments continued to receive intermittent waste water discharges consisting of unmonitored, and reportedly uncontaminated, process-chilled water and waste fluids discharged to the LWDS through sinks and floor drains in the TA-V Hot Cell Facility. The DOE issued orders to stop these discharges in September 1992, and the impoundments have been inactive since.

Possible contaminants in the impoundments include radionuclides from the discharge of reactor cooling water, organic solvents and heavy metals from various industrial processes in TA-V, and polychlorinated biphenyls (PCBs) from a one-time discharge event.

III. SITE INVESTIGATION

Field investigations performed at the LWDS surface impoundments were designed to evaluate the horizontal and vertical extent of contamination. Investigation activities included a surface inspection/walk-over, radiation and organic vapor surveys, surface sampling, a geophysical survey, and the installation of nine boreholes and one ground-water monitor well.

A. Data Evaluation

Statistical and spatial correlations were performed on the data collected during the investigation. Initially, a constituent population was statistically compared to natural background using EPA-approved methods. Statistical tests used were the Wilcoxon Rank Sum Test (WRS), the Quantile Test, the Hot-Measurement Comparison (Upper Tolerance Limit Calculation), and the Student's T-test.[2,3,4] While these tests will not be discussed in detail here, it is generally accepted that each test has relative strengths and weaknesses and that the combination of all tests is superior to any single test. Any constituent of concern (COC) failing the statistical comparison was further analyzed for its spatial distribution. A strong spatial correlation between the impoundment discharge points and the suspected contamination at the impoundments was demonstrated. The combination of statistical techniques with the use of process history helped ensure a robust analysis.

B. Nature and Extent of Contamination

The previously described evaluation of the analytical results identified seven metals (cadmium, chromium (both chromium VI and total chromium), copper, lead, nickel, zinc, and barium), four radionuclides (cobalt-60, cesium-137, uranium-235, and tritium), and PCBs as contaminants. As expected, most of the contamination in the impoundments was concentrated under the drainline outfalls, and contamination was higher in Impoundment 1 than in Impoundment 2. No contamination was detected at depths greater than 5 ft. PCBs were concentrated in the southwest corner of Impoundment 2 and were clearly associated with a separate discharge event.

The evaluation is summarized in Table 1, which includes a few example constituents. The statistical analyses were not always in agreement. But, as previously mentioned, the combination of tests is comparatively more powerful than any particular one. Cesium-137, for example, has a nonparametric distribution and, as such, is not subject to the Student's T-Test. Cesium-137 passed the WRS, but failed the Quantile and UTL comparison. The spatial analysis for cesium-137 is shown in Figure 2. The grouping around the Impoundment #1 drainline outfall is a sure indicator of anthropogenic contamination. The WRS, Quantile, and Student's T statistical tests examine a constituent population and may not indicate a localized contamination. For example, cadmium passed all population analyses. However, the maximum concentration is well above the UTL, and the spatial analysis (Figure 3) clearly shows a pattern of contamination consistent with other site contaminants.

Table 1 - Results of the Statistical Analysis of Selected Constituents

Parameter (Distribution)	T- Test	Wilcoxon	Quantile	Background UTL	Maximum Concentration	Spatial	Contaminant
Barium (LN)	Fail	Pass	Pass	398.1(mg/kg)	849 (mg/kg)	Fail	Yes
Cadmium (LN)	Pass	Pass	Pass	3.5 (mg/kg)	154 (mg/kg)	Fail	Yes
Chromium (LN)	Fail	Fail	Pass	22.9 (mg/kg)	97.7 (mg/kg)	Fail	Yes
Nickel (LN)	Fail	Fail	Fail	15.4 (mg/kg)	173 (mg/kg)	Fail	Yes
Zinc (LN)	Pass	Fail	Fail	46.7 (mg/kg)	198 (mg/kg)	Fail	Yes
Cesium-137(NP)	N/A	Pass	Fail	0.9 (pCi/g)	10.1 (pCi/g)	Fail	Yes
Lead-212 (LN)	Pass	Pass	Pass	1.1 (pCi/g)	1.4 (pCi/g)	Pass	No

Note: LN = Lognormal; NP= Nonparametric; mg/kg = milligrams per kilogram; N/A = not applicable; pCi/g = picocuries per gram; ppb = parts per billion; Upper Tolerance Limit = UTL.

IV. RISK ASSESSMENT

A. Model Description

All contaminants at the surface impoundments were evaluated in a site-specific risk assessment, using SNL/NM's *Précis* computer model. In this model, the basic risk assessment methodology defined by the U.S. Environmental Protection Agency[5] is modified to allow probabilistic risk assessment by including a quantitative uncertainty analysis technique. *Précis* estimates an individual's annual radiation dose and hazardous chemical intake using a stochastic technique. This method provides an estimate of potential exposures by taking into account the uncertainties inherent in the program input parameters, such as COC concentration, soil density, and depth to groundwater. *Précis* evaluates this uncertainty in the exposure using a Latin-hypercube sampling technique that randomly selects trial values for each of the input parameters according to their probability distributions and calculates an exposure concentration for each group of trial values.

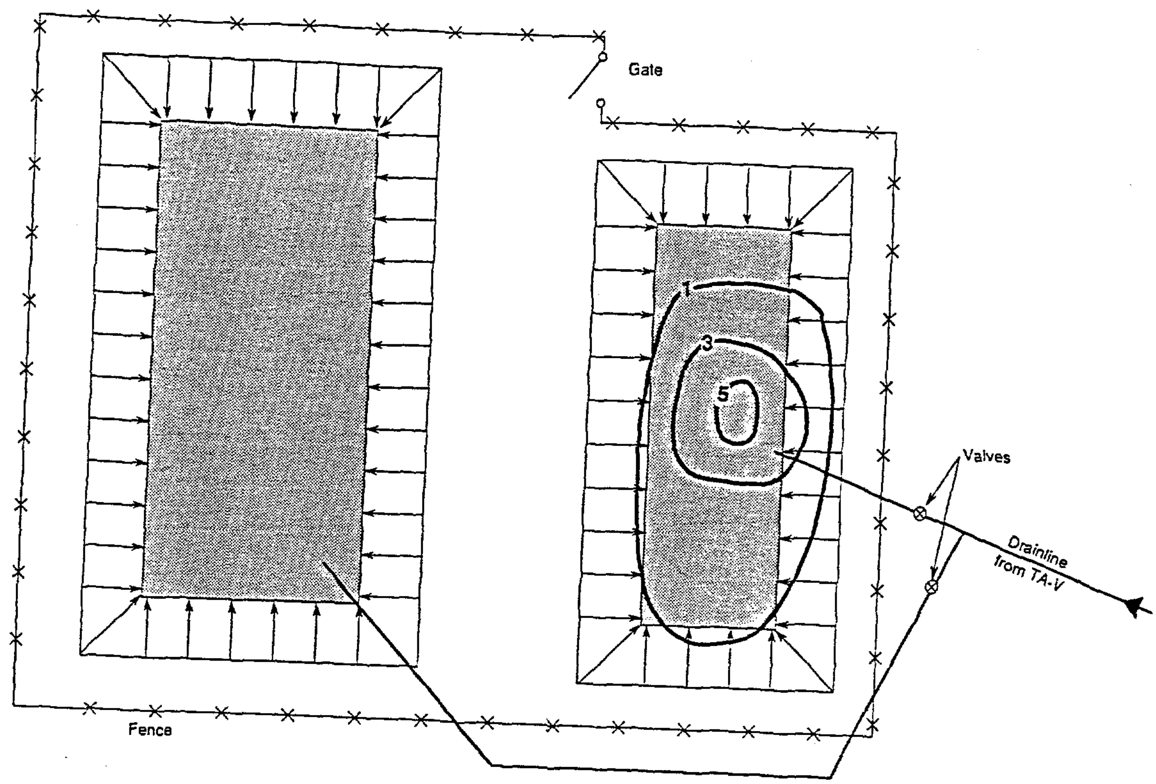

Figure 2. Surface Contaminant Contour Plots of Cesium-137 in pCi/gm

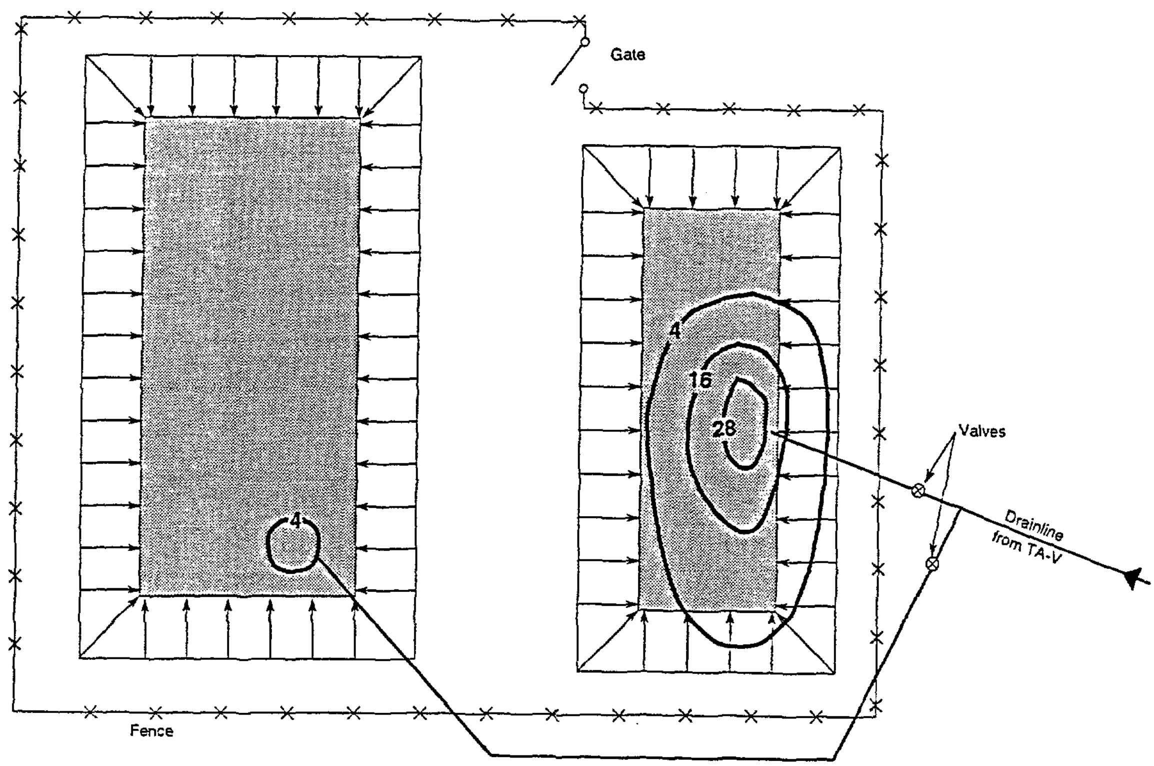

Figure 3. Surface Contaminant Contour Plots of Cadmium in mg/kg

The resulting output provides a distribution of the individual's annual dose rate and COC intake. As such, the dose, or intake, distribution represents the probability that the individual will receive a specified exposure, assuming that the exposure scenario does occur.

B. Methodology

After a constituent was determined to be anthropogenic, the *entire* sample population was used in the site-specific risk assessment, including concentrations within natural background levels. All exposure estimates were made according to an industrial land-use scenario. Initially, the SNL/NM risk assessment employs relatively simple process models to describe transport processes and conservative distributions of input parameters. If more detailed site-specific analysis is required, the preliminary risk assessment may be modified to include more rigorous analytical or numerical process models to describe transport processes.

C. Results

The radionuclide exposure evaluation is summarized in Table 2. According to the analysis, a worker would have a 95 percent probability of receiving 23 mrem/yr, approximately equal to the 25 mrem/yr radiation dose limit specified in DOE Order 5820.2A.[6] The maximum radiation dose was estimated to occur in 1994, but the estimated dose is decreasing with time as a result of the radioactive decay of the main radioactive contaminant, cobalt-60, which has a relatively short half-life of 5.27 years. Uranium-235 and tritium detected in some soil samples were not significant contributors to radiation dose.

Table 2 Annual Radiation Dose Estimates (mrem/yr)

	Time Since Sample Analyzed (year)						
	0 (1994)[a]	1 (1995)	3 (1997)	5 (1999)	10 (2004)	30 (2024)	100 (2094)
Minimum	1.7E-01	1.5E-01	1.1E-01	8.7E-02	4.4E-02	3.2E-03	4.0E-07
5 Percentile	5.7E-01	5.1E-01	3.9E-01	3.1E-01	1.6E-01	8.2E-03	9.7E-07
50 Percentile	3.1E+00	2.7E+00	2.0E+00	1.6E+00	9.3E-01	1.4E-01	7.1E-04
90 Percentile	1.5E+01	1.4E+01	1.1E+01	8.2E+00	4.4E+00	6.4E-01	2.6E-02
95 Percentile	2.3E+01	2.1E+01	1.7E+01	1.4E+01	9.3E+00	1.0E+00	4.1E-02
Maximum	8.8E+01	7.7E+01	5.9E+01	4.5E+01	2.4E+01	2.9E+00	8.6E-02

[a]The maximum radiation dose occurs in 1994, the year the samples were taken and analyzed.

Similar tables were developed, but not included here, for risks associated with exposure to carcinogenic and toxic contaminants. Estimates of incremental lifetime cancer risk from potential exposures to carcinogenic chemicals indicate that a worker in 1994 would have had a 52 percent probability of incurring greater than the 1×10^{-6} cancer risk limit judged acceptable by the EPA.[5] This cancer risk was associated primarily with potential ingestion of soil containing cadmium and chromium-VI. Estimates of systemic toxicity associated with potential exposures to heavy metal contamination indicate that the hazard index for a worker at ER Site 4 (with 95 percent probability) would be 0.04, far less than the value of 1.0 specified by the EPA.[5]

Because sufficient information is not currently available to address the potential health risk associated with lead in soil, no risk assessment for lead was made. The highest concentration of lead detected in soil at the LWDS surface impoundments was 72.5 ppm, well below the 400-ppm screening level specified by the EPA[7]. As discussed previously, the HI is very low and the potential contribution of lead is considered negligible.

D. Soil cover analysis

The risk assessment was repeated taking the proposed soil cover into account. The results showed no calculable cancer risk in this scenario based on no intake of carcinogenic chemicals. The maximum radiation dose was calculated to be less than 2×10^{-8}

mrem/year at the ground surface. The 2-m clean soil cover would effectively eliminate the exposure pathways for both radionuclide and chemical COCs under the industrial land-use scenario.

V. RESULTS AND RECOMMENDATIONS

The risk assessment performed for the LWDS indicates that concentrations of cobalt-60, cadmium, and chromium-VI may be high enough to require remediation at ER Site 4, if the site remains as it is presently configured. However, the following recommendations were made to support a proposal of No Further Action:

1. Part of the site closure activities under any circumstance will include filling the impoundments to grade with native soil. This leveling is required for safety considerations and is not considered a corrective measure. This fill will be a minimum of 6 ft thick, and more than 12 ft in most places. This action, although not specifically required for risk reduction, will lower the total risk from carcinogenic chemicals and radionuclides, such that estimated cancer risks and radiation doses are far below the applicable limits for the residential land-use scenario at 1×10^{-6} risk and 25 mrem/yr.

2. The risk assessment was based on the conservative EPA cancer risk limit of 1×10^{-6} specified by the EPA (1989). Recent EPA guidance suggests that cancer risk estimates up to 1×10^{-4} might be acceptable.[8] The latter guidance states, in part, "Records of Decision for remedial actions taken at sites posing risks within the 10^{-4} to 10^{-6} range must explain why remedial action is warranted." This risk assessment demonstrated that the cancer risk from cadmium and chromium-VI is well within the 1×10^{-4} risk limit and, therefore, a decision of No Further Action would be appropriate.

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