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*An Analysis of Precipitation Occurrences
in Los Alamos, New Mexico,
for Long-Term Predictions
of Waste Repository Behavior*

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Prepared by Sylvia M. Gonzales, Group HSE-12

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John Nyhan

Richard Beckman

Brent Bowen



AN ANALYSIS OF PRECIPITATION OCCURRENCES IN LOS ALAMOS, NEW MEXICO, FOR LONG-TERM PREDICTIONS OF WASTE REPOSITORY BEHAVIOR

by

John Nyhan, Richard Beckman, and Brent Bowen

ABSTRACT

This study describes precipitation as an uncontrolled natural input influencing the hydrology of waste repositories in terms of their ultimate long-term closure. The general climatology of the western states, including that of New Mexico and Los Alamos, is first described. An analysis of the precipitation patterns at Los Alamos is then presented to be used for predicting long-term precipitation occurrences and shallow land burial site behavior. The waste management implications of this precipitation analysis are then discussed and future meteorological research needs are identified.

I. INTRODUCTION

A. Background

Since the beginning of the Manhattan Project during World War II, major federally funded research involving the use of radioactive materials has been conducted at Government-owned and -operated laboratories. Weapons production, nuclear power research, and marine power production are the main Government-sponsored activities generating radioactive waste. In the weapons program, radioactive materials used for nuclear explosive devices are produced, processed chemically, assembled, and maintained. The Department of Energy (DOE) reprocesses spent fuel from marine power plants and DOE-owned test reactors and reuses the recovered uranium and performs nuclear power research activities. Each of these activities generates significant quantities of radioactive waste, much of which is disposed of in near-surface disposal facilities at DOE sites such as those at the Los Alamos National Laboratory.

Regulations and DOE Orders exist which mandate stabilization and final closure of

low-level radioactive waste disposal sites. Present requirements are based on radioactive half-lives and other characteristics of radionuclides contained in low-level wastes (LLW). However, uranium and transuranic wastes were also buried before 1970 at most existing DOE LLW disposal sites. The half-lives of these radioisotopes greatly exceed the required performance period for LLW stabilization activities. In addition, many sites contain uncharacterized volumes of both liquid and mixed hazardous waste. Requirements for management of LLW, specifically for stabilization and closure of disposal sites, are sometimes inadequate for site stabilization or are contradictory to regulations pertaining to other materials buried in existing DOE disposal sites. Inadequate disposal records and lack of cost-effective in situ characterization techniques complicate determining which regulations apply to a site or to areas within a waste disposal site.

Because DOE Order 5820.2 contains only general requirements for site closure, other regulations that are pertinent but perhaps not legally applicable, should be reviewed in the development of site-specific performance requirements, such as those published by the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA). Specific performance requirements for closure of disposal sites containing LLW, transuranic (TRU) wastes or hazardous wastes found in present regulations 10 CFR 61 (US NRC 1982), 40 CFR 265 (US EPA 1980), and 40 CFR 191 (US EPA 1985) are shown in Table 1. Regulations for disposal of LLW and TRU are based on both site selection and design requirements stipulated under these requirements and on a site containing only one waste type. Obviously, it is the intent of these postclosure requirements (Table 1) to limit the exposure of the general public to radioactive and hazardous wastes for time periods ranging from 100 to 10,000 years.

B. Hydrology of Shallow Land Burial

If we examine for potential impact on dose to man the ecosystem processes that influence site closure and long-term site performance (Figure 1), we note that water

Table 1. Postclosure Requirements for Disposal of LLW, TRU, and Hazardous Waste

Statute	Sites Governed	Postclosure Performance Objectives
DOE Order 5820.2 Chapter III ^a	DOE low-level waste disposal sites.	– Annual dose limit of 500 mrem to any member of the general public; doses must be maintained at levels as low as reasonably achievable. (Operational limit only. No DOE-wide limits exist for closure.)
10 CFR 61 ^b	Commercial sites for shallow-land disposal of low-level waste.	– Annual dose to any member of the general public not to exceed 25 mrem to whole body, 75 mrem to thyroid, 25 mrem to any other organ. – Protection of individuals from inadvertent intrusion. – Long-term stability of site (500 years). – 100-year maximum institutional control period. – Buffer zone.
10 CFR 191 ^c	Sites developed for management and disposal of spent nuclear fuel, high-level and transuranic radioactive wastes.	– Long-term stability of site (10,000 years). – Meet release limits for specific radionuclides (191.13). – Annual dose to any member of the general public not to exceed 25 mrem to whole body, 75 mrem to thyroid, 25 mrem to any other organ, for 1000 years after (undisturbed) disposal. – Meet specific ground water protection requirements for 1000 years disposal (undisturbed).
40 CFR 265 ^d	Hazardous waste facilities.	– Minimize need for further maintenance of hazardous waste constituents, leachate, contaminated rainfall, or waste composition products to the ground or surface waters or the atmosphere.

^aRadioactive waste management, management of low-level waste.

^bLicensing requirements for land disposal of radioactive waste.

^cEnvironmental standards for the management and disposal of spent nuclear fuel and high-level and transuranic radioactive wastes.

^dInterim status standards for owners and operators of hazardous waste treatment, storage, and disposal facilities.

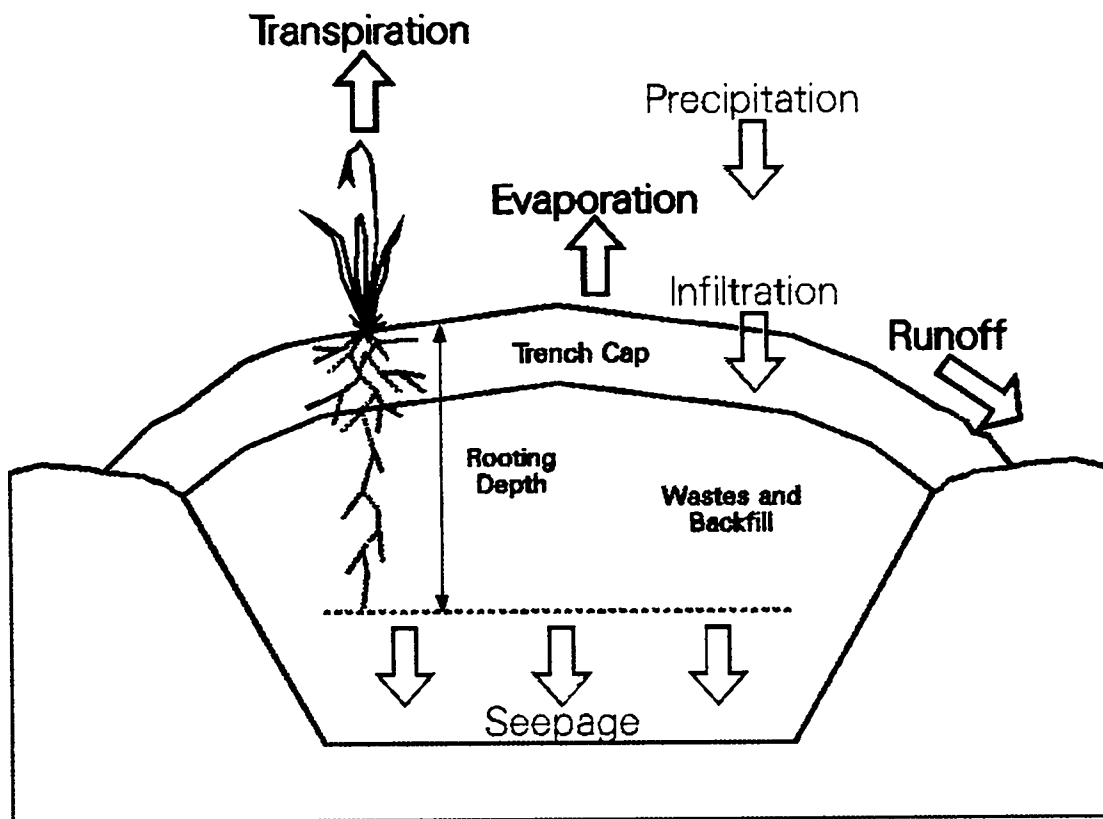


Figure 1. Hydrologic processes affecting shallow land burial sites.

and soil dynamics, as influenced by physical and biological factors, account for most of the performance-related problems (Nyhan 1988). For example, erosion associated with the runoff from a trench cap can breach the cap and expose waste to the biosphere.

Consequently, erosion rates on the shallow land burial (SLB) cap must be within tolerances that leave the cap intact over the entire life of the LLW disposal facility. Likewise, water that infiltrates the trench cap can accumulate in the trench (bathtub effect) and/or percolate in association with solutes into ground water. Percolation also enhances subsidence of the trench cap as a result of decomposition of bulky waste in the trench. Finally, both plants and animals, in addition to playing an important role in water balance, can penetrate into the waste and transport radionuclides to the ground surface as a result of root uptake and/or burrowing activities.

Although hydrology is only one component of the total SLB system, water is the principal element: it causes erosion, carries contaminants, and is an uncontrolled natural input. Each climatic region and physiographic area has its own characteristic uncontrolled natural input of water to the SLB system, and this precipitation input affects the response of the system (Fig. 1). These varied meteorological conditions must be kept in mind when considering wide-scale applicability of a long-term SLB site closure design.

In this study, the climatology of the western states, including that of New Mexico and Los Alamos, is first described as a unique setting for an SLB waste repository site. Because temperature and precipitation are the principal climatic elements, patterns for the distribution of these elements are discussed at all three of these land scales. An analysis of the precipitation patterns at Los Alamos, New Mexico, from 1911 to 1986 is then presented, with the ultimate target goals of predicting both long-term precipitation occurrences and SLB site behavior (Fig. 1).

II. CLIMATOLOGY OF THE WESTERN STATES, INCLUDING THAT OF NEW MEXICO AND LOS ALAMOS, AS A FACTOR INFLUENCING WASTE DISPOSAL SITE DESIGN

Many different and distinct climates exist over the eleven continental western states and influence hydrologic, biological, chemical, and pedogenetic processes occurring at waste disposal sites in these diverse environments. This diversity in climate is due to a number of geographical and meteorological factors.

First, this western area is extremely large, extending through 1,200 miles of latitude and through 1,100 miles of longitude (Soils of the Western United States 1964). Such great distance in latitude causes a great variation in temperatures. An average change of 2 to 2 1/2°F in mean annual temperature is found for each 100-mile segment of the transect. Other factors being equal, one can expect a change of about 27°F in mean annual

temperature from the Canadian border to Mexico, and a similar change of about 7⁰F from the northern to the southern border of New Mexico.

Secondly, climate varies with topography. An extensive part of the western United States consists of elevated plateaus, mountains, and mountain basins. The orientation and slope of these mountain ranges with respect to the direction of prevailing winds exert important effects on the climate. For mountain ranges in the western portions of this region, areas on the windward side of the mountains receive greater amounts of precipitation than do areas on the leeward side. Within the Los Alamos environs, precipitation is heavier over and east of the Jemez Mountains (adjacent to Los Alamos) and the Sangre de Cristo Mountains than farther west because thunderstorms are carried by upper winds away from the mountains (toward the east). In addition, mean annual temperature decreases about 3⁰F for each 1,000-foot rise in elevation. Considering the large range in elevation—from sea level to over 14,000 feet—the corresponding reduction in mean annual temperature can amount to a change of about 40⁰F in the western states. In New Mexico, the mean annual temperatures range from 64⁰F in the extreme southeast to 40⁰F or lower in the high mountains and valleys of the north [National Oceanic and Atmospheric Administration (NOAA) 1977]. Other climatic elements such as wind, humidity, cloudiness, and radiation are similarly modified by their location or by their elevation.

Meteorological forces inherent in the general atmospheric circulation produce large-scale climatic patterns over the western states. For example, the cloudy and rainy winter climate (with warm and dry summer seasons) that occurs over the coastal states is the result of atmospheric forces that prevail over the eastern Pacific Ocean (Soils of the Western United States 1964). This general regime of wet winters and dry summers is modified gradually over the inland areas, but its effect can be traced to the Continental Divide in the Rocky Mountains, particularly during the winter season. In contrast, the

eastern border of the western United States, the Great Plains, is influenced by frequent cold and dry air masses from Canada during the winter, and by the persistent flow of warm southerly winds from Mexico and the Gulf of Mexico.

The vast intermountain area between the Pacific Coast and the Great Plains thus becomes a region for interplay of these atmospheric forces from the Pacific Ocean to the west, from Canada to the north, and from Mexico and the Gulf of Mexico to the south and southeast. It is these forces in combination with the vast size and varied relief of the western area that produce a multiplicity of climates. As a result, much of the western United States is characterized by a change in climate within relatively short distances.

Because temperature and precipitation are the principal climatic elements, patterns for the distribution of these elements are discussed in greater detail.

A. Temperature

The temperature patterns range from rather cool summer weather (moderate in winter) along the Pacific Coast to hot summers (and mild winters) over the southwest plateaus and deserts. The intermountain basins and Great Plains are generally mild to quite warm during summer and cold during the winter. There are variations in these sections occasioned by differences in altitude. Along the coast, the climate is marked by a small diurnal change, by small day-to-day changes, and by a minimum of change from one season to another. Inland, the continental influence gradually prevails so that temperatures not only average higher in summer (and lower in winter) but also show greater variability in diurnal range and in day-to-day changes. Over the western United States, these temperature variations reach a maximum over the Great Plains.

Mean annual temperatures in New Mexico range from 64°F in the extreme southeast to 40°F or lower in high mountains and valleys of the north; elevation is a greater factor in determining the temperature of any specific locality than is latitude (NOAA 1977). During the summer months, individual daytime temperatures quite often

exceed 100°F at elevations below 5,000 feet; but the average monthly maximum temperatures during July, the warmest month, range from slightly above 90°F at lower elevations to the upper 70s at high elevations. Warmest days quite often occur in June before the thunderstorm season sets in; during July and August, afternoon convective storms tend to decrease incoming solar radiation, lowering temperatures before they reach their potential daily high. The highest temperatures of record in New Mexico are 116°F at Orogrande on July 14, 1934, and at Artesia on June 29, 1918. A preponderance of clear skies and low relative humidities permits rapid cooling by radiation from the earth after sundown; consequently, nights are usually comfortable in summer. The average range between daily high and low temperatures is from 25° to 35°F.

In January, the coldest month, average daytime temperatures range from the middle 50s in the southern and central valleys to the middle 30s in the higher elevations of the north. Minimum temperatures below freezing are common in all sections of the state during the winter, but subzero temperatures are rare except in the mountains. The lowest temperature recorded at regular observing stations in the state was -50°F at Gavilan on February 1, 1951. An unofficial low temperature of -57°F at Ciniza on January 13, 1963, was widely reported by the press. The freeze-free season ranges from more than 200 days in the southern valleys to less than 80 days in the northern mountains where some high mountain valleys have freezes in summer months.

Plentiful sunshine occurs in New Mexico, with from 75% to 80% of the possible sunshine being received. In winter, this is particularly noticeable with from 70% to 75% of the possible sunshine being received. It is not uncommon for as much as 90% of the possible sunshine to occur in November and in some of the spring months. This solar radiation directly affects New Mexico's temperature and potential evaporation, which is much greater than average annual precipitation. Evaporation from a Class A pan ranges from near 56 inches in the north-central mountains to more than 110 inches in

southeastern valleys. During the warm months, May through October, evaporation ranges from near 41 inches in the north—central to 73 inches in the southeast portions of the state.

More specifically, Los Alamos has a semiarid, temperate mountain climate. Summers are generally sunny with moderately warm days and cool nights (Environmental Surveillance Group 1987). Maximum temperatures are usually below 90°F. Brief afternoon and evening thundershowers are common, especially in July and August. High altitude, light winds, clear skies, and dry atmosphere allow night temperatures to drop below 60°F after even the warmest day. Winter temperatures typically range from about 15° to 25°F during the night and from 30° to 50°F during the day. Occasionally, temperatures drop to near 0°F or below. Many winter days are clear with light winds, so strong sunshine can make conditions quite comfortable even when air temperatures are cold. Snowstorms with accumulations exceeding 4 inches are common in Los Alamos.

B. Precipitation

One common distinguishing feature of the western United States is that much of the area is dry; i.e., annual precipitation is less than 20 inches (Soils of the Western United States 1964). This dryness is, in general, most acute (precipitation under 10 inches) in portions of the southwestern United States where high temperatures and high evaporation rates decrease the efficiency of the scant precipitation and thus intensify the arid conditions. In contrast, there are sizable areas that receive substantial precipitation (30–40 inches or more) and can be considered as water—surplus areas. These areas would include sections west of the Sierra Nevada and Cascade mountains in the three coastal states as well as the Pacific side of higher mountain locations in each of the eleven western states.

Another characteristic feature about distribution of precipitation in the western United States is the large variation that occurs within rather short distances. Topography is largely responsible for these abrupt changes. It is not unusual for annual precipitation to

increase (or decrease) a total of 50 inches in a distance of 20 miles as the terrain changes from a valley location to a mountain summit.

There are also seasonal differences in the various precipitation patterns. Over the Pacific Northwest, the heaviest rainfall month is December; farther south along the California coast, the heaviest precipitation is delayed until January and February. Over the northern and central intermountain region, a continental effect produces a secondary precipitation pattern during the spring months of April and May. In some sections, these springtime showers are greater than the wintertime precipitation. Farther south, specifically in Arizona and New Mexico, the spring months are dry. Here the primary precipitation peak is delayed until July and August, when later summertime thunderstorms are common in the higher mountains. East of the Continental Divide (the Great Divide), the Great Plains receive their maximum precipitation during May or June.

In New Mexico, average annual precipitation ranges from less than 10 inches over much of the southern desert and the Rio Grande and San Juan valleys to more than 20 inches at higher elevations in the state. Summer rains fall almost entirely during brief but frequently intense thunderstorms. The general southeasterly circulation from the Gulf of Mexico brings moisture for these storms into the state, and strong surface heating combined with orographic lifting as the air moves over higher terrain causes expansional cooling and condensation. July and August are the rainiest months over most of the state, with from 30% to 40% of the year's total moisture falling at that time. The San Juan Valley area is least affected by this summer circulation, receiving about 25% of its annual rainfall during July and August. During the warmest 6 months of the year, May through October, total precipitation averages from 60% of the annual total in the northwestern plateau to 80% of the annual total in the eastern plains.

Average total annual precipitation at Los Alamos is nearly 18.5 inches (46.9 cm) for the years 1911 through 1986 (Fig. 2). The annual precipitation data for 1916–1918,

ANNUAL PRECIPITATION AT LOS ALAMOS

1911-1986

Annual average 1911-1986: 18.48 in. (46.94 cm)

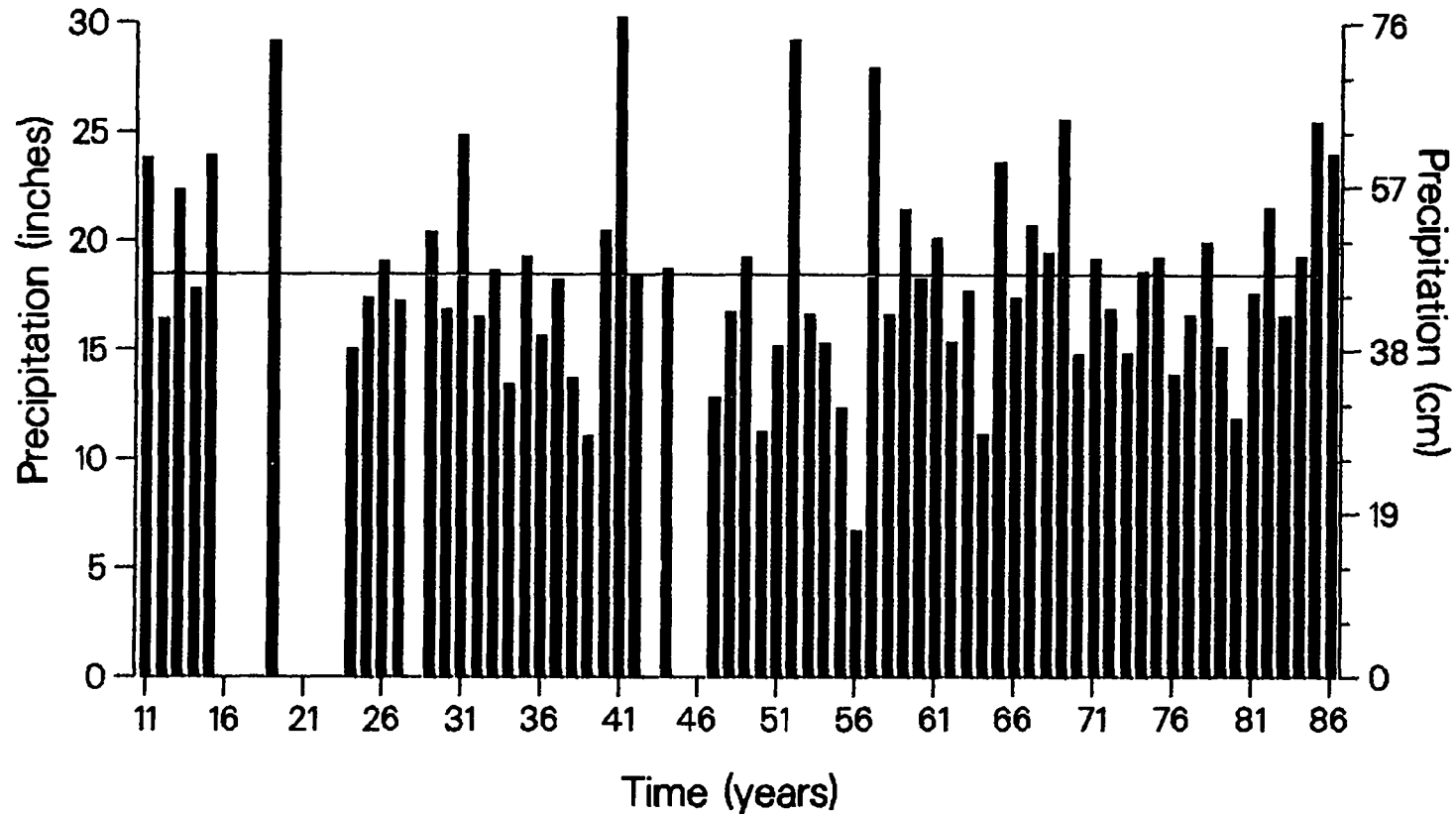


Figure 2. Distribution of annual precipitation between 1911 and 1986 at Los Alamos.

1920–1923, 1928, 1943, 1945, and 1946 were either not collected or incomplete and were not plotted in Figure 2 (data collected by the Environmental Surveillance Group at the Los Alamos National Laboratory). However, for the 65 years on record, the minimum and maximum total annual precipitation ranged from 6.80 inches in 1956 to 30.34 inches in 1941. A wide variation in annual totals like this is characteristic of arid and semiarid climates, as illustrated by annual extremes of 2.95 and 33.94 inches at Carlsbad during a period of more than 71 years. The coefficient of variation (CV, standard deviation/mean) for annual precipitation was equal to 0.25.

Almost 48% of this annual precipitation at Los Alamos occurs in the summer months in the form of thundershowers (Fig. 3). The average precipitation for the month of August, for example, is 3.63 inches (9.22 cm) with a CV of 0.52 over the years 1911 to 1986. This large CV for the average August precipitation is indicative of the large range in values for this month, with maximum and minimum August precipitation recorded in 1952 (11.18 inches or 28.40 cm) and in 1922 (0.51 inch or 1.30 cm), respectively.

Throughout the western states, the interior high mountains receive and store large amounts of precipitation in the form of snow. During the winter, the snow line lowers to between 2,500 and 4,500 feet in the northern mountains and to between 3,500 and 7,000 feet in the southern mountains (Soils of the Western United States 1964). The largest snow pack occurs in the Cascade Sierra mountain system where depths of 30 to 38 feet of snow have been recorded. As the lower temperature and forest canopy tend to insulate snow against melt, this large accumulation of snow becomes a major source of delayed water supply and tends to assure a year-round flow in many rivers and streams. Along the Pacific Coast and over the interior basins and deserts of the southwest, snowfall does not occur in significant amounts. Over other inland basins and valleys, seasonal snowfall depends upon location, elevation, and latitude. On the Great Plains, considerable wind accompanies most snowstorms, but the effectiveness of this moisture is reduced by

Monthly Precipitation at Los Alamos 1911-1986

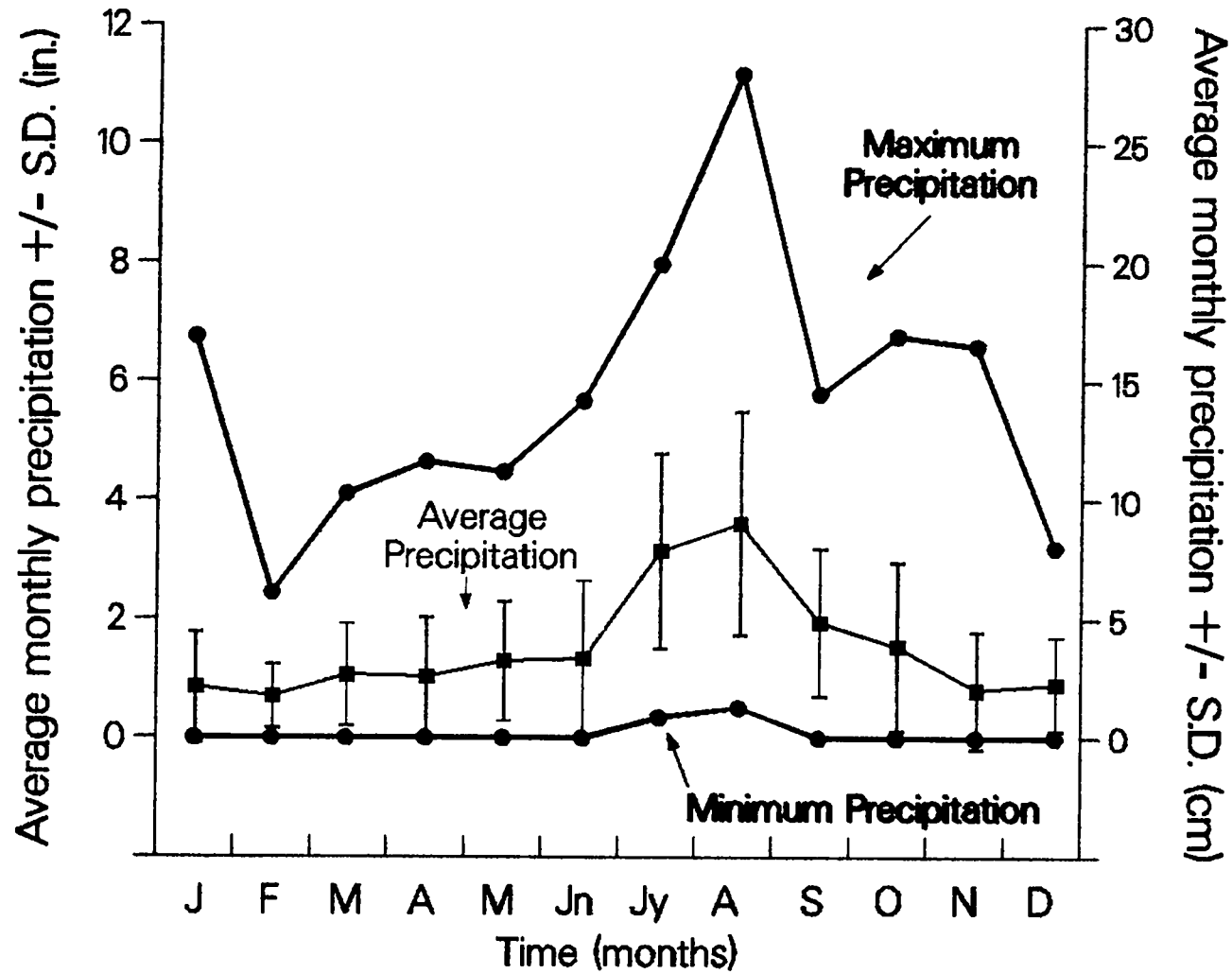


Figure 3. Distribution of average, maximum, and minimum monthly precipitation between 1911 and 1986 at Los Alamos.

enhanced evaporation and sublimation. In the higher mountains, total snowfall ranges from 50 to 200 inches in Arizona to 200 to 1,000 inches in Washington.

Winter precipitation in New Mexico is usually caused mainly by frontal activity associated with the general movement of Pacific Ocean storms across the country from west to east. Some storms can entrain Gulf of Mexico moisture from the south and east, resulting in heavy snows on the eastern mountain slopes. As these storms move inland, much of the moisture is precipitated over the coastal and inland mountain ranges of California, Nevada, Arizona, and Utah. Much of the remaining moisture falls on the western slope of the Continental Divide and over northern and high central mountain ranges. Winter is the driest season in New Mexico except for the portion west of the Continental Divide. This dryness is most noticeable in the central valley. Much of the winter precipitation in New Mexico falls as snow in the mountain areas, but it may occur as either rain or snow in the valleys. Average annual snowfall ranges from about 3 inches at the southern desert and southeastern plains stations to well over 100 inches at northern mountain stations. It may exceed 300 inches in the highest mountains of the north.

Most of the winter precipitation and some of the spring and fall precipitation occur as snow in Los Alamos. The average annual snowfall from 1911 to 1986 was 51.73 inches (131.4 cm) with a CV of 0.47. The record maximum and minimum annual snowfalls were 112.8 inches (286.5 cm) in 1984 and 8.9 inches (22.6 cm) in 1950, respectively (Fig. 4); however, the record maximum was changed in 1987 to 178.4 inches (453 cm). The monthly distribution of snowfall is shown in Figure 5, which demonstrates that 56% of the snowfall usually occurs from January through March, with about 34% being added from October through December. Within the 1911 to 1986 time interval, the largest average monthly snowfall occurred in December (11.07 inches or 28.1 cm), as well as the record maximum monthly snow, which happened in December 1967 when 104.9 cm (41.3 inches) of snow fell in Los Alamos (Fig. 5).

ANNUAL SNOWFALL AT LOS ALAMOS

1911-1986

Annual average 1911 - 1986: 51.73 in. (131.4 cm)

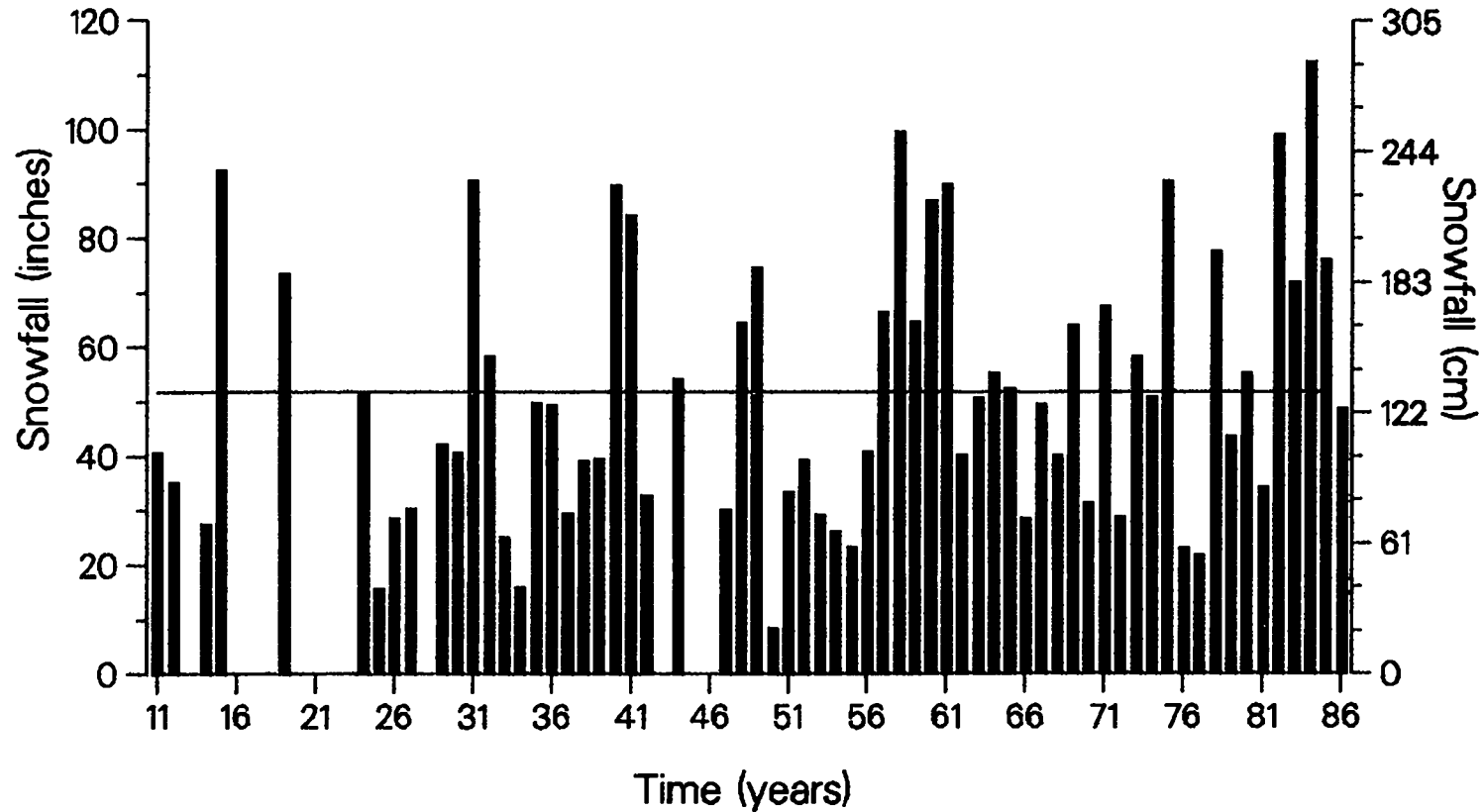


Figure 4. Distribution of annual snowfall between 1911 and 1986 at Los Alamos.

Monthly Snowfall at Los Alamos 1911-1986

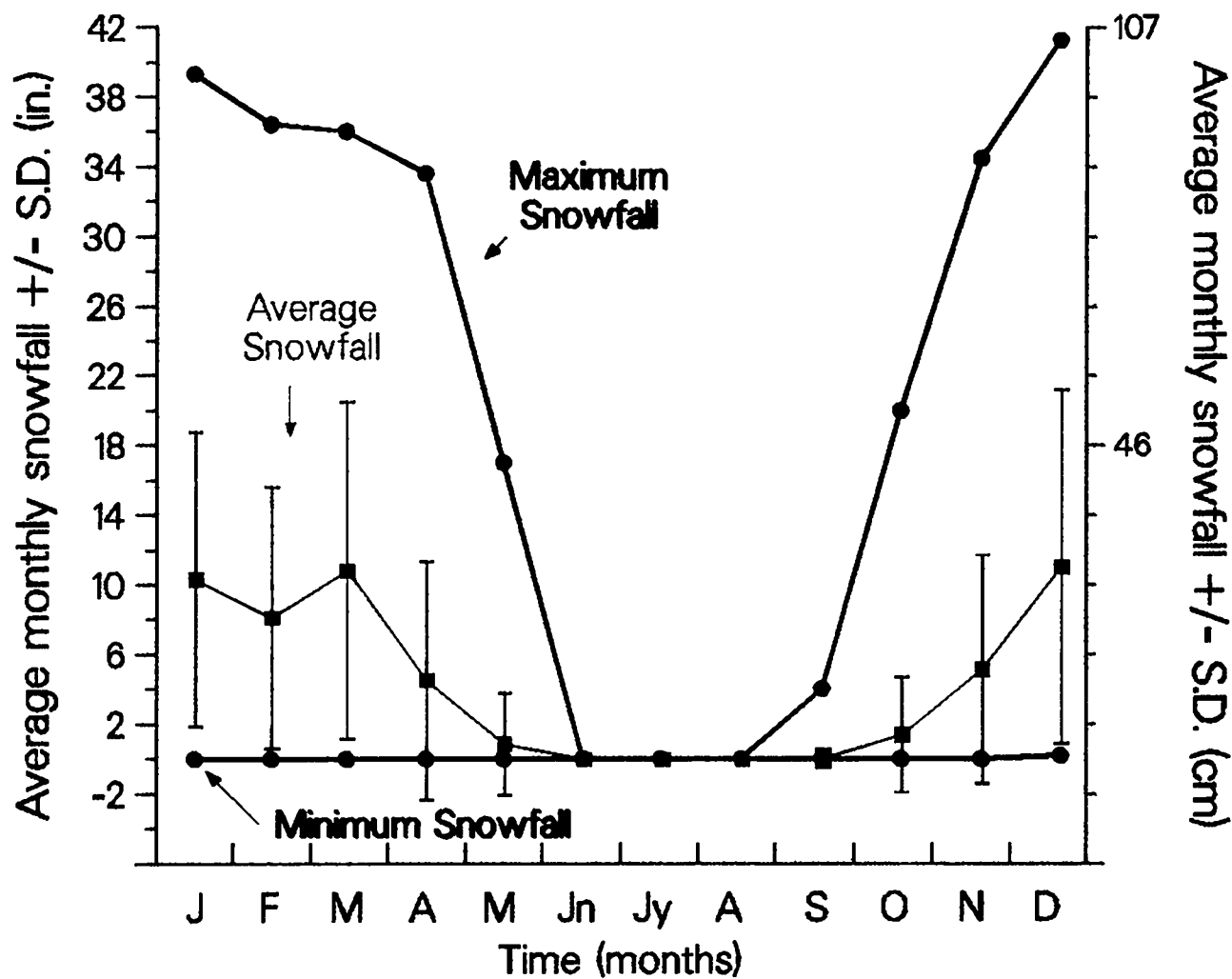


Figure 5. Distribution of average, maximum, and minimum monthly snowfall between 1911 and 1986 at Los Alamos.

III. FUTURE CREDIBLE PRECIPITATION OCCURRENCES AT LOS ALAMOS WASTE DISPOSAL SITES

Several federal agencies have passed regulations requiring that various types of waste disposal sites perform satisfactorily for very long periods of time (Table 1). This performance is strongly influenced by the behavior of precipitation falling on the site. Rain or snow can lead to erosion of the trench cap and percolation of water through the trench cap and into the underlying waste materials.

However, taking climatic records and looking for past trends to forecast precipitation events up to 500 years in the future without a physical understanding of the underlying mechanisms that triggered past trends, often leads to erroneous results. Few climatic models include interactions between the atmosphere ocean polar ice cap system responsible for climatic change on various time scales. Even then, the reliability of these models hinges on factors totally external to the model, such as volcanic eruptions and solar radiation fluctuations.

A National Academy of Sciences study (1977) concluded that theory is yet unable to predict future climates, so that an analysis of recent past records is probably the best quantitative way to estimate the range of future variability for waste management considerations. Because precipitation is the most important climatic element influencing the hydrology of any given area, and consequently the performance of an SLB site, an analysis was performed of the precipitation patterns observed in Los Alamos from 1911 through 1986 (records from the Environmental Surveillance Group at the Laboratory for Technical Area 59 with an elevation of 2248 m). Because most regulations are concerned with the long-term performance of an SLB site, our analysis focused on predicting precipitation events occurring once in one hundred years.

Using the annual precipitation data presented in Figure 2, normal and lognormal probability plots of the data were generated to determine how the data were distributed.

A formal statistical differentiation between these two types of distributions would have required hundreds of observations, and we only had 65 years of complete data. Thus, we arbitrarily chose the lognormal probability plot (Fig. 6) to represent the data because the data appeared to be more linearly aligned than on a normal distribution plot. However, notice that even on a lognormal distribution plot of the data, annual precipitation deviates slightly from lognormality for years when annual precipitation is less than about 15 inches (Fig. 6). However, this deviation appeared to have a minor influence on the graphically derived prediction of precipitation for annual precipitation events occurring between once in ten years and once in 200 years. The evidence supporting this conclusion is that the statistically calculated values for the 10-year, 100-year, and 200-year events (25.0, 32.9, and 35.0 inches, respectively) matched the corresponding graphically derived values for annual precipitation (25.9, 32.9, and 35.0 inches, respectively).

Because the agreement between the statistically calculated and graphically derived estimates of the 10-year, 100-year, and 200-year annual precipitation events was so good, we also calculated the 95% one-sided tolerance intervals for these estimates to provide estimates of the variation about these mean values (Steel and Torrie 1960). The 95% tolerance intervals for the 10-year, 100-year, and 200-year annual events were 27.0, 36.8, and 41.3 inches, respectively. The interpretation of this statistical analysis for the 100-year event, for example, is that 95% of all the 100-year precipitation events will be less than 36.8 inches, with the average 100-year event being 32.9 inches.

Lognormal probability plots were also performed for the monthly precipitation data collected between 1911 and 1986 at Los Alamos (Figs. 7–10). It should be noted that these data sets usually were a little larger ($n = 70$ to 75) than the annual precipitation data sets ($n = 65$) because all of the monthly data were used, even for years when some of the monthly data were missing. Another important consideration in the treatment of the

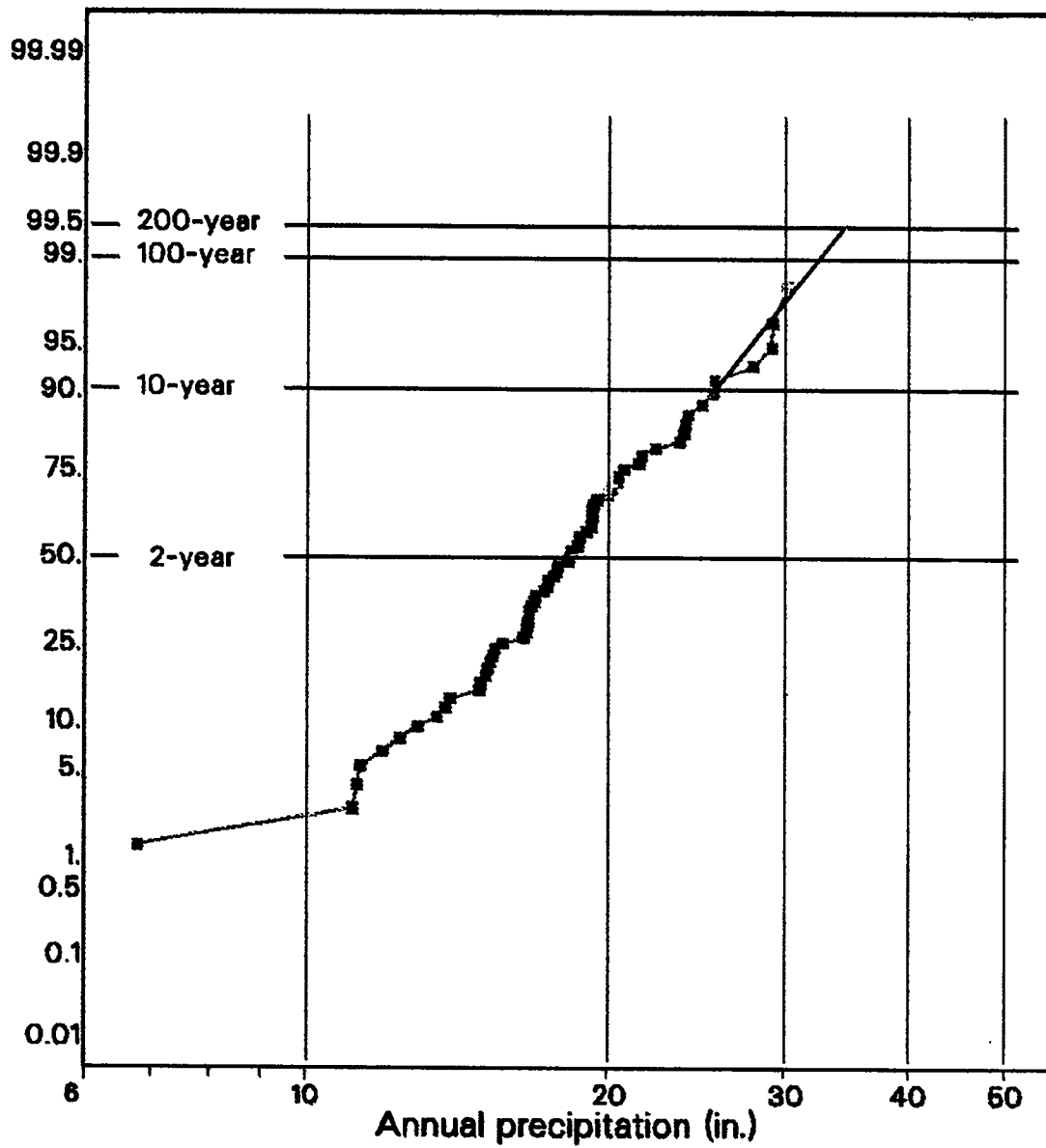


Figure 6. Lognormal probability plot of annual precipitation data collected at Los Alamos between 1911 and 1986.

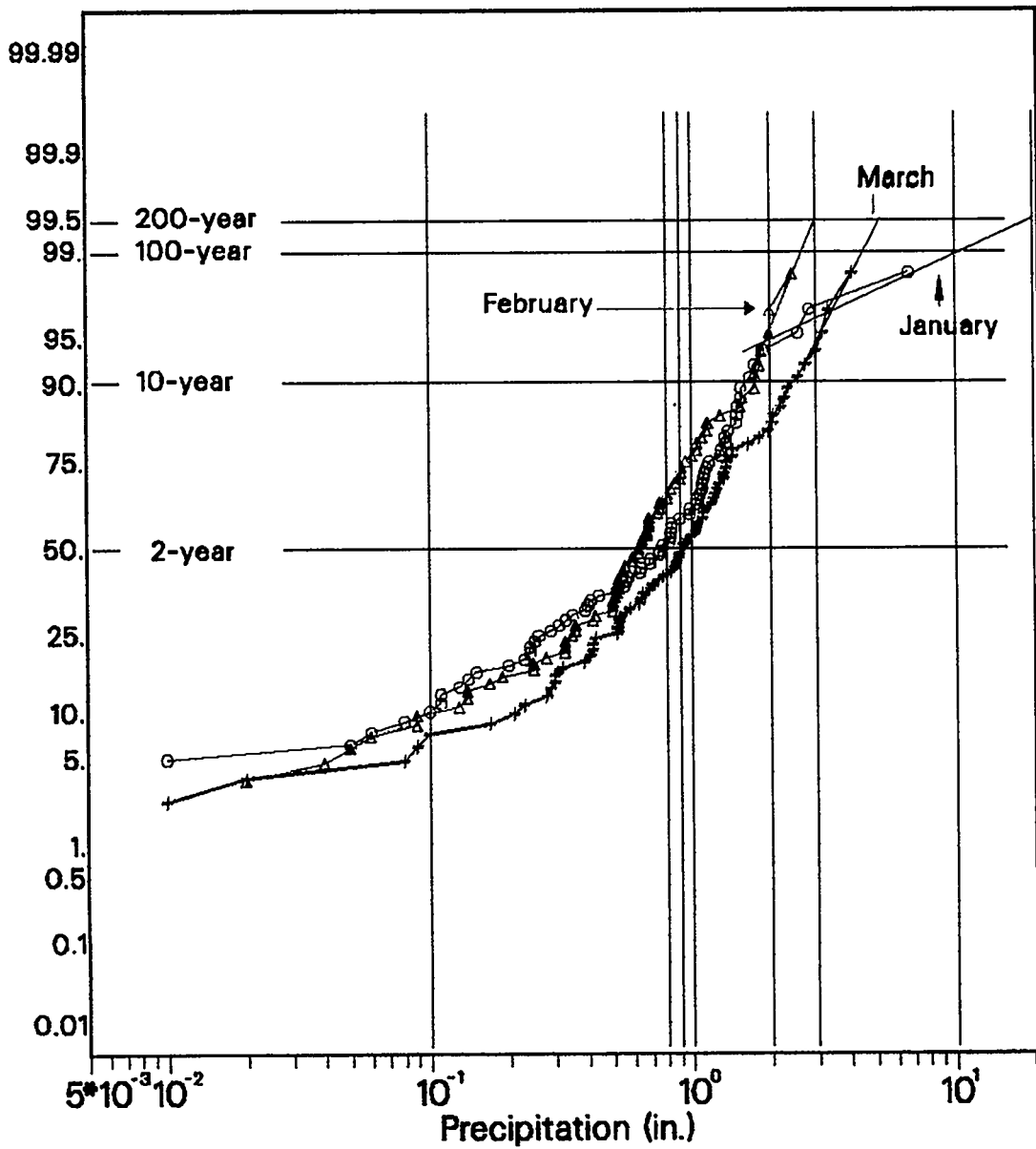


Figure 7. Lognormal probability plot of first quarter precipitation data collected at Los Alamos between 1911 and 1986.

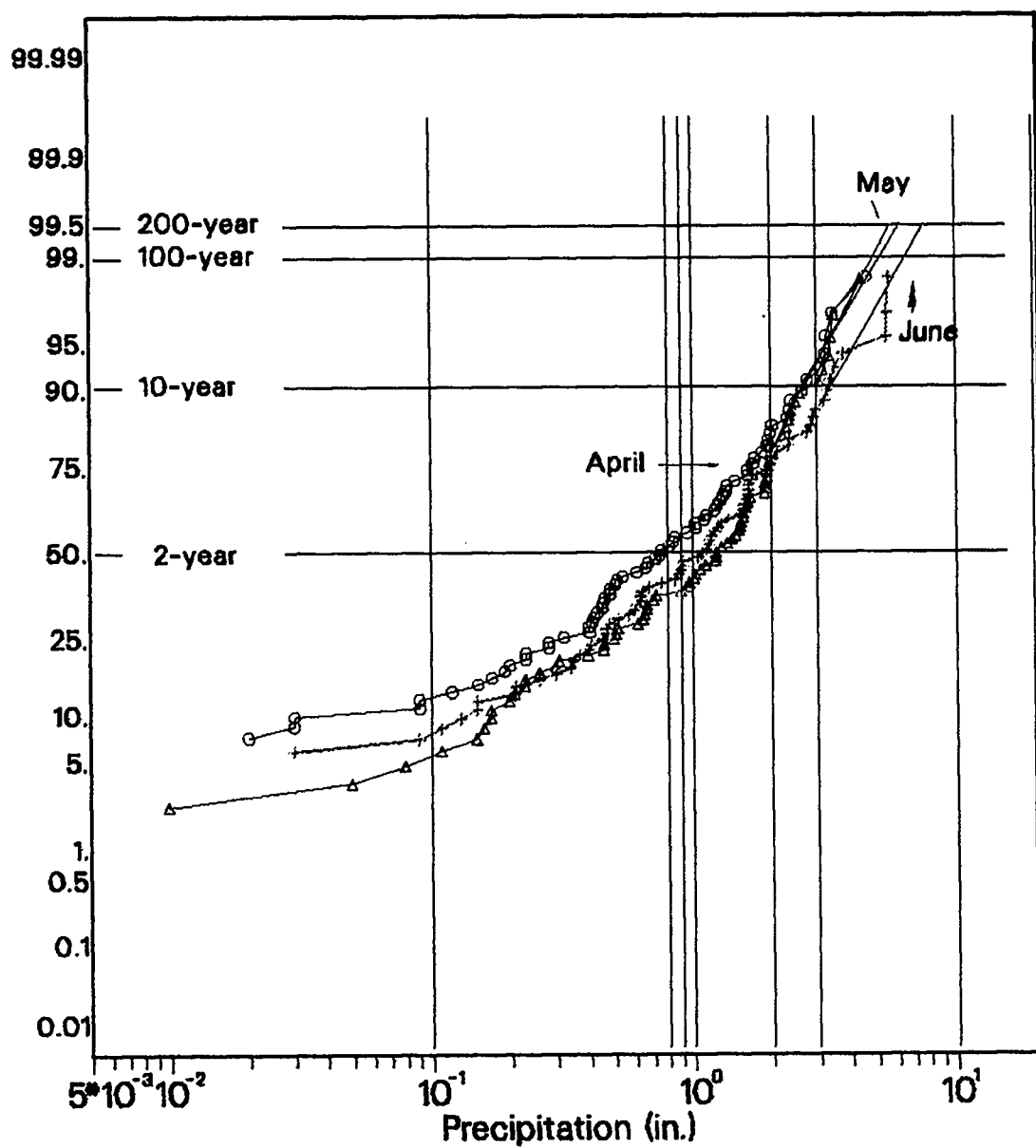


Figure 8. Lognormal probability plot of second quarter precipitation data collected at Los Alamos between 1911 and 1986.

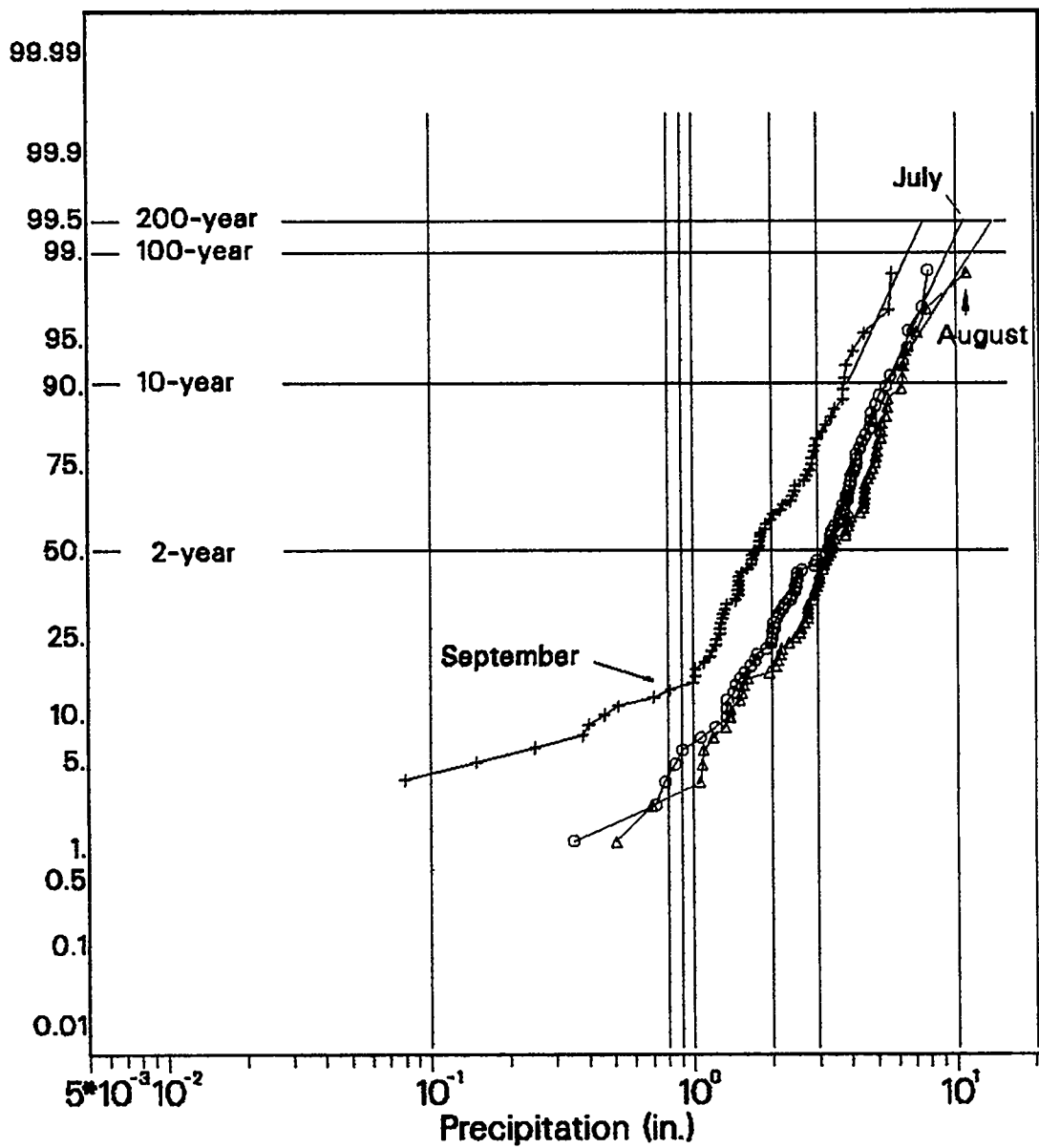


Figure 9. Lognormal probability plot of third quarter precipitation data collected at Los Alamos between 1911 and 1986.

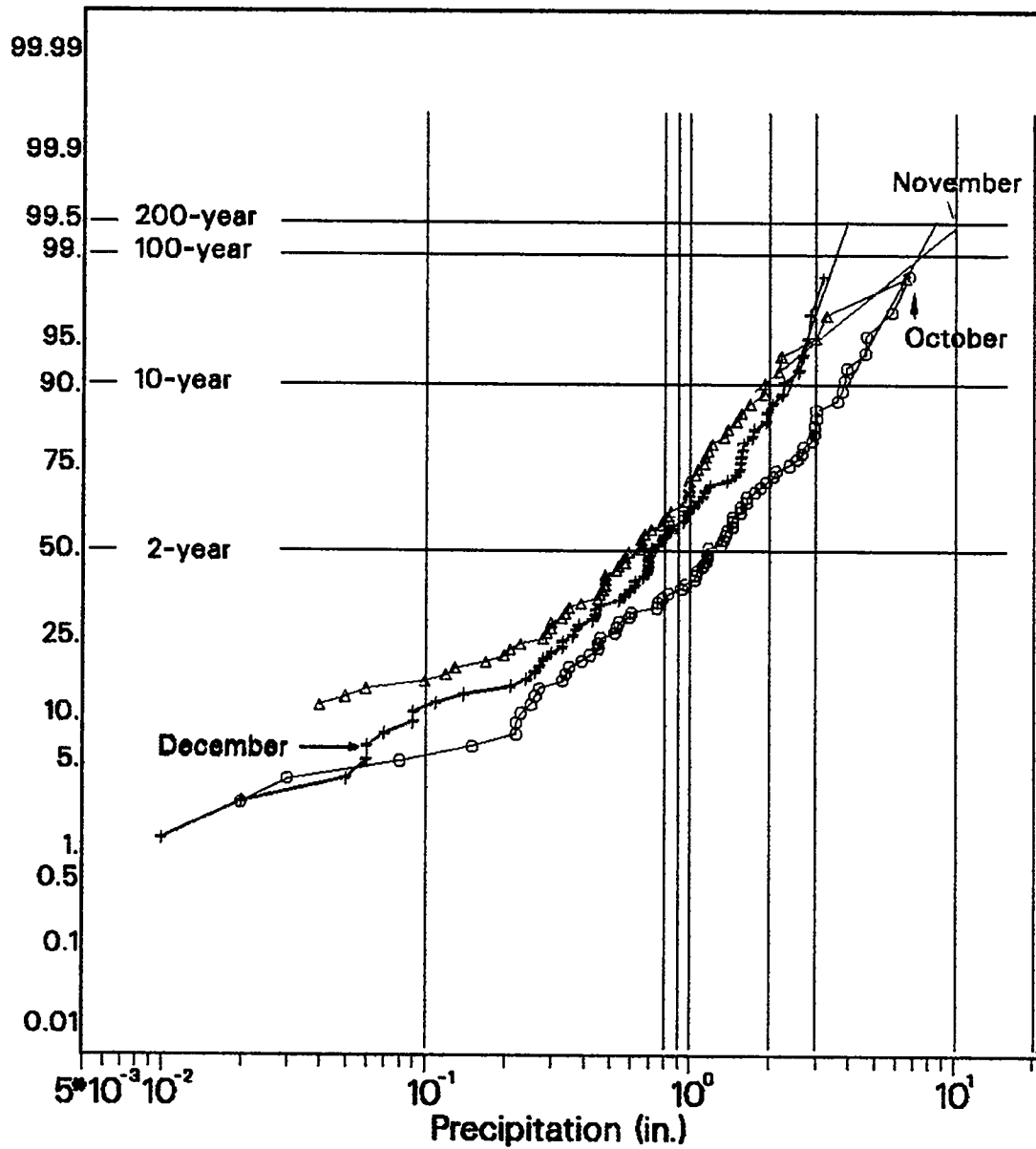


Figure 10. Lognormal probability plot of fourth quarter precipitation data collected at Los Alamos between 1911 and 1986.

monthly data was that no measurable precipitation was received on 23 months throughout the period of record. We felt that the best way to treat these data was to assume that 0.005 inch of precipitation fell in these months, approximately half of what the detection limit (0.01 inch) was for this estimate. This was done this way both for statistical convenience and because a recorded value of 0.00 inch probably did not mean that there was absolutely no precipitation received for a month. Furthermore, when these 23 months of data occurred in the 12 monthly data sets, the decision was made not to plot the points in Figs. 7–10, although they are taken into account as 0.005–inch values in making the probability plots.

The results of the lognormal probability plots (Figs. 7–10) show that practically none of the monthly precipitation data were perfectly lognormally distributed over the period of record, and making normal probability plots of the monthly precipitation data made this overall problem even worse, i.e.—even less linearity was observed in these data plots. Just as with the annual precipitation data, time periods when small amounts of precipitation were received showed large deviations from lognormality, whereas a maximum–precipitation month such as August (Figs. 3 and 9) exhibited less of a departure from lognormality.

Because there was such a large departure from lognormality in the monthly data (Figs. 7–10), it is not surprising that there was a very large difference between the statistically calculated and the graphically derived estimates of the 10–year and 100–year monthly precipitation events, making the statistically derived values essentially meaningless. Thus, the graphical solution estimates for the monthly data are summarized in Table 2, and represent our best estimation of the average precipitation that should be received in the 10–year and 100–year monthly events. Because of the large departure from lognormality in the January precipitation data, the 100–year event of 11.3 inches is probably greatly over estimated, due to the occurrence of a 6.75–inch precipitation data

point occurring in 1916. The occurrence of more data points of January precipitation in the future will probably result in a much smaller predicted 100-year event for this month.

Table 2. Graphical Solution Estimates of the 10-year and 100-year Precipitation Events for Each Month of the Year, Based on the 1911–1986 Data Set from Los Alamos

Month	Monthly Precipitation (inches)	
	10-year Event	100-year Event
January	1.7	11.3
February	1.8	2.8
March	2.5	4.5
April	2.8	5.3
May	2.7	5.0
June	3.5	6.8
July	5.7	9.5
August	6.5	12.6
September	3.8	6.8
October	3.9	7.4
November	2.0	7.6
December	2.4	3.6

IV. IMPLICATIONS FOR WASTE MANAGEMENT AND FUTURE RESEARCH NEEDS

A recent publication (Lockhart 1982) makes the recommendation that the meteorology of a low-level radioactive waste burial site should be characterized "based upon a one-year record of valid and representative data." From the precipitation data collected at Los Alamos from 1911 through 1986 (Fig. 2), we can observe more than 70 "representative" years of annual precipitation data, ranging from the 6.8 inches observed in 1956 to 30.34 inches measured in 1941. Perhaps the burial site operator should really be anticipating what will happen to SLB site during the future once-in-a-hundred-year event at Los Alamos, when the site will receive an average of 32.9 inches of precipitation.

Climatology includes precipitation, temperature, and other weather factors that affect evapotranspiration and seepage production at a landfill (Fig. 1). In a truly dynamic

and interactive sense, the quantities and seasonality of the precipitation received at the SLB waste repository will strongly influence seepage generation, a process we would like to minimize at a closed burial site. Generally, 50 inches of rainfall annually is more likely to lead to seepage production than is 5 inches annually, and 40 inches yearly falling in one month will have a different impact than 3 inches monthly for 12 months. Field studies at Los Alamos have shown seepage production in SLB scenarios to occur after high snowmelt periods, accompanied by reduced evapotranspiration and enhanced soil water storage in the landfill earthen cover (Nyhan et al. 1988). Thus, the type of precipitation received by the burial site also plays an important role in the hydrologic cycle.

Very few hydrologic models have been field-validated to help with the design of SLB sites, except at Los Alamos (Nyhan and Barnes 1987 and 1988). However, as these models are developed, it is increasingly obvious that their success depends largely on having a continuous and long-term record of the amount of precipitation occurring at a burial site. Actual experience in gathering this type of data at Los Alamos and other locations across the United States suggests that back-up measurement systems are a must for the future to ensure the continuity of data collected.

Because the spatial and temporal variability of precipitation events is so large in the western states, numerous measurement locations are required. Without a direct measure of this variability in precipitation, it is difficult to predict if precipitation data collected at one location can be used to represent precipitation occurrences at a different location where burial site performance is to be evaluated.

REFERENCES

Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1986," Los Alamos National Laboratory report LA-10992-ENV (1987).

Lockhart, T. J., "On-site Meteorological Measurements for Low-Level Radioactive Waste Disposal," U. S. Nuclear Regulatory Commission report NUREG/CP-0028, Silver Spring, Maryland (1982).

National Academy of Sciences, "Climate, Climatic Changes and Water Supply," U. S. Government Printing Office, Washington, DC (1977).

National Oceanic and Atmospheric Administration (NOAA), "Climate of New Mexico," Climatography of the United States report No. 60, National Climatic Center, Asheville, NC (1977).

Nyhan, J. W., "Development of Technology for the Long-Term Stabilization and Closure of Shallow Land Burial Sites in Semiarid Environments," Los Alamos National Laboratory report LA-11283-MS (1988).

Nyhan, J. W., and F. J. Barnes, "Development of an Arid Site Closure Plant," Proceedings of the Ninth Annual DOE Low-Level Radioactive Waste Management Conference, Denver, Colorado, August 25-27, 1987, EG&G Idaho (1987).

Nyhan, J. W., and F. J. Barnes, "Development of a Prototype Plan for the Effective Closure of a Waste Disposal Site in Los Alamos, New Mexico," Los Alamos National Laboratory report LA-11282-MS (1988).

Nyhan, J., B. Drennon, and T. Hakonson, "Field Evaluation of Two Shallow Land Burial Trench Cap Designs for Long-Term Stabilization and Closure of Waste Repositories at Los Alamos, New Mexico," Los Alamos National Laboratory report LA-11281-MS (1988).

Soils of the Western United States, A Joint Regional Publication by the Agricultural Experiment Stations of the Western States Land-Grant Universities and Colleges with Cooperative Assistance by the Soil Conservation Service of the United States Department of Agriculture, Washington State University, Yakima, Washington (1964).

Steel, R. G., and J. H. Torrie, Principles and Procedures of Statistics with Special Reference to the Biological Sciences, McGraw-Hill Book Company, Inc, New York, (1960).

U.S. Nuclear Regulatory Commission, Rules and Regulations, Title 10, Chapter 1, Code of Federal Regulations, Part '61, Licensing Requirements for Land Disposal of Radioactive Waste (10 CFR 61), December 30, 1982.

U.S. Environmental Protection Agency, "Interim Status Standards for Owners and Operators of Hazardous Waste Facilities," Title 40, Code of Federal Regulations, Part 265 (40 CFR 265) in Federal Register, Vol. 45, May 19, 1980.

U.S. Environmental Protection Agency, "Environmental Standards for the Management and Disposal of Spent Fuel, High-Level and Transuranic Radioactive Waste," (50 CFR 191) in Federal Register, Vol. 50, No. 182, September 19, 1985.

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