6.0 HISTORICAL TRENDS IN ONSITE THERMOLUMINESCENT DOSIMETER DATA

Film badges were used during early activities on the Nevada Test Site (NTS) for ambient gamma exposure monitoring. Thermoluminescent dosimeters (TLDs) replaced the film badges in 1977, with ten monitoring stations (locations) chosen to be near work sites. By 1981, this network had expanded to 163 locations covering most operational areas of the NTS. Since 1981, a few locations have been added or removed. From 1977 to 1987, the TLDs used were manufactured by the Harshaw Chemical Company. In 1987, a changeover was made to TLDs manufactured by Panasonic. Because of this changeover, a comparison of the early years to current years is not totally appropriate. The designated background and control locations are not comparable between the two types of TLDs because of the calibration procedures. In late 1988, a calibration problem was discovered that may have caused inaccurate results in the 1988 data. At the end of 1996, there were a total of 158 active TLD locations.

In 1996, 24 TLD locations were placed in inactive status due to reductions in funding levels. Some of these changes in status occurred at the beginning of the year, some at the beginning of the second quarter, and some at the beginning of the third quarter. Fifteen new TLD locations were established to satisfy requirements in the NTS Radiological Control Manual. The new locations are at the corners of three facilities that process radiological waste: the Area 3 Radiological Waste Management Site (RWMS-3), the Area 6 Decontamination Pad, and the Waste Examination Facility (WEF) in Area 5. In addition, a new TLD location was established at Gate 30-3P, at the junction of Cat Canyon Road and Buggy Road in Area 30, which replaces Boundary Station 349, which is now inaccessible, and two TLD locations were established at RWMS Pit 5.

BACKGROUND DATA

Table 6.1 displays the annual average millirem per year data from the 27 background and control locations for the current year and the previous ten years. An alphabetic notation (b) in this table denotes that no monitoring was performed at that location for the year. Most of the alphabetic notations (b) represent the boundary stations established in 1993, 1994, and 1995 which replaced locations that could only be reached by helicopter with locations that could be reached by truck. For comparison, the average external exposure for the United States is generally assumed to be 100 to 120 millirem per year, and the 1996 NTS average of all environmental locations was 120 mR/year. Figure 6.1 is a time series of boxplots of the data in Table 6.1. Boxplots consist of a box, whiskers, and outliers. A line is drawn across the box at the median. The bottom of the box is at the first quartile, and the top is at the third quartile value of the data. The whiskers are lines that extend from the top and bottom of the box to adjacent values. Adjacent values are the lowest and highest data values that are less that one and one-half times the interquartile range from the ends of the box. Outliers are data values outside the adjacent values and are plotted with an asterisk. Figure 6.1 and Table 6.1 reveal no obvious trends in the background TLD data. The years 1988 and 1993 show slightly elevated values compared to other years, and the other years have means and medians that are within generally accepted norms.

A review of the statistical properties of all TLD data (Chapter 5 herein and the corresponding chapters of previous annual reports) concludes that historically TLD data have lognormal statistical distributions. The reports for 1994, 1995, and 1996 found normal statistical distributions in those years. This presents a statistical problem since all parametric statistical

methods assume that all data have the same statistical distribution. Nonparametric methods have to be used otherwise. However, for just the background and control locations, the data for the individual years from 1986 through 1996 are reasonably fit by both lognormal and normal statistical distributions. Thus it is reasonable to use the untransformed data values for statistical test. A one-way analysis of variance (ANOVA) is the appropriate parametric statistical method to determine if there are any significant differences between years. This type of test will determine if there are any significant differences between years caused by any type of trend. If significance is found, then an evaluation for the type of trend can be done. Table 6.2 gives the results of the ANOVA on TLD mR/year to test for differences among the years 1986 through 1996 at the control and boundary locations. This table indicates that there is a significant difference among years. A probability value of less than 0.05 indicates that the hypothesis of no differences can be rejected with at least 95 percent confidence.

The next step is to determine what the significant differences are. An examination of the means and confidence intervals part of Table 6.2, along with the Tukey's multiple comparisons tests of this data indicate that the significance is due to the differences between the lowest annual average for 1986 and the two highest annual averages for 1988 and 1993. No other pairwise differences between annual mean values are statistically significant. This finding along with an examination of the boxplots in Figure 6.1 suggest that, although there are significant differences among years, no consistent trend is present in the control and background data.

ENVIRONMENTAL SAMPLING STATIONS

The historic data for the present year and the previous five years for all TLD sampling locations is presented in Attachment 6.1. The data are presented as annual exposures, mR/year. The background and control data analyzed in the previous section are included in this attachment. The attachment also contains the historical data for the operational monitoring TLDs at the waste management facilities. These locations are also identified in Table 5.2, in the previous chapter. An alphabetic notation (a) in this attachment indicates that no TLDs were placed at a location for the year. The pattern of the alphabetic notations (a) shows how monitoring locations have been added and removed over the years. The operational monitoring locations were removed from the data analyses discussed below because their exposures reflect operational activities rather than ambient exposures. The statistical procedures used to analyze the data in Attachment 6.1 are essentially the same as those used for only the background and control locations. Because substantially more data are available in Attachment 6.1 than the background and control locations, some additional analyses were performed.

The previous chapter discussed the statistical distribution of the control and background data, and concluded that the data could be analyzed using methods that assumed the data have a normal statistical distribution. The current year and past five years data were examined for statistical distribution using the same methods. The normal plot of the combined data for the six years showed two approximately linear segments that have a junction at a value between 200 and 250 mR/year. An examination of the data values that composed the two segments revealed that the upper segment contained the data from the operational monitoring locations and the locations that have been found to consistently yield atypical values. When this non-environmental data is removed from the data set the combined six years of data has an approximately normal statistical distribution. Thus parametric statistical methods can be used to test for historical trends.

A two-way ANOVA was used to test for differences in millirem per year due to differences among years or differences between operational areas or both of these effect variables. The test for both effects simultaneously is the interaction term of the ANOVA and in this case it is a test to determine if any time series trends are the same for all operational areas. Chapter 5, and the

corresponding chapters of previous years data reports, have found that there are significant differences in TLD gamma exposures among NTS operational areas. The areas are included in this ANOVA to remove that source of variability from the residual error and thus increase the power of the analysis. This effect could be considered a blocking variable. Both the classification variables were specified as fixed effects. It might be argued that the years considered, 1991 through 1996, are a sampling of all the years of historical data and thus should be a random ANOVA effect. However, any trend found in these six years of data is not likely to be a trend that is representative of longer time periods. Since the data is statistically unbalanced and rank deficient (there is no data for Area 30 in 1996), a General Linear Model program was used to compute the ANOVA.

The results of this ANOVA are presented in Table 6.3. This table shows no significant interaction and very significant effects for differences among years and differences among operational areas. Figure 6.2 is a normal probability plot of the residuals from this ANOVA. This plot is approximately linear and thus the assumption of normality is reasonable for this data. The significant differences between years were further examined graphically and with a one-way ANOVA. Figure 6.3 is a time series plot of boxplots of the data used in the ANOVA on environmental TLD data. The one-way ANOVA grouped the years into three nonoverlapping clusters. The first cluster is composed of the data from 1991 and 1992 and has a mean value of 147 mR/year. The second cluster contains only the data from 1993 and has a mean value of 167 mR/year. A calibration problem was discovered in the 1993 data. This problem was never resolved. The final cluster includes the data from 1994, 1995, and 1996 and has a mean value of 121 mR/year. This pattern of two years of intermediate gamma exposure levels, then a year of higher levels, followed by three years of lower exposure levels can be seen in Figure 6.3. This pattern is also present in the background data displayed in Figure 6.1. The boxes of the boxplots in Figure 6.3 show substantial overlapping of the interquartile ranges of the several years, thus the trend is not remarkable even though it is statistically significant. These results are consistent with the trends reported in the previous years data report. Note that the annual averages beginning in 1994 are approximately at the level that is generally considered to be worldwide background which is about 10 mR per month or 120 mR per year.

CONCLUSIONS

Two types of TLD data were analyzed to see if any significant historical trends might be detected. The analysis of the data from the control and background monitoring locations for the current year and the previous ten years found statistically significant differences between the lowest annual average from the 1986 data and the two highest annual averages from the 1988 and 1993 data. No consistent trend was found, and except for the two high annual averages, the background data values averaged within the generally accepted range of worldwide background exposure levels. There was a calibration problem in 1988, and thus the data for that year may less reliable than the data from other years. The second type of data consisted of all of the data from the NTS environmental monitoring TLDs for the current year and the previous five years. These data can be divided into three nonoverlapping groups of annual mean values: 1991 and 1992 annual means form the first group, then a significantly higher annual mean in 1993, followed by significantly lower annual means from 1994 through 1996. No consistent trend was noted, and the recent annual averages are at worldwide background levels.

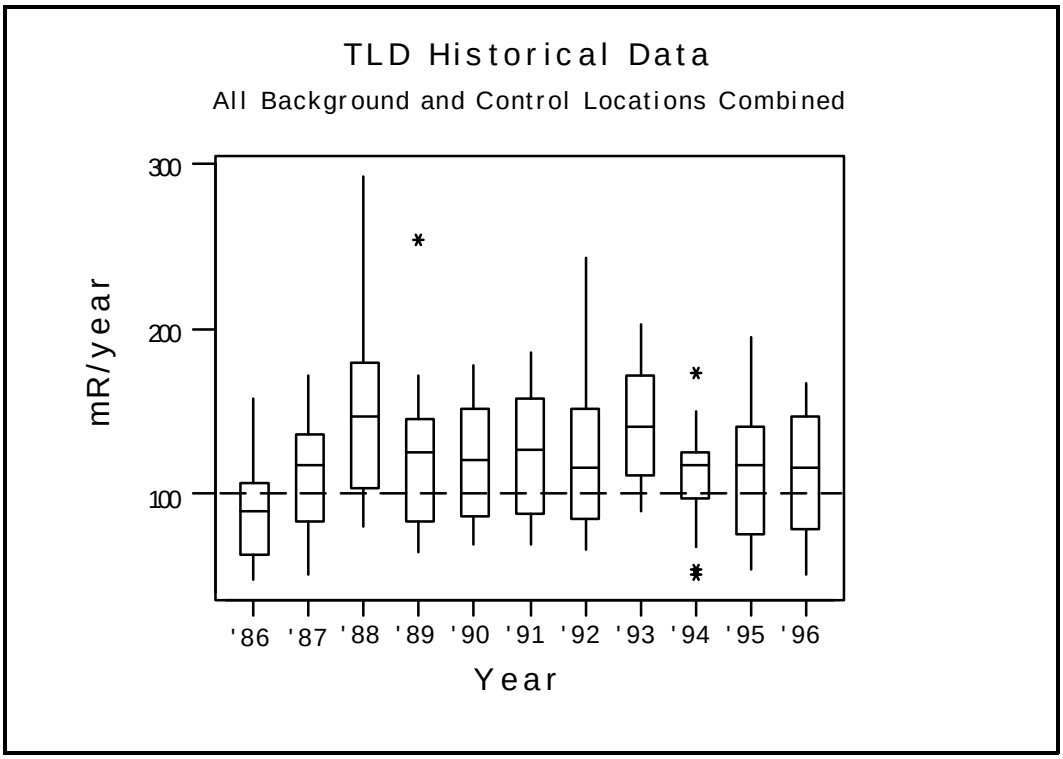

Figure 6.1 Time Series of Boxplots of Historical Background TLD Data

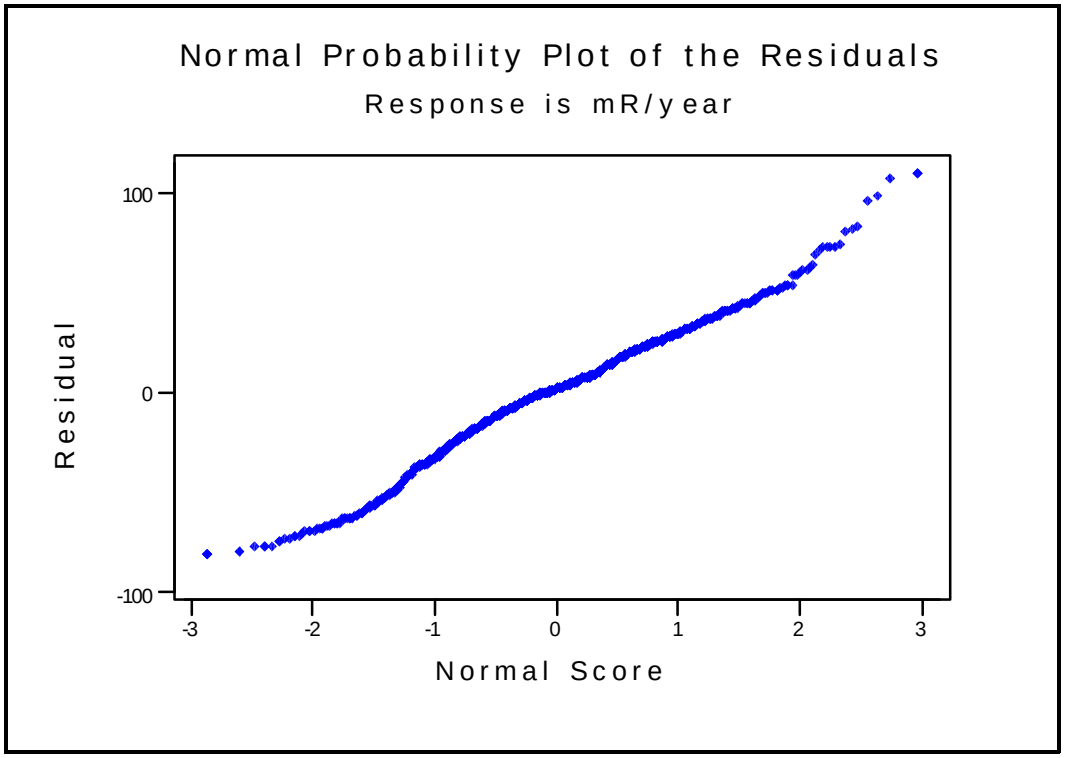

Figure 6.2 Probability Plot of Residuals from Two-Way ANOVA

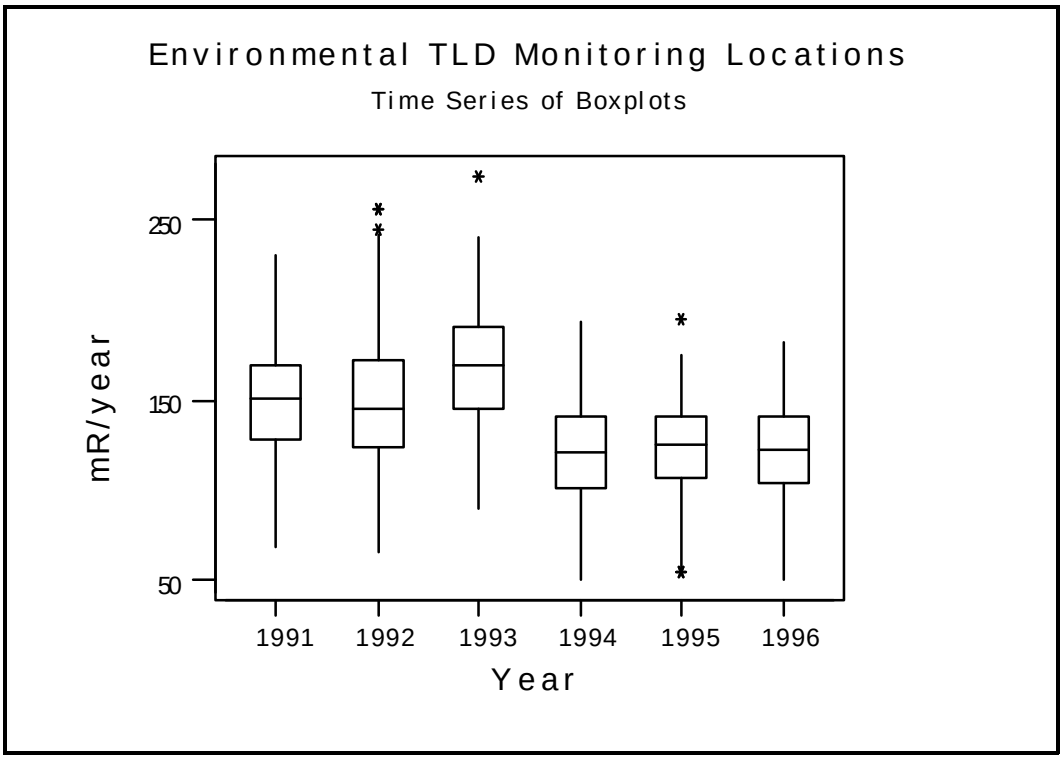

Figure 6.3 Time Series of Boxplots for Environmental TLDs

Table 6.1 Average Annual Millirem per Year for Designated Background and Control Locations

Area/Location	Year 1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Area 3, Hill Top	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	131	128
Area 5, Well 5B	79	119	157	129	125	133	113	144	125	108	109
Area 5, 3.3 Miles SE of Aggregate Pit	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	58	61
Area 6, CP-6	49	76	131	100	90	86	84	109	69	71	75
Area 6, Yucca Oil Storage	79	112	106	115	116	120	113	136	98	96	102
Area 9, Papoose Lake Road	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	116	77	76
Area 11, East of U11B	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	114	115
Area 12, Gold Meadows	99	115	135	135	114	119	117	135	97	95	102
Area 15, U-15e Substation	67	129	137	254	109	111	113	135	104	103	93
Area 18, Stake A-106	(b)	(b)	292	120	177	186	179	202	150	157	154
Area 19, Stake C-31	137	(a)689	262	264	174	178	176	183	123	195	146
Area 19, Stake R-29	158	172	179	172	170	167	242	197	142	140	147
Area 19, Gate 19-3P	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	108	135	147
Area 20, Stake J-41	(b)	(b)	(b)	(b)	(b)	(b)	(b)	186	143	140	129
Area 20, Stake LC-4	(b)	(b)	(b)	(b)	(b)	(b)	(b)	237	124	161	166
Area 20, Stake A-118	(b)	(b)	(b)	(b)	(b)	(b)	(b)	218	142	126	146
Area 22, Army Well No. 1	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	80	78
Area 23, Building 650 Dosimetry	112	51	95	69	73	69	66	95	53	54	51
Area 23, Building 650 Roof	47	62	86	64	69	69	66	90	51	54	50
Area 23, Post Office	57	89	106	83	83	86	84	109	78	71	64
Area 25, NRDS Warehouse	100	144	166	139	142	144	135	167	121	130	115
Area 25, Jackass Flats & A27 Rds.	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	71	80
Area 25, HENRE Site	99	123	170	138	143	147	132	163	115	119	123
Area 25, Guard Station 510	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	122	126
Area 25, Yucca Mountain	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	155	129
Area 27, Area 27 Cafeteria	89	139	179	118	146	154	143	169	121	121	124
Area 30, Gate 30-3P	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	165
Annual Averages	91	111	154	127	124	127	126	145	111	112	111

(a) Denotes a statistical outlier that was not used in the statistical analyses.

(b) Missing data values.

Table 6.2 One-Way ANOVA on Background Locations for Differences Among Years

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio	Probability Value
Year	10	44135	4414	2.69	0.004
Error	170	278470	1638		
Total	180	322606			

Year	N	mR/Year Mean	Deviation
1986	13	90.85	32.02
1987	12	111.33	35.07
1988	14	153.57	62.76
1989	14	127.36	49.09
1990	14	123.50	36.78
1991	14	126.50	38.66
1992	14	125.93	48.43
1993	14	145.29	36.05
1994	19	111.05	32.08
1995	26	111.77	37.70
1996	27	111.04	34.89

Pooled Standard Deviation = 40.47

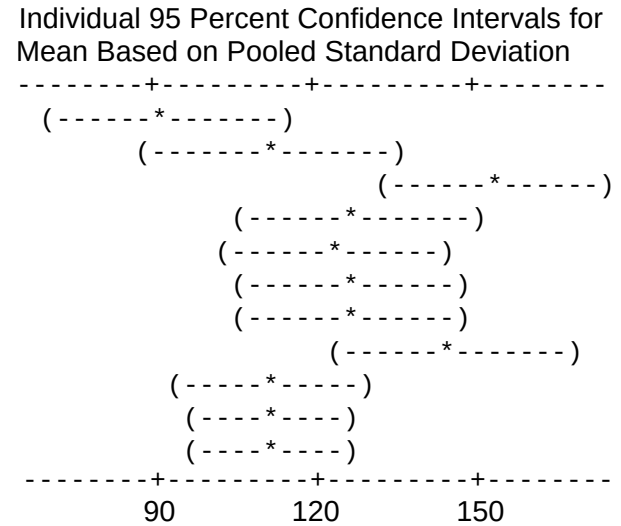

Table 6.3 ANOVA on mR/year for Effects of Years and Operational Areas

Source Term	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio	Probability Value
Year	5	92592.98	18518.6	39.10	0.0
Area	21	523446.6	24926.03	52.63	0.0
Year x Area	105	19501.76	185.7311	0.39	1.0
Error	746	353335.2	473.6397		
Total	877	1188098			