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Evaluation of Aircraft Crash Hazard at Los Alamos National Laboratory Facilities

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EVALUATION OF AIRCRAFT CRASH HAZARD AT LOS ALAMOS NATIONAL LABORATORY FACILITIES

by

Ronald D. Selvage

Abstract

This report selects a method for use in calculating the frequency of an aircraft crash occurring at selected facilities at the Los Alamos National Laboratory (the Laboratory). The Solomon method was chosen to determine these probabilities. Each variable in the Solomon method is defined, and a value for each variable is selected for fourteen facilities at the Laboratory. These values and calculated probabilities are to be used in all safety analysis reports and hazards analyses for the facilities addressed in this report. This report also gives detailed directions to perform aircraft-crash frequency calculations for other facilities. This will ensure that future aircraft-crash frequency calculations are consistent with calculations in this report.

1.0 INTRODUCTION

This report calculates the frequency of aircraft crashes for 14 facilities at the Los Alamos National Laboratory (the Laboratory) and gives the information and equations needed to calculate aircraft-crash frequency at any other facility at the Laboratory. This report was written to ensure more consistency in Laboratory safety analysis reports (SARs) and safety analysis work by establishing an approved method for calculating aircraft-crash probabilities.

The facilities addressed in this report are

Facility Name	Location
Chemical Metallurgical Research (CMR) Facility	TA-3-29
Weapons Engineering Tritium Facility (WETF)	TA-16-205
Hillside Vault (Pajarito Site)	TA-18-26
Los Alamos Critical Experiments Facility (LACEF) Kiva 1	TA-18-23
LACEF Kiva 2	TA-18-32
LACEF Kiva 3	TA-18-116
Tritium System Test Assembly (TSTA) Facility	TA-21-155
Tritium Science and Fabrication Facility (TSFF)	TA-21-209
Main Vault (Underground Vault)	TA-41-1
Radioactive Liquid Waste Treatment Facility (RLWTF)	TA-50-1
Treatment Demonstration Facility (TDF)/(CAI)	TA-50-37
Waste Characterization Reduction and Repackaging Facility (WCRRF)	TA-50-69
Waste Disposal Site, Area G (Including TWISP Project)	TA-54-G
Plutonium Facility, Building 4 (PF-4)	TA-55-4

2.0 PURPOSE

The purpose of this report is to define the approach and method for performing an aircraft-crash frequency calculation and documenting the performance of this calculation for various Laboratory facilities. When performing a hazards analysis for a facility, analysts are required to consider external events as accident initiators. Included in the external events category is an aircraft crash. This report will define the approach and method to be used in determining the frequency of an aircraft crash. This calculation is required to determine if an aircraft crash is a credible event and if the consequences of this accident should be addressed in the facility SAR. The probabilities determined in this report can be referenced in the SAR for each facility.

3.0 REQUIREMENTS

The risk of an aircraft crashing into a given facility is based upon the following:

- location of airways relative to the facility,
- location of airports relative to the facility, and
- location of missile bases relative to the facility.

The Laboratory was analyzed with respect to each of these locations. These analyses included obtaining information on the types of aircraft which could potentially crash into a facility and the number of aircraft involved.

3.1 Airways

3.1.1 Location

There are two types of airways used for air traffic: victor airways and jet airways. Victor airways are low-altitude routes in which planes must fly under 18,000 feet. Jet airways are high-altitude routes in which planes must fly above 18,000 feet. Both types of airways are approximately 8 miles wide. The closest victor airway to the Laboratory is V263. The center of this airway runs in the north-south direction approximately 11 miles to the west of the Laboratory. The only jet airway in the vicinity of the Laboratory is Airway J76, which runs in the east-west direction. An approximately 4-mile-wide section of this airway intersects the southern part of the Laboratory boundary. Airways V263 and J76 are shown in Figure 3-1.

The Standard Review Plan (SRP), NUREG-0800 (1981), states that the frequency of the aircraft crash hazard is considered to be acceptable if "the plant is at least 2 statute miles

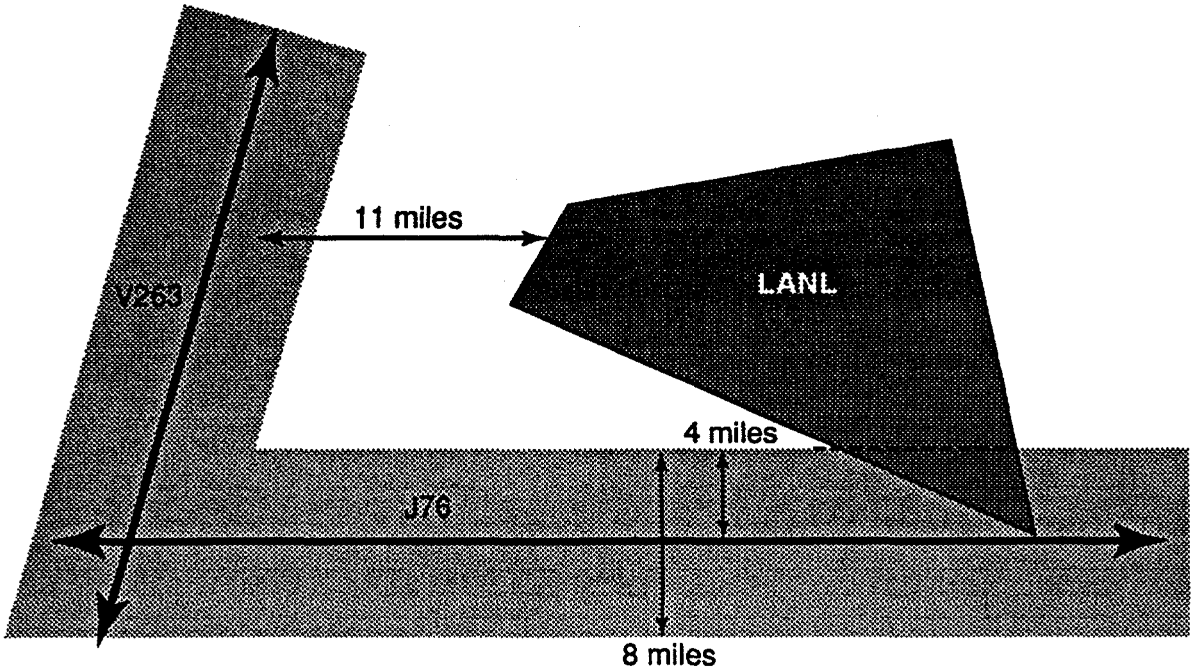

Figure 3-1

Airways in Vicinity of Los Alamos National Laboratory

beyond the nearest edge of a federal airway, holding pattern, or approach pattern." (Ref. 1) In the Solomon Model, used in this report, a site at a distance approximately 2 miles from the intended flight path of an aircraft is subject to the same risk as a site located at a distance 7 miles from the center of a federal airway in the SRP Model. (Ref. 2) Therefore only the jet airway will be analyzed because the nearest edge of the Victor airway is approximately 7 miles from the Laboratory boundary and even further away from most of the facilities addressed in this report.

3.1.2 Traffic

Because the actual number of flights per day in Jet Airway J76 was not known, the traffic was monitored over a period of two days to obtain a sample of traffic in this airway. Based on conversations with air traffic controllers at the Federal Aviation Administration, Albuquerque Center, the peak times for traffic traveling in Jet Airway J76 are, in descending order, 8:00 a.m. to 10:00 a.m., 7:00 p.m. to 9:00 p.m., and 3:00 p.m. to 5:00 p.m. The time periods for monitored air traffic are listed in Table 3-1.

Table 3-1

Measured Traffic in Airway J76

Time	Aircraft
8:15 a.m. - 11:00 a.m.	12
12:00 p.m. - 1:15 p.m.	7
1:45 p.m. - 4:05 p.m.	8
5:20 p.m. - 6:45 p.m.	8
Total	35

The number of aircraft in the airway was estimated for the times that air traffic was not monitored. The traffic in the 7:00 p.m. to 9:00 p.m. time period was estimated to be 90% of the morning traffic. The remaining time, from 9:00 p.m. to 8:00 a.m., was estimated to have 2 flights per hour in the airway. To ensure that the estimated number of planes per day in the airway remained conservative, an additional 25% was added to account for special "heavy traffic" days. These numbers are shown in Table 3-2. This brought the total number to 85 flights per day. As an added conservatism, and to account for the short sampling time of actual flights, the total number of aircraft in the airway was rounded up to 100 per day.

Because the airway in question is a jet airway and only contains traffic flying at relatively high altitudes, 80% of the total traffic is assumed to be commercial aircraft, and 20% is assumed to be general aircraft.

Table 3-2

Total Traffic in Airway J76

	Number of Aircraft
Total from Table 3-1	35
7:00 p.m. - 9:00 p.m.	11
9:00 p.m. - 8:00 a.m.	22
Total	68
Additional 25% for conservatism	17
Total estimated flights per day	85
Total number of flights per day used in calculations	100

3.2 Airports

3.2.1 Location

Based on the results of previous analyses of aircraft crash statistics, only airports located within 5 miles of a facility needs to be considered. The results indicated that the crash frequency beyond 5 miles from an airport is independent of the orientation of the airport runways (USAEC Regulatory Staff). (Ref. 3) It is assumed that beyond this point all aircraft crash hazards are associated with the inflight accidents; no takeoff and landing hazards need to be considered (Ref. 2).

At its nearest point, the Los Alamos Airport is located within 1 mile of the Laboratory. Therefore, the risk of an aircraft crashing while using the Los Alamos Airport must be addressed in the aircraft-crash calculation.

3.2.2 Description of Los Alamos Airport

The Los Alamos Airport is located north of the Laboratory and is shown in Figure 3-2. The Laboratory is separated from the airport by mesas and canyons. The Los Alamos Airport consists of a single runway running from east to west. Because of local conditions, all air traffic enters from and exits to the east. The west end of the runway is used only for run-ups or taxiing. For purposes of this report, all of the aircraft operating at the Los Alamos Airport will be grouped into two different categories: general aircraft and commercial aircraft. (Between the time this report was initially written and when it was published, commercial air service to Los Alamos Airport has been discontinued. This part of the calculation will be left in however, in case air service returns to the airport.)

3.2.3 Traffic

Pilots must receive permission to take off from or land at the Los Alamos Airport, and a log is kept documenting airport usage. A review of this log for 1993 indicates that the total number of take-offs and landings at the Los Alamos Airport were 3600 commercial flights and 8834 general aviation flights. The approach path is in a northwest direction and parallels the Laboratory boundary. The take-off path is in a southeast direction, away from the Laboratory, and follows the Rio Grande.

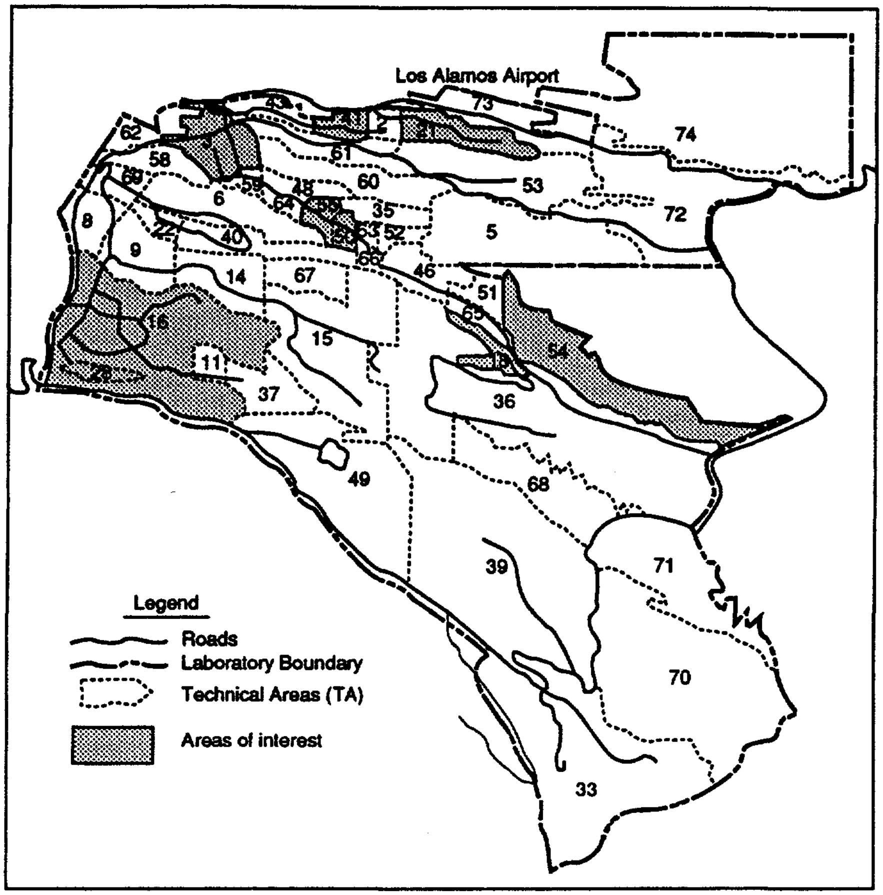

Figure 3-2

Los Alamos National Laboratory

Pilots utilizing the Los Alamos Airport must follow specific procedures for missed approaches. These procedures require that the pilot turn toward the northeast, away from Laboratory property, and retry the approach. Pilots are not allowed to circle over Laboratory property when reattempting an approach. The missed approach flight path is shown in Figure 3-3.

3.2.4 Restricted Airspace/Airspace

The airspace over the Laboratory is restricted (Restricted Airspace R-5101) up to 14,000 feet. This results in the requirement that flights taking off from or landing at the Los Alamos Airport follow a flight path around the Laboratory. The Laboratory grants permission to overfly the Live Firing Range (TA-72) during certain inclement weather

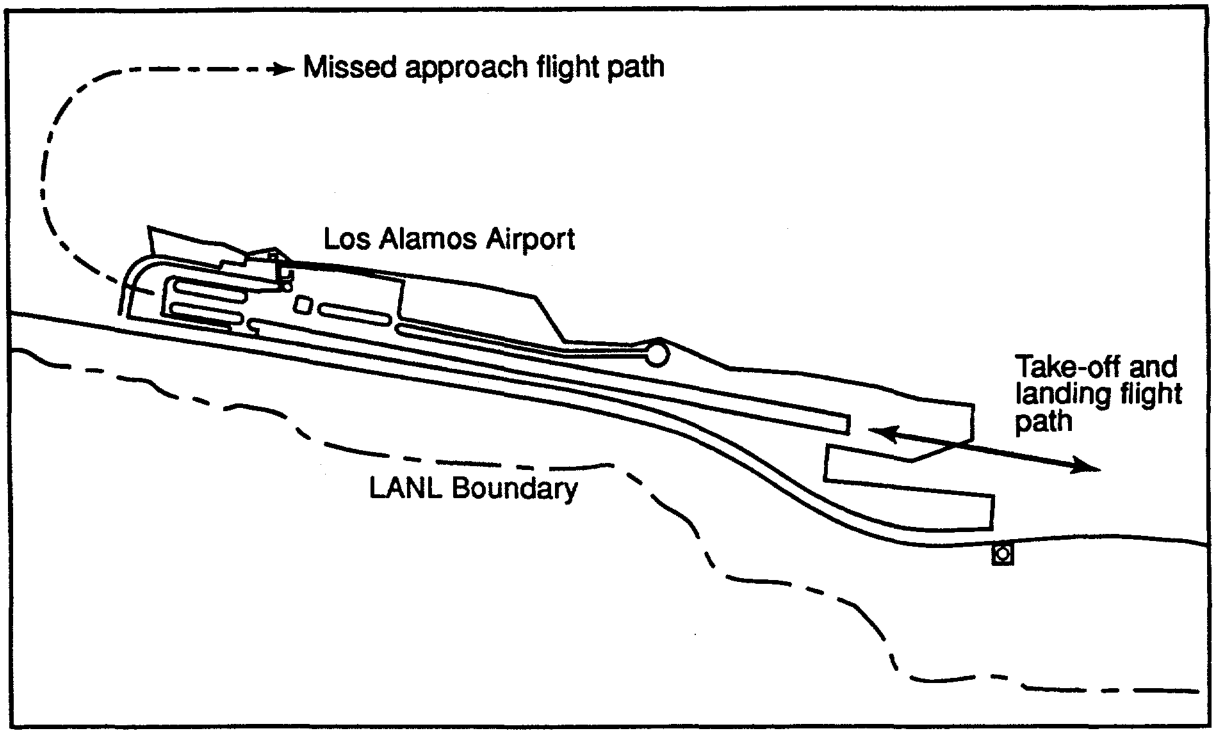

Figure 3-3
Los Alamos Airport

flight conditions. Pilots must receive permission prior to performing this overflight, and the firing range will cease operations during the overflight.

3.3 Location of Missile Bases

There are no missile bases located within 100 miles of Laboratory. Therefore, the risk of aircraft activity from a missile base does not need to be addressed in the aircraft crash calculation.

4.0 METHODOLOGY

Several methods for calculating the frequency of aircraft crashes were examined to determine the most appropriate one to use at the Laboratory. Based upon the characteristics of the aircraft using the Los Alamos Airport and the airport's location with respect to the Laboratory, the method developed by K. Solomon was deemed appropriate. This method is similar to the method used in NUREG-0800. Solomon cites two equations to be used to calculate the frequency of an aircraft crash. The first equation is for calculating the frequency of an aircraft crashing while traveling in an airway, and the other is for calculating the frequency of a crash occurring while the aircraft is taking off or landing. The total frequency of an aircraft crashing into a facility is then the sum of these two individual probabilities.

4.1 Airway Equation

The first equation is the "airway" equation. This equation pertains to the jet airway that passes close to the southern end of the Laboratory. This equation is given as

$$P_{FA} = \sum_{i,j} N_{ij} x A_j x C_{AWj} x F_{j(a)} \quad ,$$

where

P_{FA} = Frequency per year of an aircraft crashing into the site from an airway,
N_{ij} = Number of flights per year,
A_j = Effective target area in square miles,
C_{AWj} = Probability per mile that an aircraft will crash,
$F_{j(a)}$ = Distribution of impacts orthonormal to the flight path, and
a = Orthonormal distance from the airway centerline to the structure.

The subscripts i and j correspond to the i^{th} flight path and the j^{th} aircraft. The distribution of impacts orthonormal to the flight path, $F_j(a)$, is given by the equation

$$F_{i,j}(a) = 0.5 \cdot \gamma \cdot e^{(-\gamma|a|)} \quad ,$$

where

a = The orthonormal distance from the airway to the target structure,
γ = 1.6/mile for commercial aircraft, and
γ = 2.0/mile for general aircraft.

This equation represents the crash-density function. It is assumed that the crash-density function should be symmetrical and should decay away from the location on the intended flight path where the trouble first began.

4.2 Airport Equation

The second equation is the airport equation. This equation is given below:

$$P_{AP} = \sum_{i,j} N_{ij} x A_j x C_{APj} x P_0 x P_r$$

where

P_{AP} = Frequency per year of an aircraft crashing into the site from using an airport,

N_{ij} = Number of airport operations (takeoffs and landings) per year,

A_j = Effective target area in square miles,

C_{APj} = Probability per square mile that an aircraft will crash,

P_o = Normalization factor that relates air crash probability to the angle from the intended flight path, and

P_r = Normalization factor that relates air crash probability to the distance from the end of the runway.

The subscripts i and j correspond to the i^{th} flight path and the j^{th} aircraft.

Statistics show that the greatest probability of an aircraft crash occurs when the aircraft is on the landing or takeoff path. (Ref. 4) This means that credit can be taken for the angle ϕ that is defined by the landing path and the line drawn from the runway to the crash point. According to Solomon et al., "If $\phi = 10°$, the probability for crash is approximately 1/10 as great as when the plane is on the landing or takeoff path. If $\phi = 90°$ or $270°$ the probability is about 1/100 as great as for $\phi = 0°$." This relationship is given as

$$P_0 = \begin{cases} 1 & 0° \le \phi \le 1° \\ 1/|\phi| & 1° < \phi \le 90° \end{cases}$$

The value for ϕ is facility dependent and will be different for each facility. The normalization factor P_r is also given by Solomon.

Statistics indicate that it is about as likely for a plane to crash within 5 miles of the runway (while landing) as 5 or more miles away. But it is about 2 times more likely that the plane will crash one mile from touchdown than two miles from touchdown. Based on this and other statistical data, the functional relationships for crash probability dependence on r, for takeoff and landing are as follows:

Takeoffs:

$$P_{r,\,\text{Takeoff}} = \begin{cases} 1 & r < 1 \text{ mile} \\ \dfrac{4}{1.5r} & 1 \text{ mile} \le r < 2 \text{ miles} \\ \dfrac{4}{2.4r} & 2 \text{ miles} \le r \le 5 \text{ miles} \\ 0.40 & 5 \text{ miles} < r \end{cases}$$

Landings:

$$P_{r,\,\text{Landing}} = \begin{cases} 1 & r < 1 \text{ mile} \\ \dfrac{2}{3r} & 1 \text{ mile} \le r < 2 \text{ miles} \\ \dfrac{2}{4.5r} & 2 \text{ miles} \le r \le 5 \text{ miles} \\ 0.08 & 5 \text{ miles} < r \end{cases}$$

4.3 Effective Target Area

The effective target area of a facility consists of a summation of three separate areas. The first is called the shadow area. The shadow area is the area of the plant elevation upon the horizontal plane based on the assumed crash angle for the different kinds of aircraft and failure modes. The second is the skid area. The skid area around the plant is determined by the characteristics of the aircraft being considered and the layout of the facility. The third area is the plan area. This is the actual footprint area of the facility. The units of the areas are in square miles, and each of these areas are facility specific.

The total effective facility area to be used in the aircraft crash calculation is

$$A_e = A_{sh} + A_{sk} + A_{pv} \quad ,$$

where

A_e = Total effective area,

A_{sh} = Shadow area,

A_{sk} = Skid Area, and

A_{pv} = Plan Area.

4.3.1 Shadow Area

The shadow area is given as

$$A_{sh} = (L + ws)(H)\cot\theta \quad ,$$

where

L = Facility length,

ws = Wing span (dependent upon type of aircraft),

H = Facility height, and

θ = Crash angle (degrees off horizontal), 15°.

The building's largest horizontal dimension is artificially increased to account for aircraft dimensions by adding the aircraft wing span to the building dimension. For aircraft utilizing the Los Alamos Airport, the maximum wing span is 93 feet for commercial aircraft and 35 feet for general aircraft.

The largest vertical building dimension should be used for H.

4.3.2 Skid Area

The skid area is defined as the product of the sum of the widths of the impacting aircraft and the building postulated to be impacted and the skid length. Again, the building's largest horizontal dimension is artificially increased to account for aircraft dimensions by adding the aircraft wing span to the building dimension.

$$A_{sk} = (L + ws)(sd) \quad ,$$

where:

L = Facility length,

ws = Wing span, and

sd = Skid length.

According to Seigler (1990) (Ref. 5), the skid length is generally taken to be 0.06 mile for general aircraft and 0.3 mile for commercial aircraft. The greatest horizontal dimension of the facility should be used for the length of the building. Skid area is also greatly effected by facility layout. Natural barriers, such as high road cuts, the presence of trees, and the relative location of nearby buildings all can decrease the possible skid length for a given facility. Facilities are encouraged to account for natural barriers when determining skid length. However, note that parking lots filled with cars cannot be considered barriers, as the crash may occur at night.

4.3.3 Plan Area

This area is generally taken to be the base area of the facility, unless it can be clearly demonstrated that safety-related structures, systems, and components, are segregated in a specific portion of the facility. Note that the length of the facility should be increased by the wing span of the aircraft. Therefore,

$$A_{pv} = (L + ws)W \quad ,$$

where

L = Facility length,
ws = Wing span, and
W = Facility width.

4.4 Crash Frequency

Data for crash probabilities are taken from NUREG-0800 and are modified as described in Appendix A of the safety evaluation report for the Pantex Plant Zone 4 Magazines (1992). (Ref. 6)

4.4.1 Values for Airway Equation

The value chosen for C_{AW}, the crash probability per mile, was taken from NUREG-0800. The value given for commercial flights is 4×10^{-10} 1/mile. Because NUREG-0800 does not give a value for general aviation, a value 5 times the commercial flight value, or 2×10^{-9} 1/mile, is used. This value is taken from the Safety Evaluation Report for the Pantex Plant Zone 4 Magazines. These values are summarized below.

Commercial Aircraft	$C_{AW} = 4 \times 10^{-10}$ 1/mile
General Aircraft	$C_{AW} = 2 \times 10^{-9}$ 1/mile

4.4.2 Values for Airport Equation

The data from NUREG-0800 are also used here with a slight modification. The modifications consists of replacing the observed data with smoothly varying functional fits based on the facility's distance from a runway (Ref. 6). Conversations with the Federal Aviation Administration Office of Accident Investigation (Ref. 7) indicate that these crash data are still accurate. Advances in aircraft safety indicate the crash probabilities are trending downward; however, the change is not yet statistically significant. The equations for the functional fits are shown below.

Commercial Aircraft	$C_{AP} = 5.53 \times 10^{-8}\ r^{-1.75}$
General Aircraft	$C_{AP} = 27.6 \times 10^{-8}\ r^{-1.8}$.

where

C_{AP} = crash probability per square mile per aircraft movement, and

r = distance from the end of the runway. The distance is measured from the runway to the center of the facility.

4.5 Summary of Calculation Variables

The list of variables needed for calculating the frequency of an aircraft crash at the Laboratory is given in Table 4-1. Most of these variables are facility specific, but all are listed to facilitate the calculation of probabilities for future facilities.

Table 4.1

List of Variables

Variable		Commercial Aviation	General Aviation
r	distance from runway	facility specific	facility specific
L	facility length	facility specific	facility specific
W	facility width	facility specific	facility specific
H	facility height	facility specific	facility specific
ws	wing span	93 feet (0.0176 miles)	35 feet (0.0066 miles)
sd	skid distance	facility specific	facility specific
a	distance from airway	facility specific	facility specific
C_{AW}	probability per mile that an aircraft will crash	4×10^{-10}	2×10^{-9}
C_{AP}	probability per square mile that an aircraft will crash	facility specific, based upon distance from runway	facility specific, based upon distance from runway
N (airport)	number of airport operations per year	3600	8834
N_{FA} (Airway)	number of flights per year	29,200	7300
θ	crash angle	15°	15°
ϕ	angle from runway to facility	facility specific	facility specific
F	distribution of impacts orthonormal to the flight path	facility specific	facility specific
P_o	normalization factor based on ϕ	facility specific	facility specific
$P_{r\ Takeoff}$	normalization factor based on r	facility specific	facility specific
$P_{r\ Landing}$	normalization factor based on r	facility specific	facility specific
A_c	total facility area	facility specific	facility specific
A_{sh}	shadow area	facility specific	facility specific
A_{sk}	skid area	facility specific	facility specific
A_{py}	plan area	facility specific	facility specific

5.0 SAMPLE CALCULATION: WASTE DISPOSAL SITE, AREA G

When performing an aircraft crash calculation, the facility should review the number of operations at the Los Alamos Airport to determine if they have increased. Also, the validity of the crash probability data should be verified. A sample calculation is shown in Table 5-1.

Table 5-1

Facility Specific Values for Variables in the Solomon Equations

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	17680	3.3485
L	Length (feet)	320	0.0606
W	Width (feet)	246	0.0466
H	Height (feet)	38	0.0072
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	58	
$P_{r\ Landing}$	factor based on r for landing	0.133	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.498	
P_o	factor based on ϕ; $=1/\phi$	0.017	

Area G is the low-level waste (LLW) and transuranic (TRU) waste disposal and storage site. It presently consist of two storage domes. Also located at Area G is the TRU Waste Inspectable Storage Project (TWISP). This project will consist of a single retrieval dome during retrieval operations and 4 storage domes when the project is complete. For the purpose of these calculations, the dimensions of the largest storage dome will be used. The area of the largest structure to be built for the TWISP project is calculated below for both commercial aviation and general aviation. Since this structure is, or will be, the largest structure at Area G, the results of this calculation will bound the frequency of an aircraft crashing into any facility at Area G.

Commercial Aviation:

Plan area

$$Apv = (L+ ws)W$$
$$= (0.\ 0606 + 0.0176) \times 0.\ 0466$$
$$Apv = 3.64 \times 10^{-3} \text{ miles}^2$$

Skid area

$$Ask = (L+ ws)sd$$
$$= (0.0606 + 0.0176) \times 0.0178$$
$$Ask = 1.39 \times 10^{-3} \text{ miles}^2$$

Shadow area

$$Ash = (L+ ws)H \cot\theta$$
$$= (0.0606 + 0.0176) \times .0072 \times \cot 15$$
$$Ash = 2.10 \times 10^{-3} \text{ miles}^2$$

Total effective area

$$Ae = Apv + Ask + Ash$$
$$\underline{Ae = 7.14 \times 10^{-3} \text{ miles}^2}$$

General Aviation:

Plan area

$$Apv = (L+ ws)W$$
$$= (0.0606 + 0.0066) \times 0.0466$$
$$Apv = 3.13 \times 10^{-3} \text{ miles}^2$$

Skid area

$$Ask = (L+ ws)sd$$
$$= (0.0606 + 0.0066) \times 0.0178$$
$$Ask = 1.20 \times 10^{-3} \text{ miles}^2$$

Shadow area

$$Ash = (L+ ws)H \cot\theta$$
$$= (0.0606 + 0.0066) \times .0072 \times \cot 15$$
$$Ash = 1.81 \times 10^{-3} \text{ miles}^2$$

Total effective area

$$Ae = Apv + Ask + Ash$$
$$\underline{Ae = 6.14 \times 10^{-3} \text{ miles}^2}$$

The values for C_{AP}, the probability per square mile that an aircraft will crash, is given by the equations below:

Commercial Aviation:

$$C_{AP} = 5.53 \times 10^{-8}\ r^{-1.75}$$
$$C_{AP} = 5.53 \times 10^{-8}\ (3.35)^{-1.75}$$
$$\underline{C_{AP} = 6.67 \times 10^{-9}\ 1/\text{mile}^2}$$

General Aviation:

$$C_{AP} = 27.6 \text{ X } 10^{-8}\ r^{-1.8}$$
$$C_{AP} = 27.6 \text{ X } 10^{-8}\ (3.35)^{-1.8}$$
$$\underline{C_{AP} = 3.13 \text{ X } 10^{-8}\ 1/\text{mile}^2}\ .$$

The next variables to calculate are the normalization factors related to the angle of the facility to the flight path and the distance of the facility from the airport. The normalization factor that relates air crash probability to the angle from the intended flight path is expressed as

$$P_0 = \begin{cases} 1 & 0^{\circ} \leq \phi < 1^{\circ} \\ 1/|\phi| & 1^{\circ} < \phi \leq 90^{\circ} \end{cases}$$

$$\phi = 58^{\circ}$$
$$P_o = 1/58$$
$$P_o = 0.017\ .$$

The normalization factor that relates air crash probability to the distance from the runway is given by

$$P_{r,\,\text{Landing}} = \begin{cases} 1 & r < 1 \text{ mile} \\ \dfrac{2}{3r} & 1 \text{ mile} \leq r < 2 \text{ miles} \\ \dfrac{2}{4.5r} & 2 \text{ miles} \leq r \leq 5 \text{ miles} \\ 0.08 & 5 \text{ miles} < r \end{cases}$$

$$P_{r,\,\text{Landing}} = 2/(4.5 \text{ x } r)$$
$$P_{r,\,\text{Landing}} = 2/(4.5 \text{ x } 3.35)$$
$$P_{r,\,\text{Landing}} = 0.133$$

$$P_{r,\,\text{Takeoff}} = \begin{cases} 1 & r < 1 \text{ mile} \\ \dfrac{4}{1.5r} & 1 \text{ mile} \leq r < 2 \text{ miles} \\ \dfrac{4}{2.4r} & 2 \text{ miles} \leq r \leq 5 \text{ miles} \\ 0.40 & 5 \text{ miles} < r \end{cases}$$

$$P_{r,\text{ Takeoff}} = 4/(2.4 \text{ x r})$$
$$P_{r,\text{ Takeoff}} = 4/(2.4 \text{ x } 3.35)$$
$$P_{r,\text{ Takeoff}} = 0.498$$

Substituting the effective areas, along with the values for N, P_o, P_r, and C into the airport equation gives

$$P_{AP} = \left(\frac{N_{commercial}}{2} xA_{commercial} xC_{commercial}\right) xP_{r,\text{ Takeoff}} xP_0 + \left(\frac{N_{commercial}}{2} xA_{commercial} xC_{commercial}\right) xP_{r,\text{ Landing}} xP_0 +$$
$$\left(\frac{N_{general}}{2} xA_{general} xC_{general}\right) xP_{r,\text{ Takeoff}} xP_0 + \left(\frac{N_{general}}{2} xA_{general} xC_{general}\right) xP_{r,\text{ Landing}} xP_0$$

$$P_{AP} = (1800x7.14x10^{-3}x6.67x10^{-9})x0.498x0.017 + (1800x7.14x10^{-3}x6.67x10^{-9})x0.133x0.017 +$$
$$(4417x6.14x10^{-3}x3.13x10^{-8})x0.498x0.017 + (4417x6.14x10^{-3}x3.13x10^{-8})x0.133x0.017$$

$$P_{AP} = 9.31 \text{ x } 10^{-10} + 9.22 \text{ x } 10^{-9}$$
$$P_{AP} = 1.02 \text{ x } 10^{-8} \text{ /year}$$

This is the total frequency of an aircraft crashing into the facility per year from planes taking off and landing at the Los Alamos Airport.

The frequency of an aircraft crashing into the facility per year from planes in the airway near Laboratory is given by

$$P_{FA} = (N_{commercial} xA_{commercial} xC_{commercial} xF(a)_{commercial}) + (N_{general} xA_{general} xC_{general} xF(a)_{general})$$
$$P_{FA} = \left(29200x7.14x10^{-3}x4x10^{-10}x\left(\frac{1.6}{2}e^{(-1.6x6.25)}\right)\right) + \left(7300x6.14x10^{-3}x4x10^{-9}x\left(\frac{2}{2}e^{(-2x6.25)}\right)\right)$$

$$P_{FA} = 3.03 \text{ x } 10^{-12} + 6.68 \text{ x } 10^{-13}$$
$$P_{FA} = 3.70 \text{ x } 10^{-12} \text{ /year}$$

For the total frequency of an aircraft crash, the frequency from the airport equation and the airway equation are added.

$$P_{TOTAL} = P_{AP} + P_{FA}$$
$$P_{TOTAL} = 1.02 \text{ x } 10^{-8} + 3.70 \text{ x } 10^{-12}$$
$$\mathbf{P_{TOTAL} = 1.02 \text{ x } 10^{-8} \text{ per year}}$$

Table 6.2 lists all of the values calculated above for Area G.

Table 6.2

Calculated Values for Variables in the Solomon Equations for Area G

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.0178	0.0178
a	The orthonormal distance from the airway to the target structure	mi	6.2500	6.2500
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	$1/mi^2$	5.53E-8 x $r^{-1.75}$ 6.67E-09	27.6E-8 x $r^{-1.8}$ 3.13E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 3.63E-05	.5x2xexp(-2xa) 3.73E-06
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	7.14E-03	6.14E-03
Apv	plan area [(L + ws) (W)]	mi^2	3.64E-03	3.13E-03
Ask	skid area [(L + ws) (sd)]	mi^2	1.39E-03	1.20E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	2.10E-03	1.81E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_rxP_o$	9.32E-10	9.23E-09
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	3.03E-12	3.34E-13
P	**Total probability per year of an aircraft crash at the facility**	**total**	**1.02E-08**	

6.0 REFERENCES

1. U.S. Nuclear Regulatory Commission, NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Commercial Nuclear Power Plants*, 1981.

2. Karimi, R., *Review of Aircraft Crash Hazard Analysis in the Commercial Nuclear Industry and at Department of Energy Facilities*, March 1994.

3. USAEC Regulatory Staff, Docket No. 50-322, Safety Evaluation Report, Appendix A, *Probability of an Aircraft Crash at the Shoreham Site*, 1969.

4. Solomon, K. A., Erdman, R. C., Hicks, T. E., Okrent, D, UCLA-ENG-7424, *Airplane Crash Risk To Ground Population*, University Of California, Los Angeles, CA., March 1974.

5. Seigler, R. S., Martin Marietta Energy Systems Inc., ORNL/ENG/TM-36 (draft), *The Annual Probability of an Aircraft Crash for the U.S. Department of Energy Reservation in Oak Ridge, TN.*, Oak Ridge National Laboratory, Oak Ridge, TN., 1990.

6. U.S. Department of Energy, *Safety Evaluation Report for the Pantex Plant Zone 4 Magazines,* Pantex Plant, Amarillo, Texas, December 1992.

7. Nelson, C., Conversation with Dallas Bishoff, Federal Aviation Administration Office of Accident Investigation, Los Alamos National Laboratory, Los Alamos, NM, August 1994.

List of Appendices

Facility Name	Location	Appendix
Chemical Metallurgical Research (CMR) Facility	TA-3-29	A
Weapons Engineering Tritium Facility (WETF)	TA-16-205	B
Hillside Vault (Pajarito Site)	TA-18-26	C
Los Alamos Critical Experiments Facility (LACEF) Kiva 1	TA-18-23	D
LACEF Kiva 2	TA-18-32	E
LACEF Kiva 3	TA-18-116	F
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Each Appendix contains tabulated values and the total probabilities for an aircraft crash at the stated facilities. All figures are included in a separate section at the end of this report.

Appendix A

Chemical and Metallurgical Research Facility

TA-03-29

The Chemical and Metallurgical Research Facility (CMR Building) was designed to house analytical chemistry facilities, plutonium metallurgy, uranium chemistry, engineering design and drafting, electronics, and other support functions of the old CMB Division. The CMR Building is a reinforced concrete building with a basement, a first floor, and an attic floor (the administration wing and wing 1 contain second-floor office areas). The plan of the building is centered on a spinal corridor with an administration wing and seven laboratory wings.

Figure A-1 shows an outline of the facility, and Figure A-2 shows the facility's distance to the airport. Credit is taken for surrounding buildings, trees and terrain to shorten the skid lengths.

Table A-1 shows the facility specific values used in the Solomon equations, and Table A-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table A-1

Facility Specific Values for CMR

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	18335	3.4725
L	Length (feet)	660	0.1250
W	Width (feet)	660	0.1250
H	Height (feet)	50	0.0095
θ	impact angle (degrees)	3	
ϕ	angle from runway to facility (degrees)	18	
$P_{r\,Landing}$	factor based on r for landing	0.128	
$P_{r\,Takeoff}$	factor based on r for takeoff	0.480	
P_{o}	factor based on ϕ; $=1/\phi$	0.056	

Table A-2

Calculated Values for CMR

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.1326	0.0568
a	The orthonormal distance from the airway to the target structure	mi	7.0076	7.0076
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	1/mi ^{2}	5.53E-8 x $r^{-1.75}$ 6.26E-09	27.6E-8 x $r^{-1.8}$ 2.94E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 1.08E-05	.5x2xexp(-2xa) 8.19E-07
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	6.25E-02	4.77E-02
Apv	plan area [(L + ws) (W)]	mi^2	1.78E-02	1.65E-02
Ask	skid area [(L + ws) (sd)]	mi^2	1.89E-02	7.48E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	2.58E-02	2.38E-02
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_rxP_o$	2.38E-08	2.09E-07
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	7.89E-12	5.71E-13
P	**Total probability per year of an aircraft crash at the facility**	**total**	**2.33E-07**	

Appendix B

Weapons Engineering Tritium Facility

TA-16-205

The Weapons Engineering Tritium Facility (WETF) was built to replace an aging tritium filling facility at TA-33. WETF provides tritium filling services, as well as the repackaging of tritium into smaller quantities, removal of tritium, and the analyses of gaseous tritium. The structure consists of concrete-filled reinforced block walls, reinforced concrete floors and columns, and a pre-cast concrete roof with a membrane coating. Building gases are exhausted through a stack 60 feet tall mounted on a rugged octagonal concrete base.

Figure B-1 shows an outline of the facility, and Figure B-2 shows the facility's distance to the airport. Credit is taken for surrounding buildings, trees and terrain to shorten the skid lengths.

Table B-1 shows the facility specific values used in the Solomon equations, and Table B-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table B-1

Facility Specific Values for WETF

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	31217	5.9123
L	Length (feet)	105	0.0199
W	Width (feet)	70	0.0133
H	Height (feet)	60	0.0114
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	40	
$P_{r\ Landing}$	factor based on r for landing	0.080	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.400	
P_o	factor based on ϕ; $=1/\phi$	0.025	

Table B-2

Calculated Values for WETF

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.3000	0.0600
a	The orthonormal distance from the airway to the target structure	mi	4.3561	4.3561
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	$1/mi^2$	5.53E-8 x $r^{-1.75}$ 2.47E-09	27.6E-8 x $r^{-1.8}$ 1.13E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 7.52E-04	.5x2xexp(-2xa) 1.65E-04
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	1.33E-02	3.07E-03
Apv	plan area [(L + ws) (W)]	mi^2	4.97E-04	3.52E-04
Ask	skid area [(L + ws) (sd)]	mi^2	1.13E-02	1.59E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	1.59E-03	1.12E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$N x A x C_{AP} x P_r x P_o$	7.11E-10	1.83E-09
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$N x A x C_{AW} x F$	1.17E-10	7.37E-12
P	**Total probability per year of an aircraft crash at the facility**	**total**	**2.67E-09**	

Appendix C

Hillside Vault

TA-18-26

The Hillside Vault is located in an excavation in the volcanic tuff canyon walls that border the north side of Pajarito site. Only the vault door and a portion of the front wall are visible from the loading dock. The remainder of the building is underground.

Because the facility is underground, there is no figure showing the outline of the facility. Figure C, D, E, F-2 shows the facility's distance to the airport. Credit is taken for surrounding buildings, trees and terrain to shorten the skid lengths.

Table C-1 shows the facility specific values used in the Solomon equations, and Table C-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table C-1

Facility Specific Values for the Hillside Vault

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	13590	2.5739
L	Length (feet)	25	0.0047
W	Width (feet)	25	0.0047
H	Height (feet)	0	0.0000
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	82	
$P_{r\ Landing}$	factor based on r for landing	0.173	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.648	
P_{o}	factor based on ϕ; $=1/\phi$	0.012	

Table C-2

Calculated Values for Hillside Vault

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.0644	0.0600
a	The orthonormal distance from the airway to the target structure	mi	6.4394	6.4394
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	1/mi ^{2}	5.53E-8 x $r^{-1.75}$ 1.06E-08	27.6E-8 x $r^{-1.8}$ 5.03E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 2.68E-05	.5x2xexp(-2xa) 2.55E-06
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi²	1.54E-03	7.36E-04
Apv	plan area [(L + ws) (W)]	mi²	1.06E-04	5.38E-05
Ask	skid area [(L + ws) (sd)]	mi²	1.44E-03	6.82E-04
Ash	shadow area [(L + ws) (H) (cot θ)]	mi²	0.00E+00	0.00E+00
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_fxP_o$	2.94E-10	1.64E-09
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	4.84E-13	2.74E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**1.93E-09**	

Appendix D

LACEF Kiva 1

LACEF is the Los Alamos Critical Experiments Facility and houses several critical assemblies used in research activities. LACEF is located in TA-18 and consists of three remote-control laboratories, known as kivas, which are located at some distances from the main laboratory building that houses individual control rooms for each kiva.

Kiva 1 is 61 feet long, 48 feet wide, and 26 feet 1 inch high. Figure D-1 shows an outline of the facility, and Figure C, D, E, F-2 shows the facility's distance to the airport. No credit is taken to shorten the skid distances, therefore the skid length is 0.06 mile for general aviation aircraft and 0.3 mile for US air carrier aircraft (commercial aviation).

Table D-1 shows the facility specific values used in the Solomon equations, and Table D-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table D-1

Facility Specific Values for LACEF Kiva 1

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	13163	2.4930
L	Length (feet)	61	0.0116
W	Width (feet)	47.5	0.0090
H	Height (feet)	26.08	0.0049
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	86	
$P_{r\ Landing}$	factor based on r for landing	0.178	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.669	
P_o	factor based on ϕ; =1/ϕ	0.012	

Table D-2

Calculated Values for LACEF Kiva 1

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.3000	0.0600
a	The orthonormal distance from the airway to the target structure	mi	6.4394	6.4394
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	$1/mi^2$	5.53E-8 x $r^{-1.75}$ 1.12E-08	27.6E-8 x $r^{-1.8}$ 5.33E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 2.68E-05	.5x2xexp(-2xa) 2.55E-06
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	9.55E-03	1.59E-03
Apv	plan area [(L + ws) (W)]	mi^2	2.62E-04	1.64E-04
Ask	skid area [(L + ws) (sd)]	mi^2	8.75E-03	1.09E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	5.38E-04	3.35E-04
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$N x A x C_{AP} x P_r x P_o$	1.89E-09	3.69E-09
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$N x A x C_{AW} x F$	2.99E-12	5.92E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**5.58E-09**	

Appendix E

LACEF Kiva 2

LACEF is the Los Alamos Critical Experiments Facility and houses several critical assemblies used in research activities. LACEF is located in TA-18 and consists of three remote-control laboratories, known as kivas, which are located at some distances from the main laboratory building that houses individual control rooms for each kiva.

Kiva 2 is 58.5 feet long, 57.5 feet wide, and 26 feet 1 inch high. Figure E-1 shows an outline of the facility, and Figure C, D, E, F-2 shows the facility's distance to the airport. No credit is taken to shorten the skid distances, therefore the skid length is 0.06 mile for general aviation aircraft and 0.3 mile for US air carrier aircraft (commercial aviation).

Table E-1 shows the facility specific values used in the Solomon equations, and Table E-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table E-1

Facility Specific Values for LACEF Kiva 2

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	14533	2.7525
L	Length (feet)	58.5	0.0111
W	Width (feet)	57.5	0.0109
H	Height (feet)	26.08	0.0049
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	88	
$P_{r\,Landing}$	factor based on r for landing	0.161	
$P_{r\,Takeoff}$	factor based on r for takeoff	0.606	
P_o	factor based on ϕ; =1/ϕ	0.011	

Table E-2

Calculated Values for LACEF Kiva 2

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.3000	0.0600
a	The orthonormal distance from the airway to the target structure	mi	6.4394	6.4394
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	$1/mi^2$	$5.53E\text{-}8 \times r^{-1.75}$ 9.40E-09	$27.6E\text{-}8 \times r^{-1.8}$ 4.46E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 2.68E-05	.5x2xexp(-2xa) 2.55E-06
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	9.45E-03	1.58E-03
Apv	plan area [(L + ws) (W)]	mi^2	3.12E-04	1.93E-04
Ask	skid area [(L + ws) (sd)]	mi^2	8.61E-03	1.06E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	5.29E-04	3.26E-04
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$N \times A \times C_{AP} \times P_r \times P_o$	1.39E-09	2.72E-09
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$N \times A \times C_{AW} \times F$	2.96E-12	5.89E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**4.11E-09**	

Appendix F

LACEF Kiva 3

LACEF is the Los Alamos Critical Experiments Facility and houses several critical assemblies used in research activities. LACEF is located in TA-18 and consists of three remote-control laboratories, known as kivas, which are located at some distances from the main laboratory building that houses individual control rooms for each kiva.

Kiva 3 is 81 feet long, 64 feet wide, and 26 feet 1 inch high. Figure F-1 shows an outline of the facility, and Figure C, D, E, F-2 shows the facility's distance to the airport. No credit is taken to shorten the skid distances, therefore the skid length is 0.06 mile for general aviation aircraft and 0.3 mile for US air carrier aircraft (commercial aviation).

Table F-1 shows the facility specific values used in the Solomon equations, and Table F-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table F-1

Facility Specific Values for LACEF Kiva 3

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	14556	2.7568
L	Length (feet)	81	0.0153
W	Width (feet)	64	0.0121
H	Height (feet)	26.08	0.0049
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	81	
$P_{r\ Landing}$	factor based on r for landing	0.161	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.605	
P_o	factor based on ϕ; =1/ϕ	0.012	

Table F-2

Calculated Values for LACEF Kiva 3

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.3000	0.0600
a	The orthonormal distance from the airway to the target structure	mi	6.4394	6.4394
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	1/mi ^{2}	5.53E-8 x $r^{-1.75}$ 9.38E-09	27.6E-8 x $r^{-1.8}$ 4.45E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 2.68E-05	.5x2xexp(-2xa) 2.55E-06
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi²	1.09E-02	1.99E-03
Apv	plan area [(L + ws) (W)]	mi²	3.99E-04	2.66E-04
Ask	skid area [(L + ws) (sd)]	mi²	9.89E-03	1.32E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi²	6.08E-04	4.05E-04
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_rxP_o$	1.74E-09	3.70E-09
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	3.41E-12	7.41E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**5.44E-09**	

Appendix G

Tritium System Test Assembly Facility

The Tritium Systems Test Assembly (TSTA)was conceived, designed, and built to provide the technological base of the tritium fuel systems for advanced fusion reactor concepts. The building walls are constructed of 20 cm concrete masonry block, reinforced with deformed reinforcing bars.

Figure G-1 shows an outline of the facility, and Figure G, H-2 shows the facility's distance to the airport. Credit is taken for surrounding buildings, trees, and terrain to shorten the skid lengths.

Table G-1 shows the facility specific values used in the Solomon equations, and Table G-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table G-1

Facility Specific Values for TSTA

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	3592	0.6803
L	Length (feet)	90	0.0170
W	Width (feet)	77	0.0146
H	Height (feet)	98	0.0186
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	23	
$P_{r\ Landing}$	factor based on r for landing	1.000	
$P_{r\ Takeoff}$	factor based on r for takeoff	1.000	
P_{ϕ}	factor based on ϕ; $=1/\phi$	0.043	

Table G-2

Calculated Values for TSTA

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.3000	0.0600
a	The orthonormal distance from the airway to the target structure	mi	8.7122	8.7122
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
	Probability per square mile that an		$5.53E\text{-}8 \times r^{-1.75}$	$27.6E\text{-}8 \times r^{-1.8}$
C_{AP}	aircraft will crash	$1/mi^2$	1.09E-07	5.52E-07
	Distribution of impacts		.5x1.6xexp(-1.6xa)	.5x2xexp(-2xa)
F	orthonormal to the flight path	1/mi	7.07E-07	2.71E-08
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	1.33E-02	3.41E-03
Apv	plan area [(L + ws) (W)]	mi^2	5.05E-04	3.45E-04
Ask	skid area [(L + ws) (sd)]	mi^2	1.04E-02	1.42E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	2.41E-03	1.65E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$N x A x C_{AP} x P_r x P_o$	2.26E-07	7.24E-07
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$N x A x C_{AW} x F$	1.10E-13	1.35E-15
P	**Total probability per year of an aircraft crash at the facility**	**total**	**9.50E-07**	

Appendix H

Tritium Science and Fabrication Facility

The Tritium Science and Fabrication Facility (TSFF) is a tritium research and development facility. It was designed and built to handle tritium in the gaseous or metal tritide form. Building 209 is a one-story building constructed in 1964 and consists of reinforced concrete frames with unreinforced masonry block and brick infill mixed with interior steel beams and columns. An addition was added in 1969 and is a one-story building with a crawl space. The height of the building is 20 feet, with a stack height of 75 feet.

Figure H-1 shows an outline of the facility, and Figure G, H-2 shows the facility's distance to the airport. Credit is taken for surrounding buildings, trees, and terrain to shorten the skid lengths.

Table H-1 shows the facility specific values used in the Solomon equations, and Table H-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table H-1

Facility Specific Values for TSFF

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	3376.6	0.6395
L	Length (feet)	96.3	0.0182
W	Width (feet)	62.3	0.0118
H	Height (feet)	75	0.0142
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	26	
$P_{r\ Landing}$	factor based on r for landing	1.000	
$P_{r\ Takeoff}$	factor based on r for takeoff	1.000	
P_{ϕ}	factor based on ϕ; $=1/\phi$	0.038	

Table H-2

Calculated Values for TSFF

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.2045	0.0600
a	The orthonormal distance from the airway to the target structure	mi	8.7122	8.7122
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	1/mi ^{2}	$5.53E\text{-}8 \times r^{-1.75}$ 1.21E-07	$27.6E\text{-}8 \times r^{-1.8}$ 6.17E-07
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 7.07E-07	.5x2xexp(-2xa) 2.71E-08
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	9.66E-03	3.10E-03
Apv	plan area [(L + ws) (W)]	mi^2	4.23E-04	2.93E-04
Ask	skid area [(L + ws) (sd)]	mi^2	7.33E-03	1.49E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	1.90E-03	1.32E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$N x A x C_{AP} x P_r x P_o$	1.62E-07	6.51E-07
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$N x A x C_{AW} x F$	7.97E-14	1.23E-15
P	**Total probability per year of an aircraft crash at the facility**	**total**	**8.12E-07**	

Appendix I

Main Vault

The Main Storage Vault is loacted at TA-41 in Los Alamos Canyon. The Main Vault provides the DOE with facilities for testing, monitoring, assembling, and storing nuclear weapon components.

The vault is approximtely 100 feet long and 45 feet wide and is below grade. Figure I-1 shows an outline of the facility, and Figure I-2 shows the facility's distance to the airport. Credit is taken for surrounding buildings, trees, and terrain to shorten the skid lengths.

Table I-1 shows the facility specific values used in the Solomon equations, and Table I-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table I-1

Facility Specific Values for the Main Vault

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	10933	2.0706
L	Length (feet)	100	0.0189
W	Width (feet)	45	0.0085
H	Height (feet)	0	0.0000
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	14	
$P_{r\,Landing}$	factor based on r for landing	0.215	
$P_{r\,Takeoff}$	factor based on r for takeoff	0.805	
P_o	factor based on ϕ; $=1/\phi$	0.071	

Table I-2

Calculated Values for Main Vault

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.0178	0.0178
a	The orthonormal distance from the airway to the target structure	mi	8.1440	8.1440
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
	Probability per square mile that an		$5.53E\text{-}8 \times r^{-1.75}$	$27.6E\text{-}8 \times r^{-1.8}$
C_{AP}	aircraft will crash	$1/mi^2$	1.55E-08	7.45E-08
	Distribution of impacts		.5x1.6xexp(-1.6xa)	.5x2xexp(-2xa)
F	orthonormal to the flight path	1/mi	1.75E-06	8.44E-08
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	9.62E-04	6.73E-04
Apv	plan area [(L + ws) (W)]	mi^2	3.12E-04	2.18E-04
Ask	skid area [(L + ws) (sd)]	mi^2	6.51E-04	4.55E-04
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	0.00E+00	0.00E+00
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_rxP_o$	1.95E-09	1.61E-08
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	1.97E-14	8.29E-16
P	**Total probability per year of an aircraft crash at the facility**	total	**1.81E-08**	

Appendix J

Radioactive Liquid Waste Treatment Facility

The Radioactive Liquid Waste Treatment Facility (RLWTF) concentrates and removes radioactive components from liquid wastes. The main building is constructed of reinforced concrete columns and beams with hollow concrete masonry block walls and steel joists for roof support.

Figure J-1 shows an outline of the facility, and Figure J, K-2 shows the facility's distance to the airport. The RLWTF is bounded on the east and west by buildings and on the north by a Security fence and an industrial fence. For a plane to skid in from the south, it would have to go through a minimum of two industrial fences, and in some cases three or four fences. The distance from the RLWTF to the furthest fence is 705 ft. This distance will be used for commercial aircraft, and the skid distance for general aircraft will be the general value of 316.8 ft.

Table J-1 shows the facility specific values used in the Solomon equations, and Table J-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table J-1

Facility Specific Values for the RLWTF

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	12495	2.3665
L	Length (feet)	310	0.0587
W	Width (feet)	233	0.0441
H	Height (feet)	65	0.0123
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	41	
$P_{r\ Landing}$	factor based on r for landing	0.188	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.704	
P_o	factor based on ϕ; $=1/\phi$	0.024	

Table J-2

Calculated Values for RLWTF

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.1335	0.0600
a	The orthonormal distance from the airway to the target structure	mi	7.3864	7.3864
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
	Probability per square mile that an		5.53E-8 x $r^{-1.75}$	27.6E-8 x $r^{-1.8}$
C_{AP}	aircraft will crash	$1/mi^2$	1.22E-08	5.85E-08
	Distribution of impacts		.5x1.6xexp(-1.6xa)	.5x2xexp(-2xa)
F	orthonormal to the flight path	1/mi	5.90E-06	3.84E-07
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	1.71E-02	9.81E-03
Apv	plan area [(L + ws) (W)]	mi^2	3.37E-03	2.88E-03
Ask	skid area [(L + ws) (sd)]	mi^2	1.02E-02	3.92E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	3.51E-03	3.00E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_rxP_o$	8.19E-09	5.52E-08
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	1.18E-12	5.50E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**6.34E-08**	

Appendix K

Treatment Demonstration Facility

The mission of the at the Treatment Development Facility (TDF) at TA-50-37 was to study methods for the volume reduction and chemical stabilization of transuranic contaminated solid wastes. Operations have included waste receipt, acceptance, and storage operations, controlled-air incinerator (CAI) operations, and ash vitrification operations. With the exception of the office addition, the facility features precast reinforced concrete construction with prestressed, pretensioned concrete double-T section exterior walls. The maximum height of the building is 9.3 m (30.5 ft), or 12.95 m (42.5 ft) including the stack.

Figure K-1 shows an outline of PF-4 and its surrounding buildings. Figure K-2 shows a map of PF-4 in relation to the Airport. Credit is taken for surrounding buildings, trees and terrain to shorten the skid length.

Table K-1 shows the facility specific values used in the Solomon equations, and Table K-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table K-1

Facility Specific Values for the TDF/CAI

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	12801	2.4244
L	Length (feet)	142	0.0269
W	Width (feet)	130	0.0246
H	Height (feet)	42.5	0.0080
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	39	
$P_{r\ Landing}$	factor based on r for landing	0.183	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.687	
P_{ϕ}	factor based on ϕ; $=1/\phi$	0.026	

Table K-2

Calculated Values for TDF/CAI

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.1477	0.0600
a	The orthonormal distance from the airway to the target structure	mi	7.3864	7.3864
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
	Probability per square mile that an		5.53E-8 x $r^{-1.75}$	27.6E-8 x $r^{-1.8}$
C_{AP}	aircraft will crash	1/mi ^{2}	1.17E-08	5.61E-08
	Distribution of impacts		.5x1.6xexp(-1.6xa)	.5x2xexp(-2xa)
F	orthonormal to the flight path	1/mi	5.90E-06	3.84E-07
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	9.01E-03	3.84E-03
Apv	plan area [(L + ws) (W)]	mi^2	1.10E-03	8.25E-04
Ask	skid area [(L + ws) (sd)]	mi^2	6.57E-03	2.01E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	1.34E-03	1.01E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_rxP_o$	4.25E-09	2.12E-08
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	6.20E-13	2.15E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**2.55E-08**	

Appendix L

Waste Characterization Reduction and Repackaging Facility

The primary mission of the WCRRF is to reduce the volume of bulky, TRU-contaminated, obsolete equipment for disposal. The WCRRF is a one-story building with a floor area of 252 m^2 (2712 ft^2) and a volume of 1,377 m^3 (1,801 yd^3). The height of the building is 7.0 m (23 ft) above grade. The enclosure and welding fume exhaust stacks extend 10.7 m (35 ft) above grade. The building exhaust stack is located next to the WCRRF and extends to a height of 12.5 m (41 ft) above grade. The exterior walls of the WCRRF are load-bearing and are constructed of structural steel stud framing with a plastic veneer finish on polystyrene insulation and gypsum wall board. The roof and mezzanine floor are constructed of reinforced concrete poured over steel joists and metal decking. The design calculations for the facility are on file in the Engineering Records Management Group, ENG-5.

Figure L-1 shows an outline of PF-4 and its surrounding buildings. Figure L-2 shows a map of PF-4 in relation to the Airport. Credit is taken for surrounding buildings, trees and terrain to shorten the skid length.

Table L-1 shows the facility specific values used in the Solomon equations, and Table L-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table L-1

Facility Specific Values for WCRRF

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	12943	2.4513
L	Length (feet)	90	0.0170
W	Width (feet)	45	0.0085
H	Height (feet)	41	0.0078
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	40	
$P_{r\ Landing}$	factor based on r for landing	0.181	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.680	
P_o	factor based on ϕ; $=1/\phi$	0.025	

Table L-2

Calculated Values for WCRRF

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.1402	0.0600
a	The orthonormal distance from the airway to the target structure	mi	7.3864	7.3864
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	1/mi ^{2}	$5.53E\text{-}8 \times r^{-1.75}$ 1.15E-08	$27.6E\text{-}8 \times r^{-1.8}$ 5.50E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa) 5.90E-06	.5x2xexp(-2xa) 3.84E-07
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi²	6.16E-03	2.31E-03
Apv	plan area [(L + ws) (W)]	mi²	2.95E-04	2.02E-04
Ask	skid area [(L + ws) (sd)]	mi²	4.86E-03	1.42E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi²	1.00E-03	6.86E-04
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$N x A x C_{AP} x P_r x P_o$	2.75E-09	1.21E-08
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$N x A x C_{AW} x F$	4.24E-13	1.29E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**1.48E-08**	

Appendix M

Waste Disposal Site, Area G

Area G is the LLW and TRU waste disposal and storage site. It presently consists of several storage domes. Also located at Area G is the TRU Waste Inspectable Storage Project (TWISP). This project will consist of a single retrieval dome during retrieval operations, and 4 storage domes when the project is complete. The area of the largest structure to be built for the TWISP project is calculated below for both commercial aviation and general aviation. Since this structure is, or will be, the largest structure at Area G, the results of this calculation will bound the frequency of an aircraft crashing into any facility at Area G.

The largest building at Area G is 320 feet long, 246 feet wide, and 38 feet high. Figure M-1 shows an outline of the facility, and Figure M-2 shows the facility's distance to the airport. No credit is taken to shorten the skid distances, therefore the skid length is 0.06 mile for general aviation aircraft and 0.3 mile for US air carrier aircraft (commercial aviation).

Table M-1 shows the facility specific values used in the Solomon equations, and Table M-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table M-1

Facility Specific Values for Area G

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	17680	3.3485
L	Length (feet)	320	0.0606
W	Width (feet)	246	0.0466
H	Height (feet)	38	0.0072
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	58	
$P_{r\ Landing}$	factor based on r for landing	0.133	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.498	
$P_{\circ}$	factor based on ϕ; $=1/\phi$	0.017	

Table M-2

Calculated Values for Area G

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.0178	0.0178
a	The orthonormal distance from the airway to the target structure	mi	6.2500	6.2500
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
	Probability per square mile that an		5.53E-8 x $r^{-1.75}$	27.6E-8 x $r^{-1.8}$
C_{AP}	aircraft will crash	1/mi ^{2}	6.67E-09	3.13E-08
	Distribution of impacts		.5x1.6xexp(-1.6xa)	.5x2xexp(-2xa)
F	orthonormal to the flight path	1/mi	3.63E-05	3.73E-06
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	7.14E-03	6.14E-03
Apv	plan area [(L + ws) (W)]	mi^2	3.64E-03	3.13E-03
Ask	skid area [(L + ws) (sd)]	mi^2	1.39E-03	1.20E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	2.10E-03	1.81E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$NxAxC_{AP}xP_rxP_o$	9.32E-10	9.23E-09
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$NxAxC_{AW}xF$	3.03E-12	3.34E-13
P	**Total probability per year of an aircraft crash at the facility**	**total**	**1.02E-08**	

Appendix N

Plutonium Facility

Facility dimensions for Building PF-4 were obtained from Dr. James A. Corll of NMT-8 via a telephone conversation on July 16, 1993, and are an east-west horizontal dimension of 284 feet, a north-south horizontal dimension of 262 feet, and an average height of 32 feet. The height of PF-4 above grade varies from 0 feet to 45 feet. The effective average height is 32 feet. Since it is equally likely that an aircraft could hit any side of the building facing the transit path into restricted space, the average building height is used to develop an average target area.

Figure N-1 shows an outline of PF-4 and its surrounding buildings. Figure N-2 shows a map of PF-4 in relation to the Airport. The area on the northeast and southwest of PF-4 is bounded by sudden drops in elevation. To the southeast, PF-4 is screened from approaching aircraft by several buildings (PF-3, -5, -1 and others). TA-48 is located to the northwest. Of these four directions, the longest possible skid distance is between PF–4 and TA-48-1. This is approximately 1125 feet (0.2131 miles). Therefore, this value will be used for the skid distance for commercial aviation.

Table N-1 shows the facility specific values used in the Solomon equations, and Table N-2 shows the calculated values, along with the total probability per year of an aircraft crashing into the facility.

Table N-1

Facility Specific Values for PF-4

	Parameter	Facility Value	Value in Miles
r	Distance from runway (feet)	13495	2.5559
L	Length (feet)	284	0.0538
W	Width (feet)	262	0.0496
H	Height (feet)	32	0.0061
θ	impact angle (degrees)	15	
ϕ	angle from runway to facility (degrees)	34	
$P_{r\ Landing}$	factor based on r for landing	0.174	
$P_{r\ Takeoff}$	factor based on r for takeoff	0.652	
P_{ϕ}	factor based on ϕ; $=1/\phi$	0.029	

Table N-2

Calculated Values for PF-4

	Parameter	Units	Commercial	General
ws	wing span	mi	0.0176	0.0066
sd	skid distance	mi	0.2131	0.0600
a	The orthonormal distance from the airway to the target structure	mi	7.1970	7.1970
C_{AW}	Probability per mile that an aircraft will crash	1/mi	4.00E-10	2.00E-09
C_{AP}	Probability per square mile that an aircraft will crash	$1/mi^2$	$5.53E\text{-}8 \times r^{-1.75}$	$27.6E\text{-}8 \times r^{-1.8}$
			1.07E-08	5.10E-08
F	Distribution of impacts orthonormal to the flight path	1/mi	.5x1.6xexp(-1.6xa)	.5x2xexp(-2xa)
			7.98E-06	5.61E-07
N	# flights per year	1/yr	3600	8834
N_{FA}	# flights per year in airway	1/yr	29200	7300
Ae	effective facility area	mi^2	2.04E-02	7.99E-03
Apv	plan area [(L + ws) (W)]	mi^2	3.54E-03	3.00E-03
Ask	skid area [(L + ws) (sd)]	mi^2	1.52E-02	3.63E-03
Ash	shadow area [(L + ws) (H) (cot θ)]	mi^2	1.61E-03	1.37E-03
P_{AP}	Probability per year of an aircraft crashing into the site from using an airport	$N \times A \times C_{AP} \times P_r \times P_o$	9.53E-09	4.37E-08
P_{FA}	Probability per year of an aircraft crashing into the site from an airway	$N \times A \times C_{AW} \times F$	1.90E-12	6.54E-14
P	**Total probability per year of an aircraft crash at the facility**	**total**	**5.32E-08**	

Figures for Appendices A-N

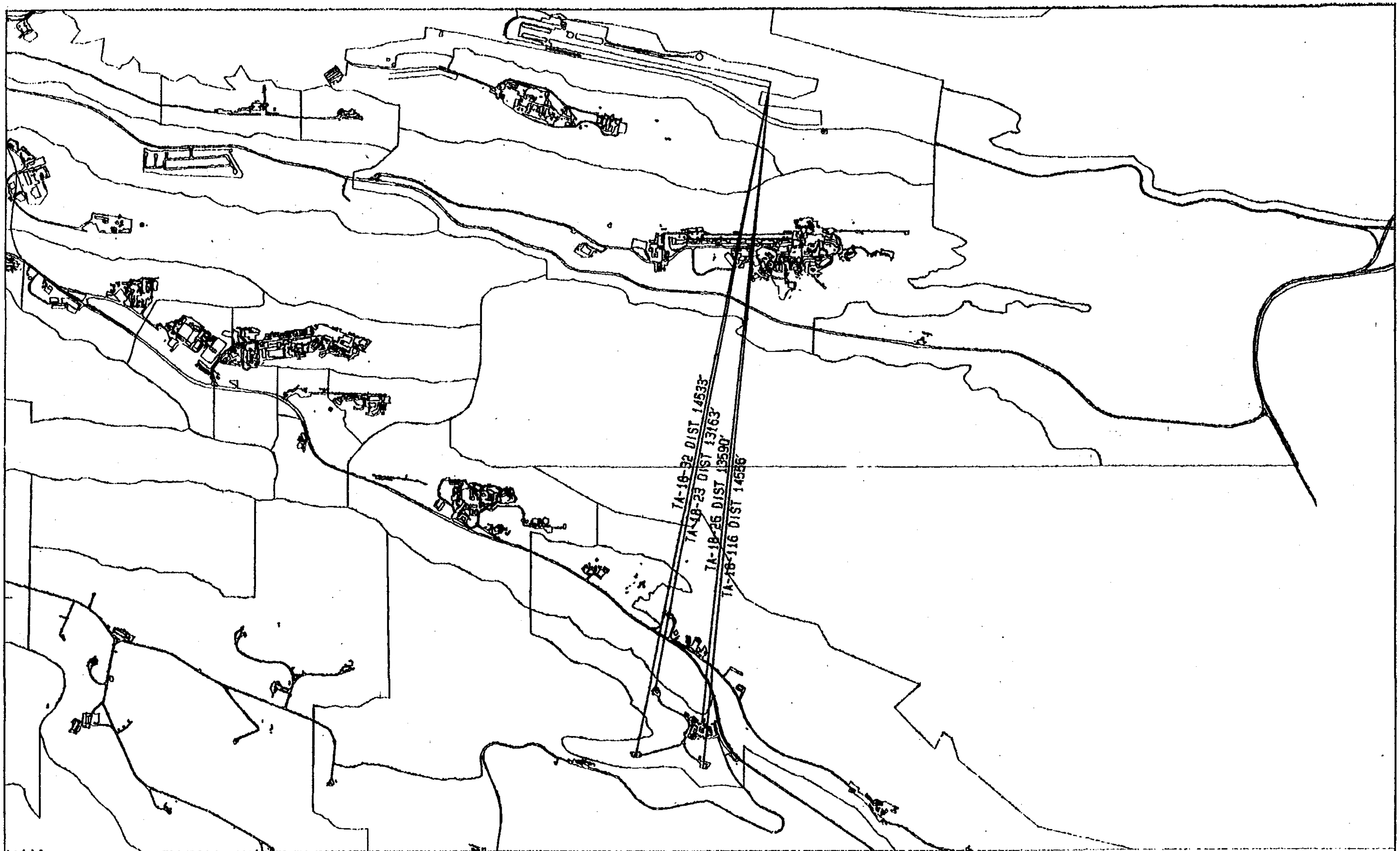


FIGURE C,D,E,F-2 FROM RUNWAY TO TA-18

Prepared for:
LOS ALAMOS NATIONAL LABORATORY
RON SELVAGE

State Plane Coordinate System, New Mexico Central Zone 1927 North American Datum

Note: The data shown on this map has not been checked for accuracy. Plan data shown is from the Los Alamos National Laboratory Engineering Division 1986 aerial survey and from As-Built field measurement updates.

3000 0 3000 6000
FEET

Prepared by: Drew Cummings
Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667-5293

LEGEND

BUILDING OF INTEREST
LABORATORY STRUCTURES
INDUSTRIAL FENCE
SECURITY FENCE

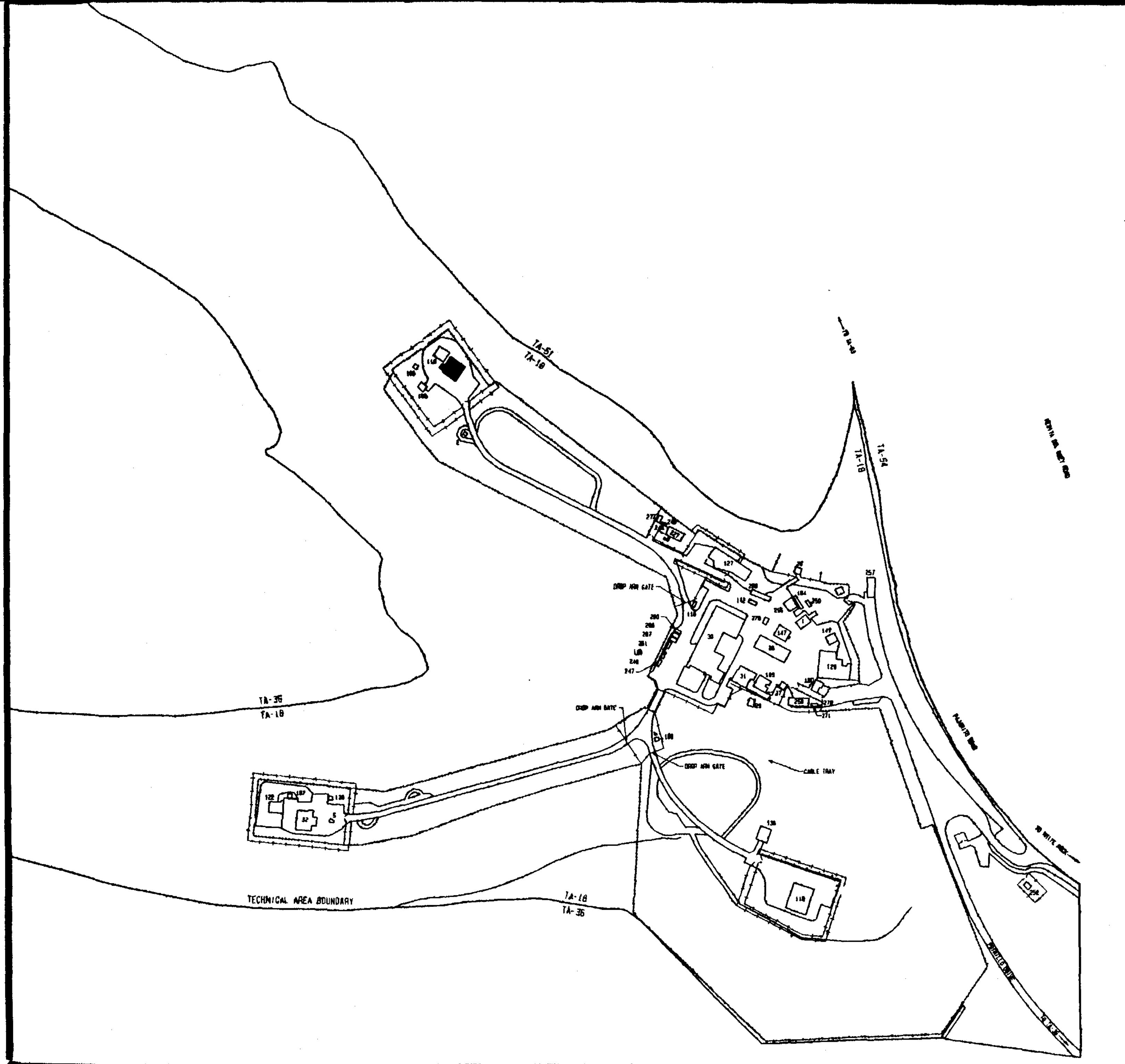
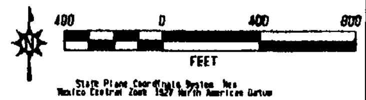


FIGURE
D-1 OUTLINE
TA-18-23

Prepared for:
LOS ALAMOS NATIONAL LABORATORY
KRISTIN NELSON

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE



State Plane Coordinate System New Mexico Central Zone 1927 North American Datum

Note: The data shown on this map has not been checked for accuracy. Plan data shown is from the Los Alamos National Laboratory Engineering Division 1986 aerial survey and from As-Built field measurement updates

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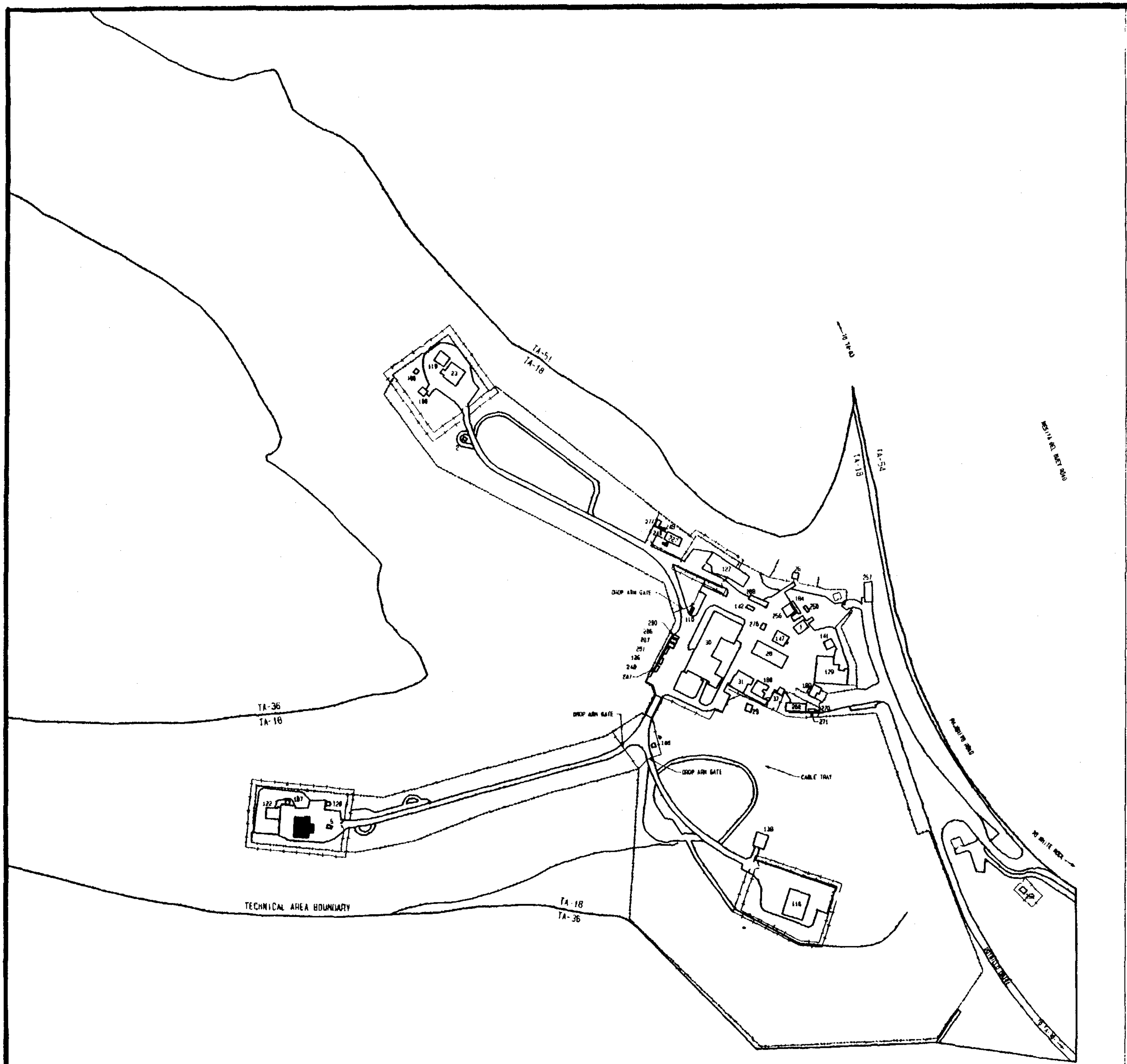

FIGURE E-1 OUTLINE TA-18-32

Prepared for
LOS ALAMOS NATIONAL LABORATORY
KRISTIN NELSON

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

400 0 400 800
FEET

State Plane Coordinate System New Mexico Central Zone 1927 North American Datum

Note: The data shown on this map has not been checked for accuracy. Plan data shown is from the Los Alamos National Laboratory Engineering Division 1986 aerial survey and from as built field measurement updates.

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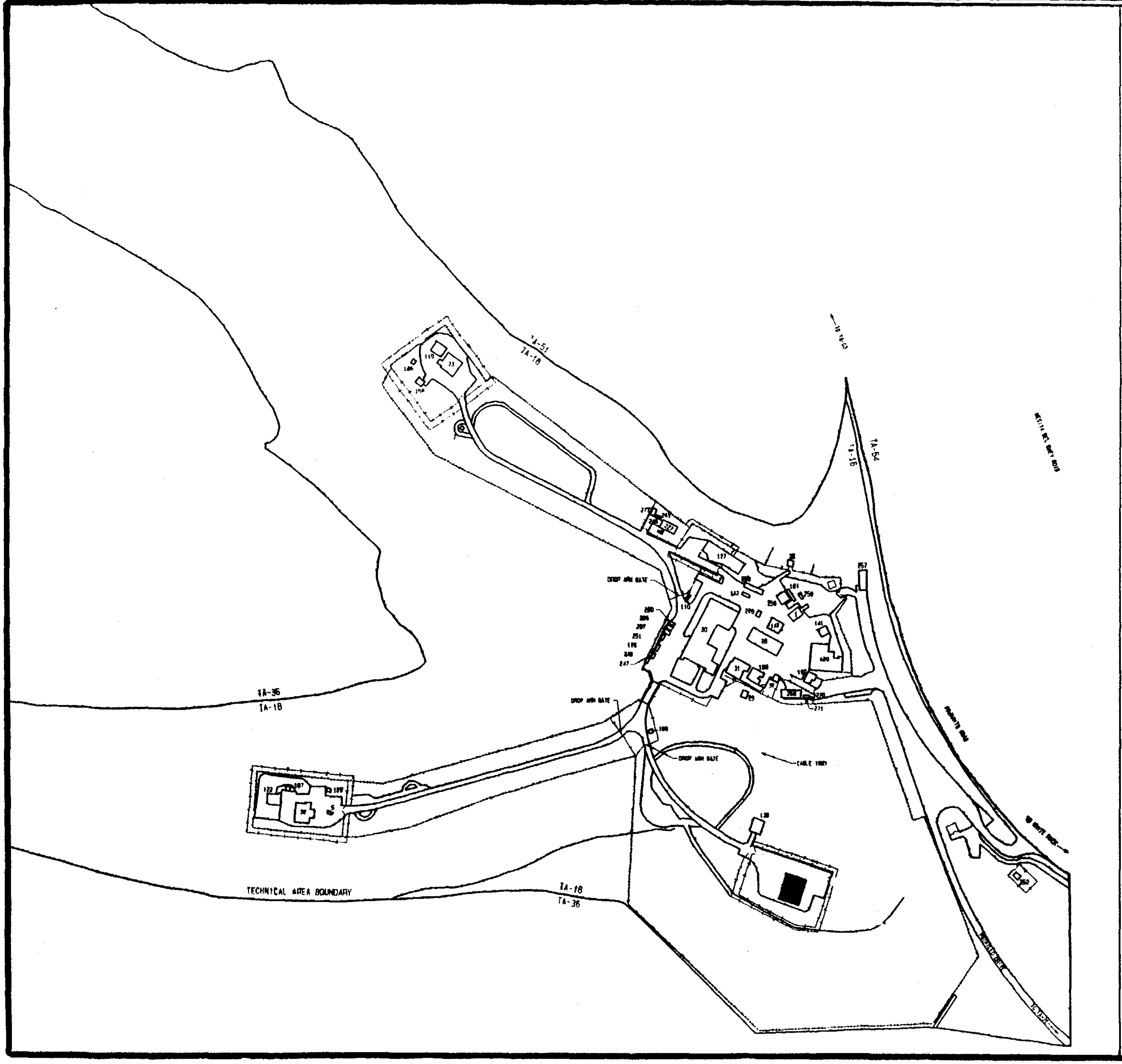

FIGURE F-1 OUTLINE TA-18-116

Prepared for
LOS ALAMOS NATIONAL LABORATORY
KRISTIN NELSON

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

400 0 400 800
FEET

State Plane Coordinate System, New Mexico Central Zone, 1927 North American Datum

NOTE: The data shown on this map has not been checked for accuracy. Plan data shown is from the Los Alamos National Laboratory Engineering Division 1986 aerial survey and from As-Built field measurement updates.

Prepared by:
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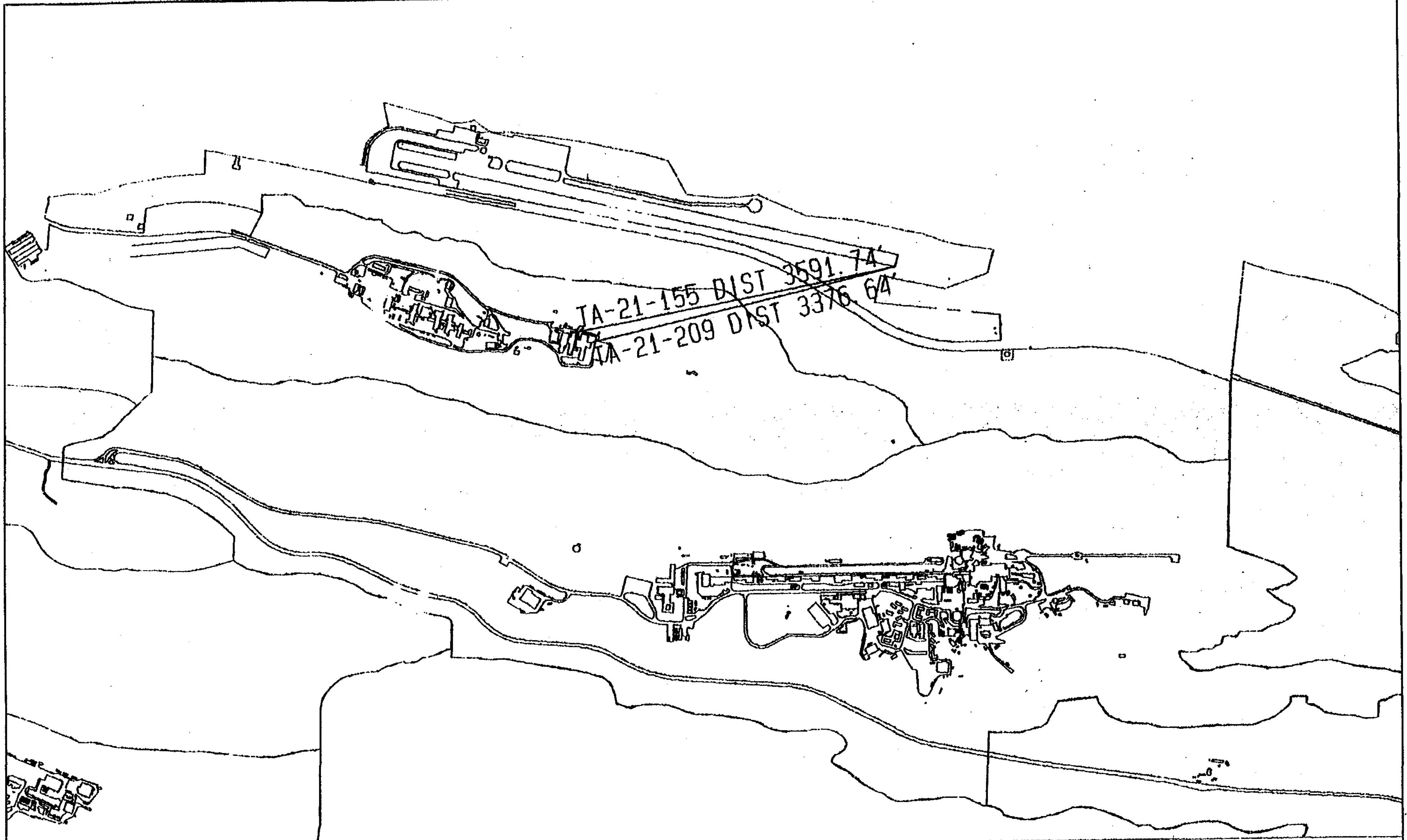
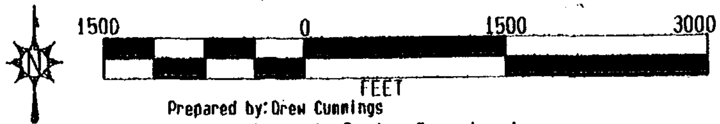


FIGURE G,H-2 FROM RUNWAY TO TA-21

Prepared for.
LOS ALAMOS NATIONAL LABORATORY
RON SELVAGE

State Plane Coordinate System, New Mexico Central Zone 1927 North American Datum

Note: The data shown on this map has not been checked for accuracy. Plan data shown is from the Los Alamos National Laboratory Engineering Division 1986 aerial survey and from As-Built field measurement updates.



Prepared by: Drew Cummings
Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667-5293

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

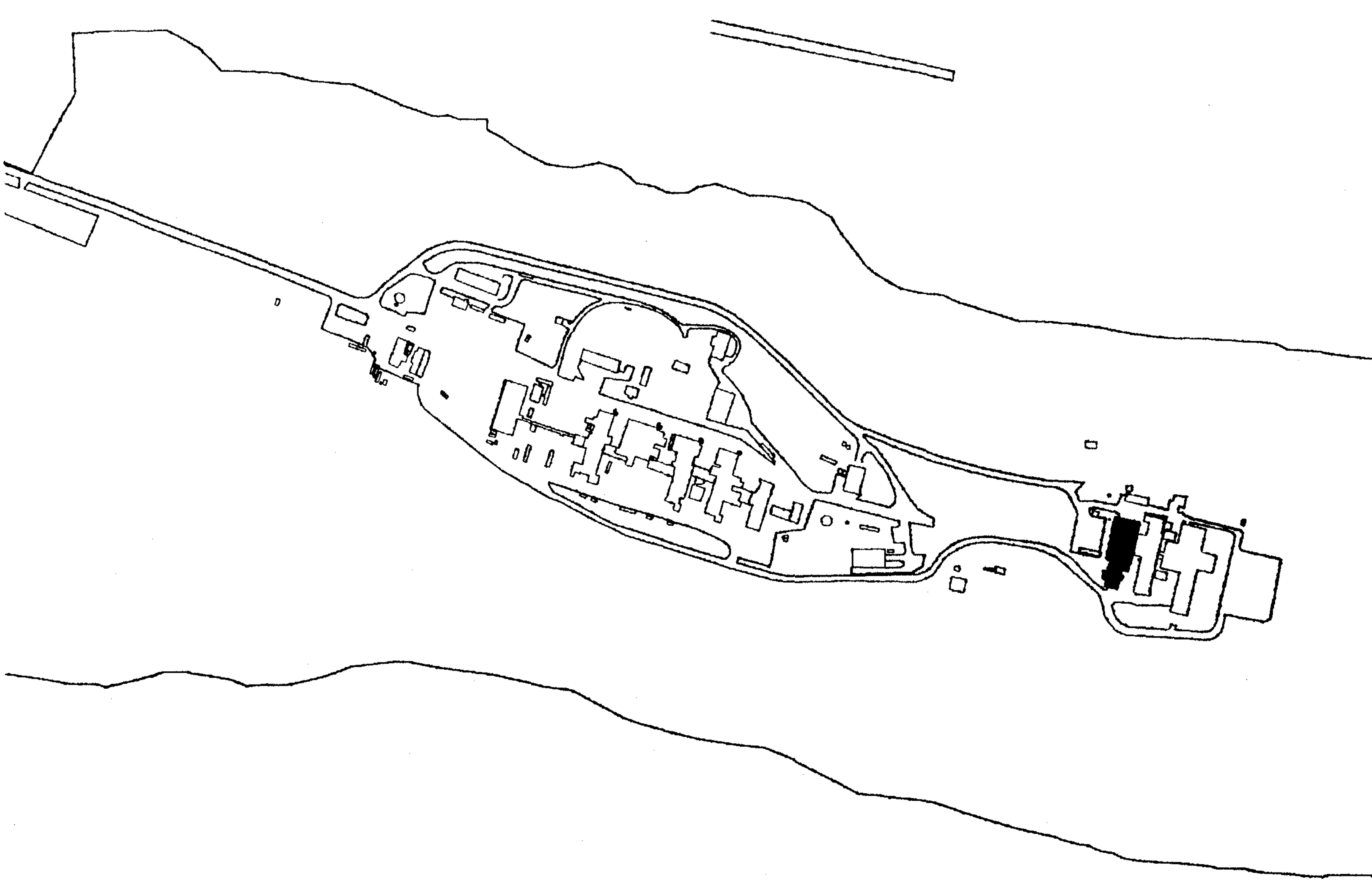


FIGURE
G-1 OUTLINE
TA-21-155

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RON SELVAGE

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

200 0 200 400
FEET

State Plane Coordinate System, New Mexico Central Zone 1927 North American Datum

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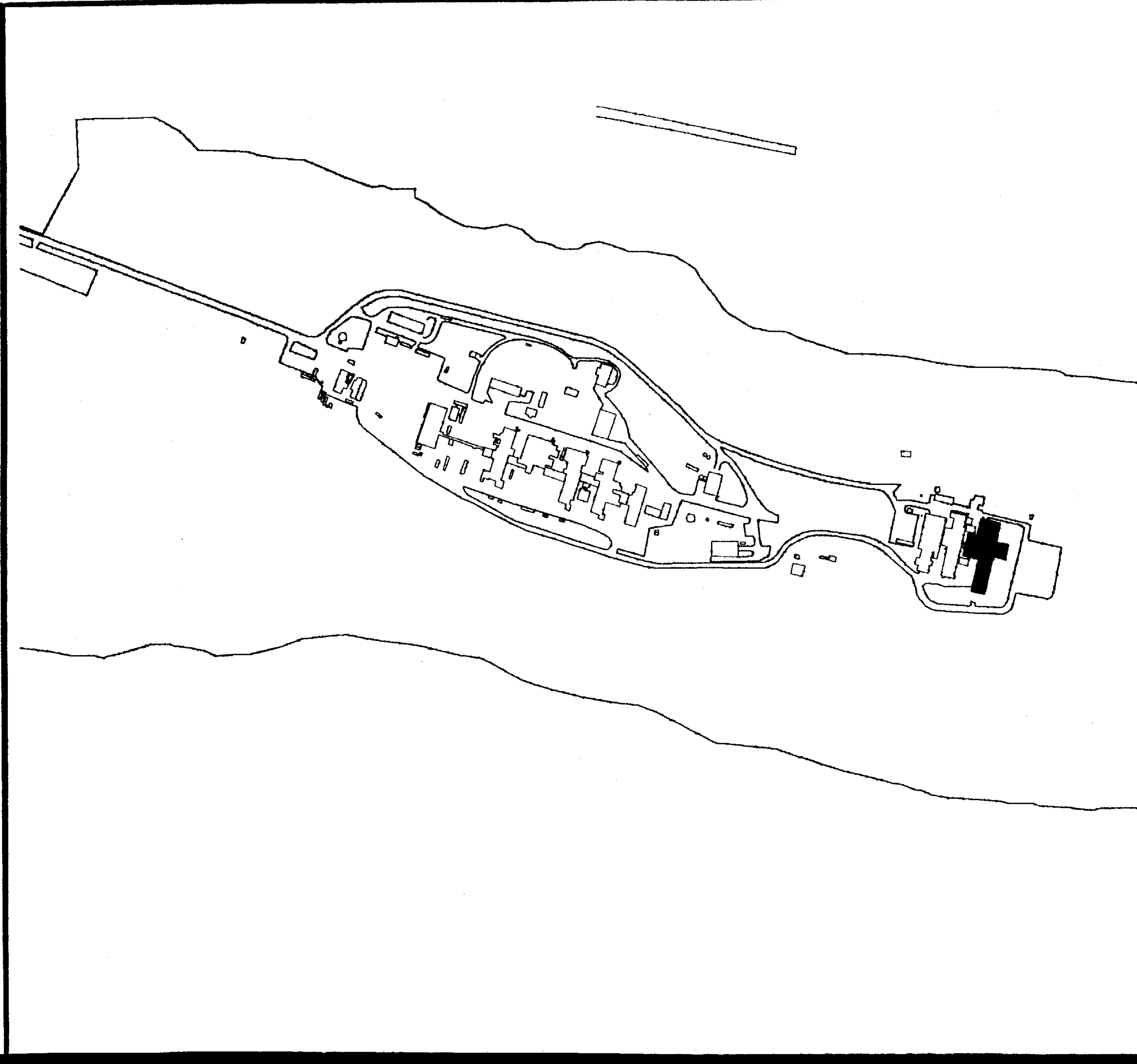

FIGURE
H-1 OUTLINE
TA-21-209

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LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

200 0 200 400
FEET

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Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667-5293

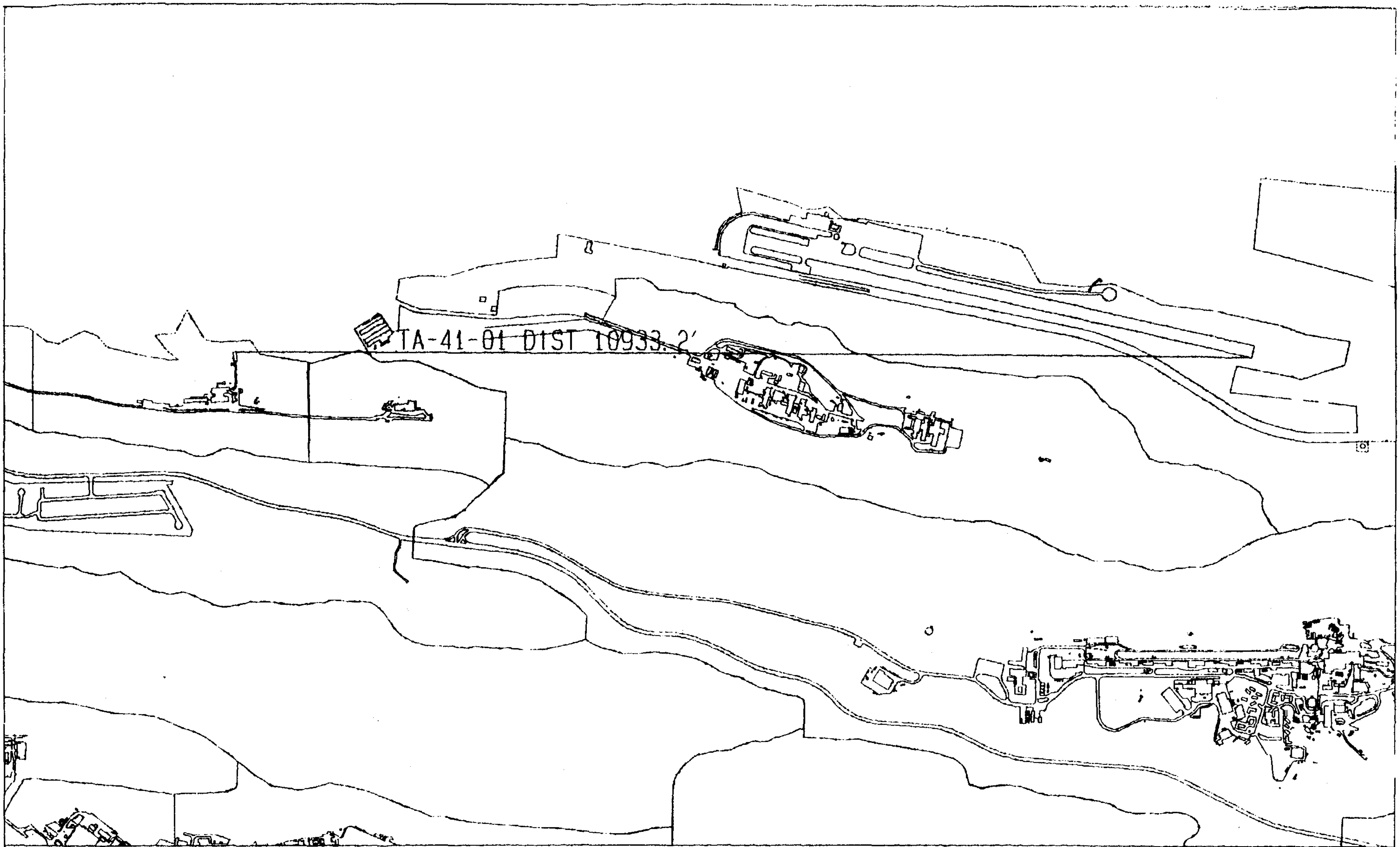

FIGURE I-2 FROM RUNWAY TO TA-41-01

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RON SELVAGE

State Plane Coordinate System, New Mexico Central Zone 1927 North American Datum

Note: The data shown on this map has not been checked for accuracy. Plan data shown is from the Los Alamos National Laboratory Engineering Division 1986 aerial survey and from As Built field measurement updates.

1500 0 1500 3000
FEET

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LEGEND

- BUILDING OF INTEREST
- LAOHATURY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

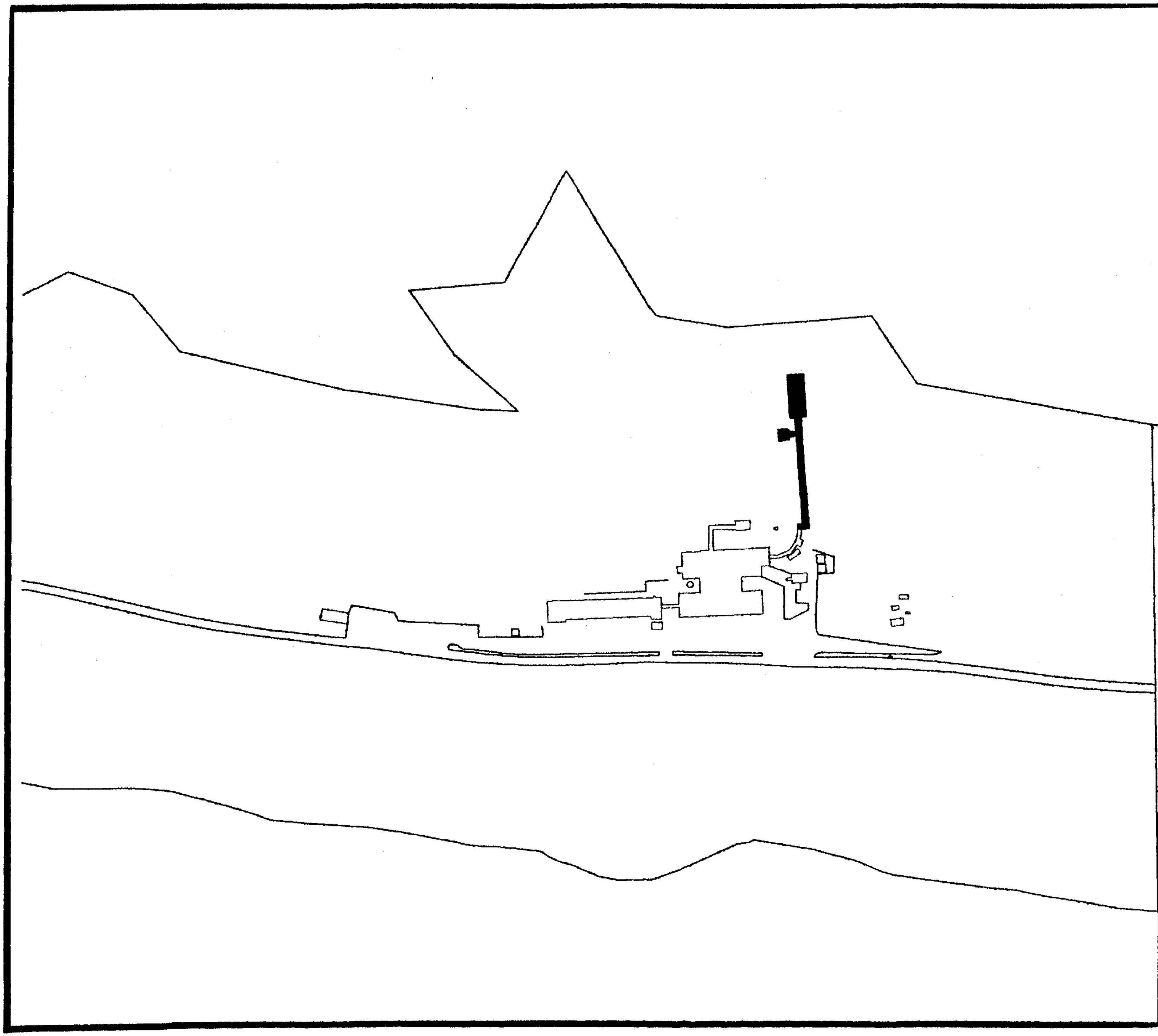

FIGURE I-1 OUTLINE TA-41-01

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RON SELVAGE

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

300 0 300 600
FEET

State Plane Coordinate System, New Mexico Central Zone 1987 North American Datum

Note: The data shown on this map has not been checked for accuracy. [illegible] data shown is from the Los Alamos National Laboratory Engineering Division [illegible] aerial survey and from As-Built field measurement updates.

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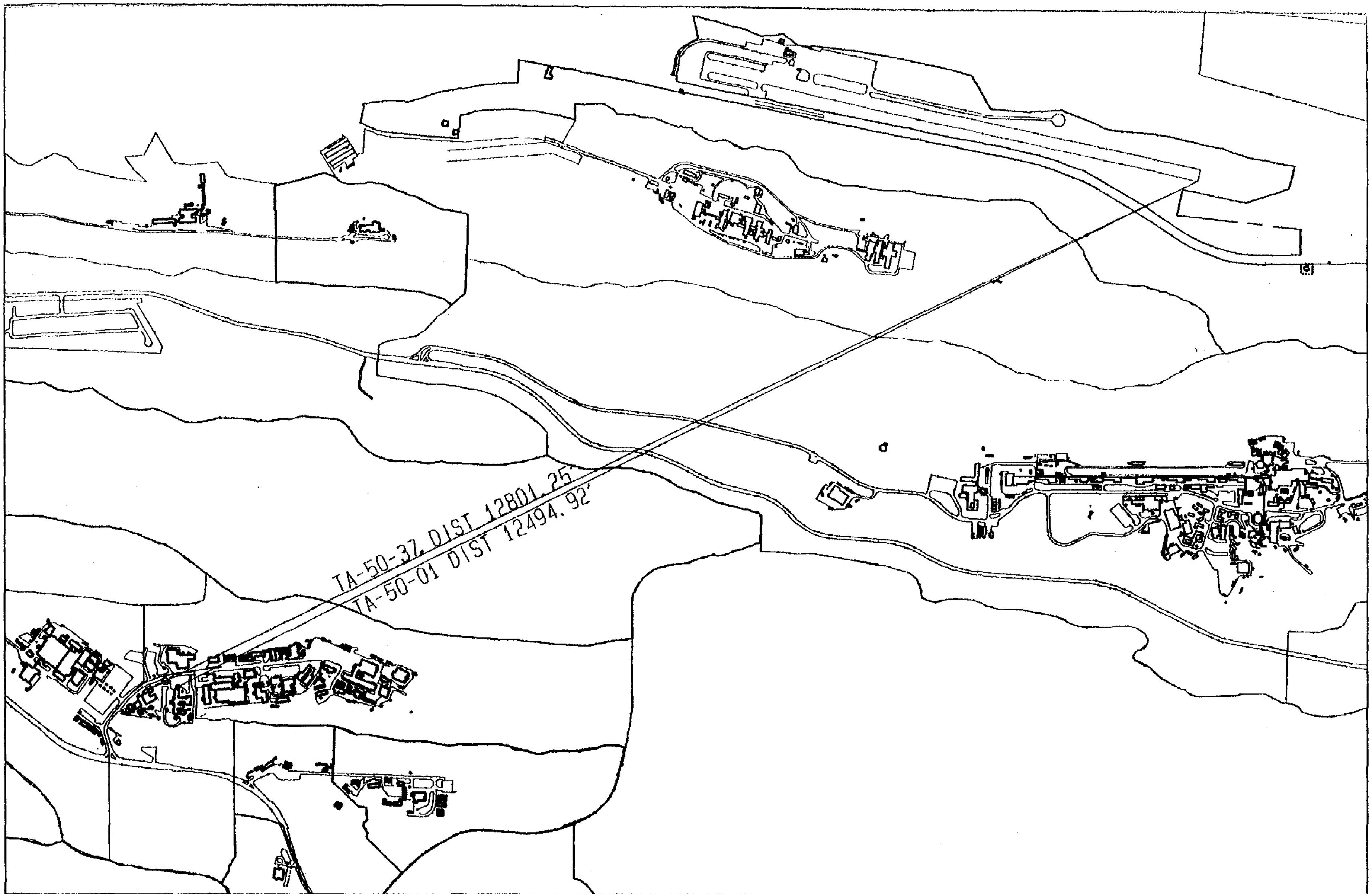

FIGURE J,K-2 FROM RUNWAY TO TA-50-01,37

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RON SELVAGE

State Plane Coordinate System, New Mexico Central Zone. 1927 North American Datum

Note: The data shown on this map has not been checked for accuracy. Plan data shown is from the Los Alamos National Laboratory Engineering Division 1986 aerial survey and from As-Built field measurement updates.

1000 0 1500 2000
FEET

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LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

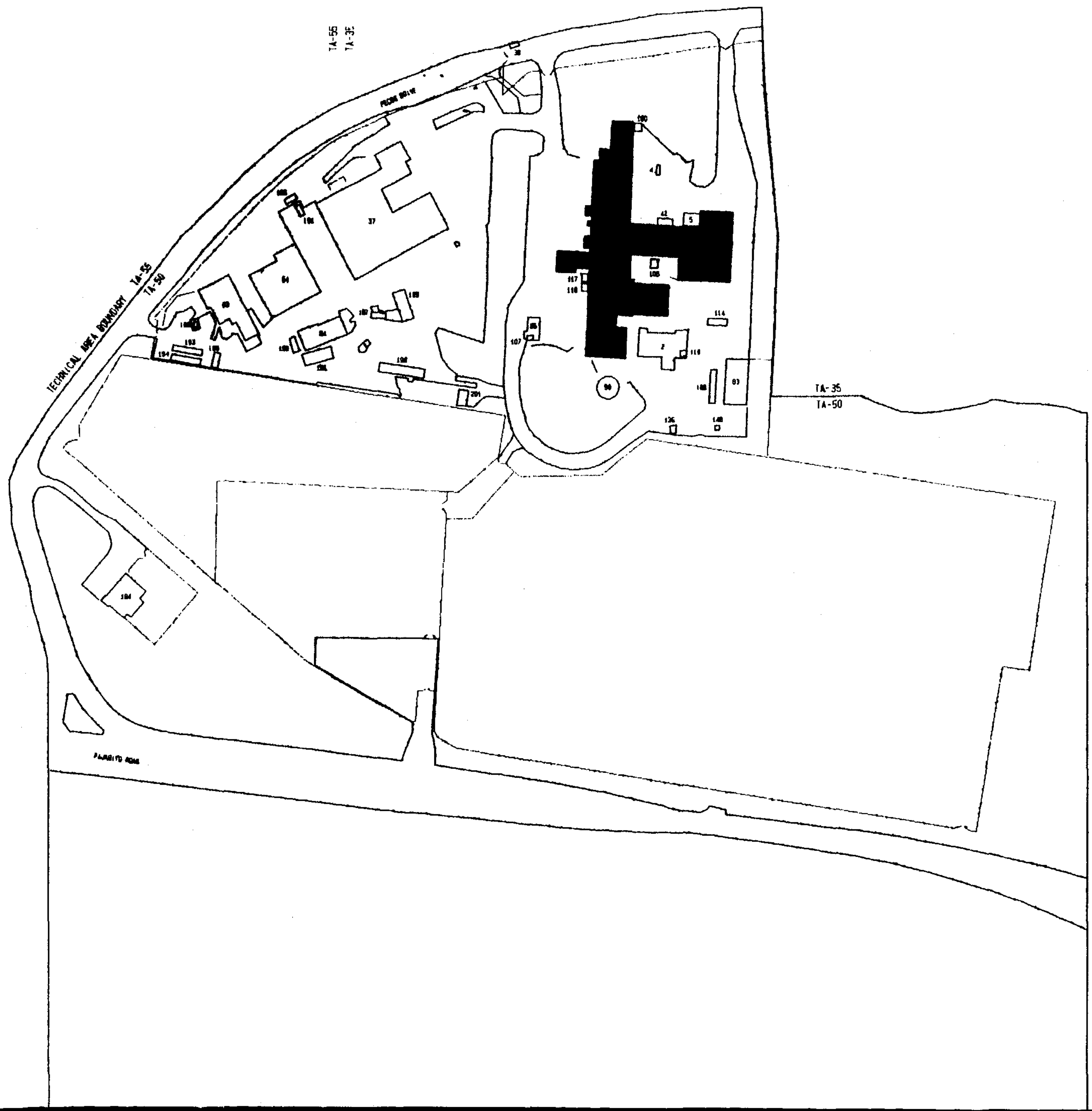

FIGURE
J-1 OUTLINE
TA-50-01

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RON SELVAGE

LEGEND

BUILDING OF INTEREST
LABORATORY STRUCTURES
INDUSTRIAL FENCE
SECURITY FENCE

200 0 200 400
FEET

State Plane Coordinate System, New Mexico Central Zone, 1927 North American Datum

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FIGURE
K-1 OUTLINE
TA-50-37

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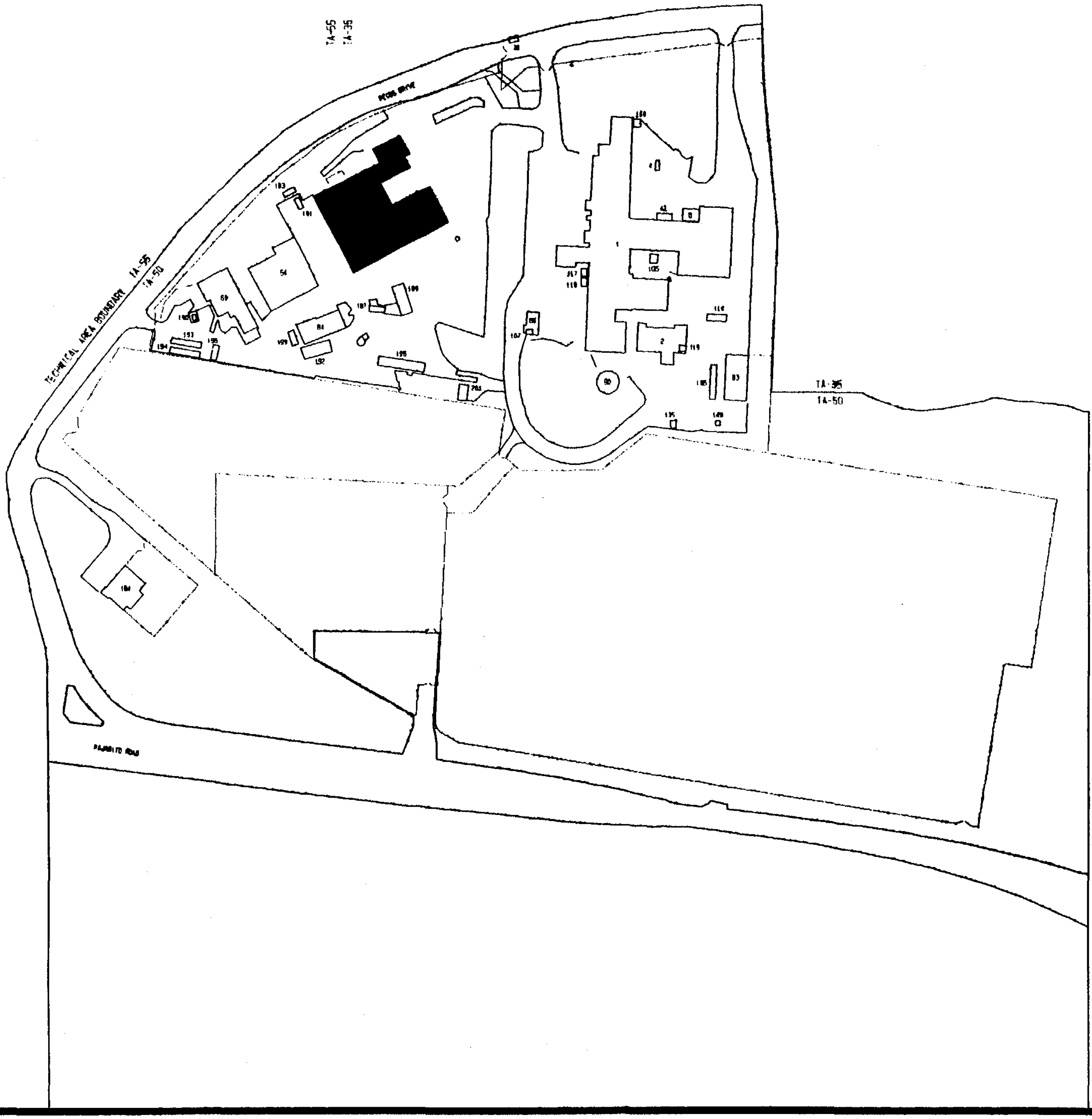
LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE



200 0 200 400
FEET

State Plane Coordinate System, New Mexico Central Zone, 1927 North American Datum
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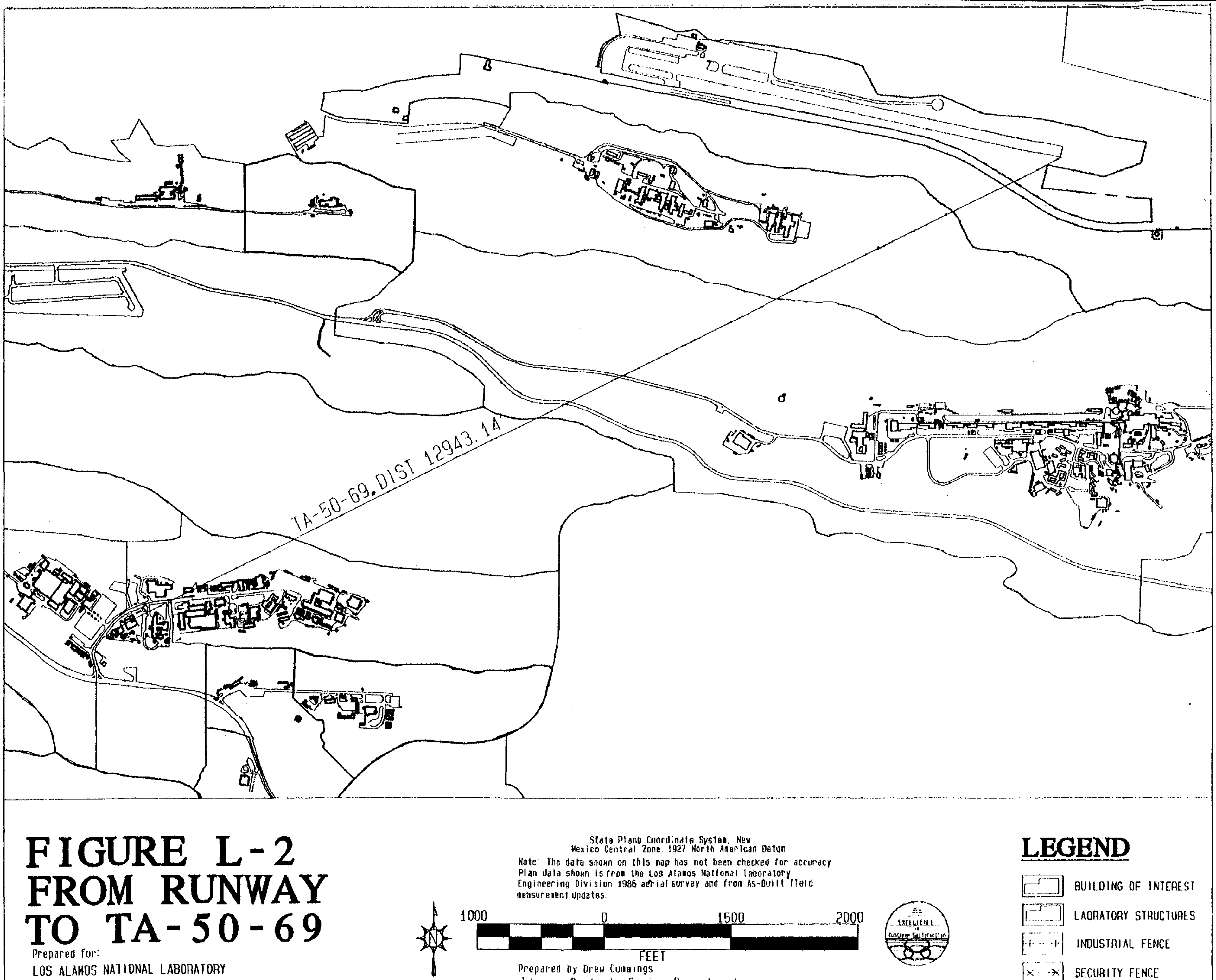

FIGURE L-2 FROM RUNWAY TO TA-50-69

Prepared for:
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DON SELVAGE

State Plane Coordinate System, New Mexico Central Zone. 1927 North American Datum
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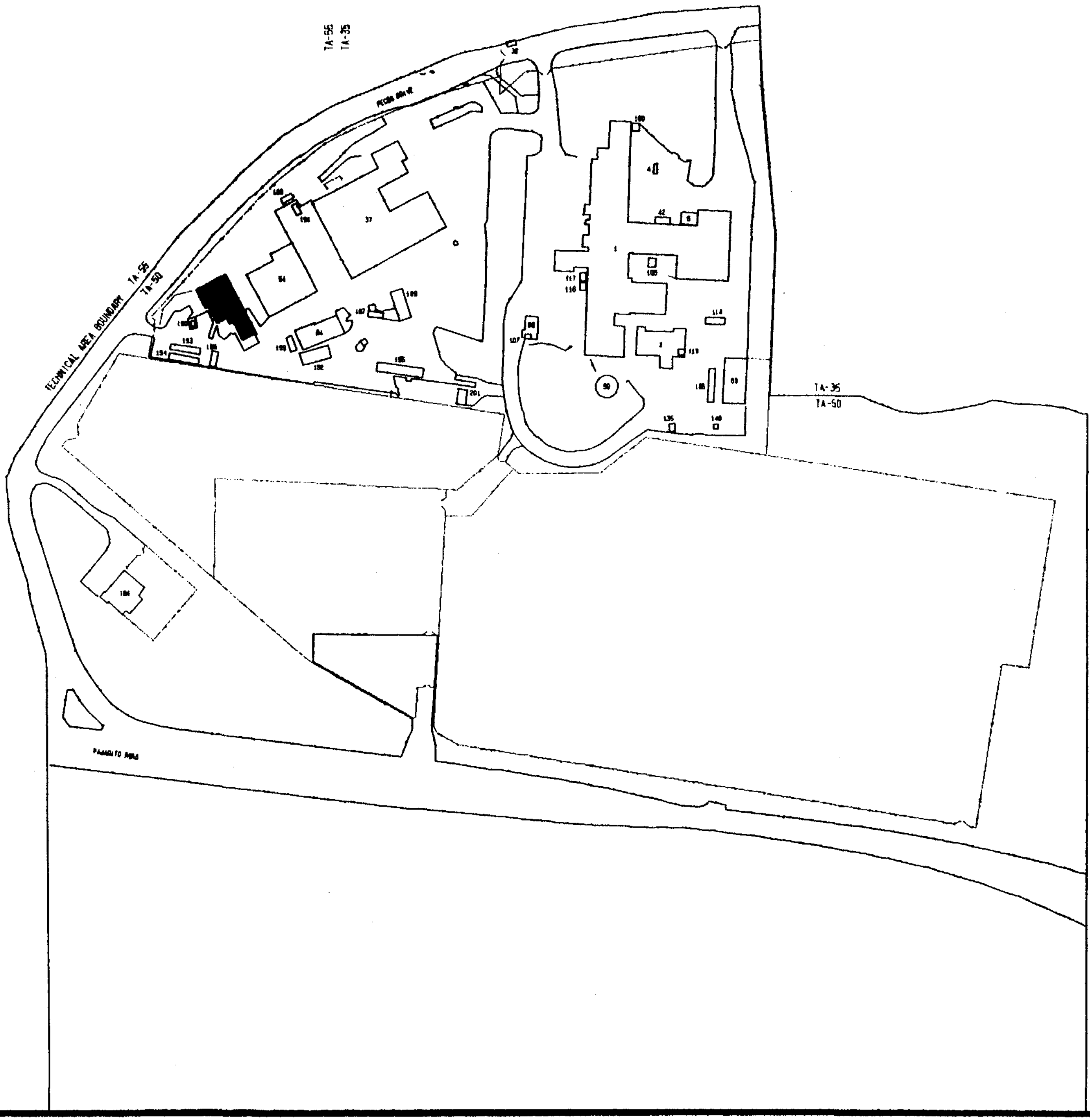
Prepared by: Drew Cummings
Johnson Controls Design Department

LEGEND

- BUILDING OF INTEREST
- LAQRATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

FIGURE
L-1 OUTLINE
TA-50-69



Prepared for:
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RON SELVAGE

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

200 0 200 400
FEET

State Plane Coordinate System, New Mexico Central Zone, 1927 North American Datum

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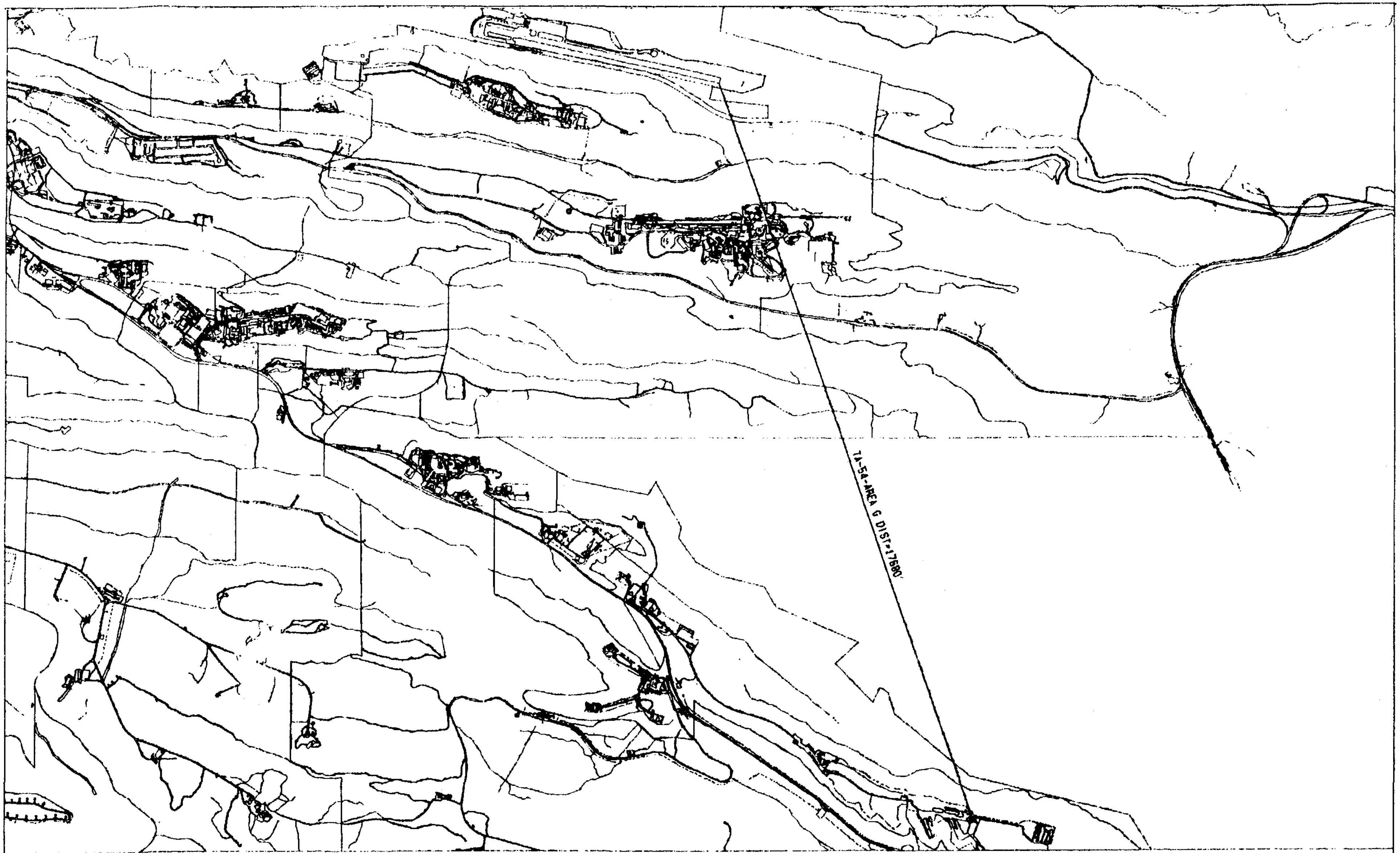

FIGURE M-2 FROM RUNWAY TO TA-54-G

Prepared for:
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DON SILVAGI

State Plane Coordinate System, New Mexico Central Zone 1927 North American Datum

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Scale: 600 0 2400 4800 FEET

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Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667-5293

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

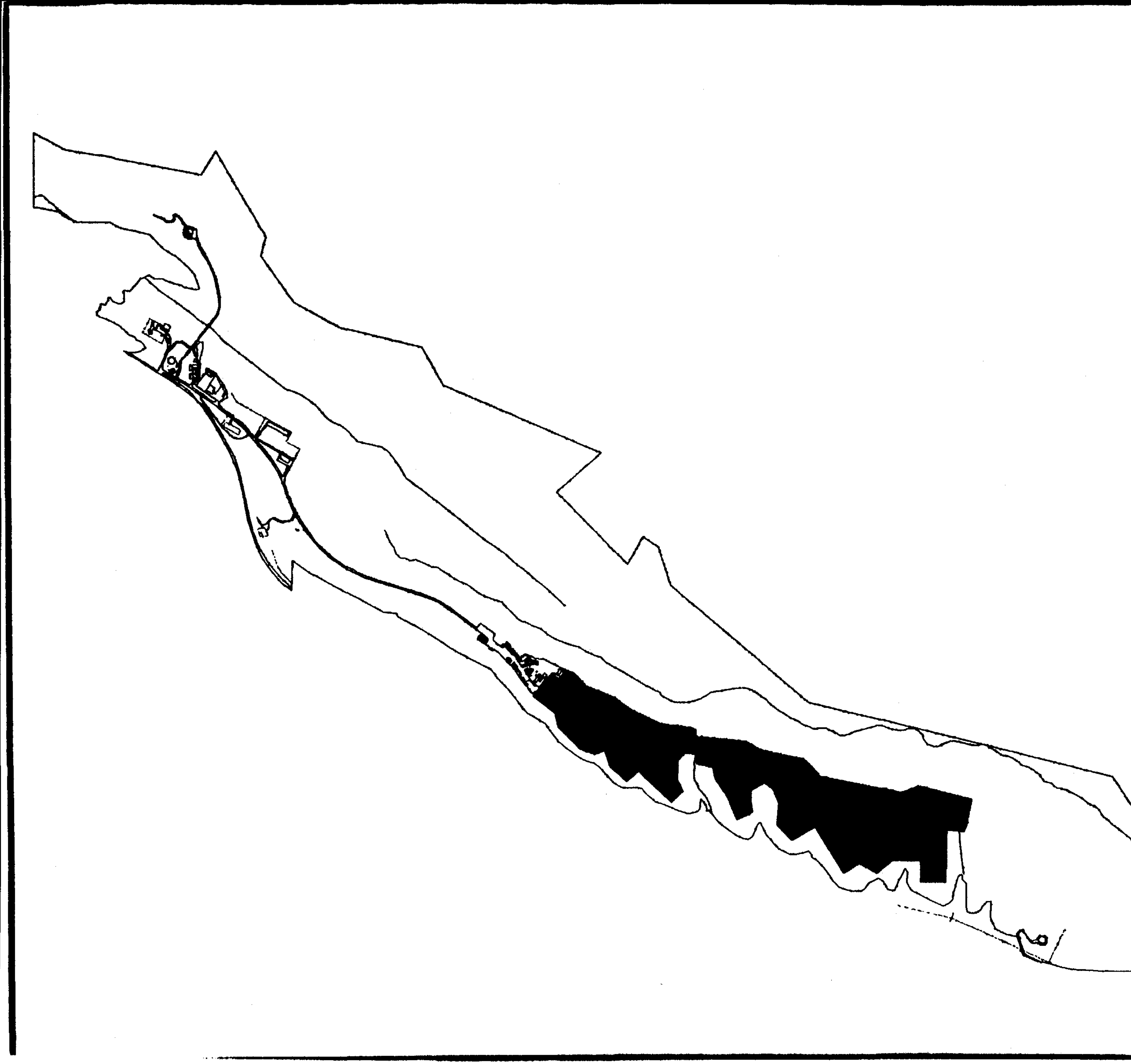

FIGURE
M-1 OUTLINE
TA-54-G

Prepared for:
LOS ALAMOS NATIONAL LABORATORY
RON SELVAGE

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

1600 0 1600 3200
FEET

State Plane [illegible]
[illegible]

Note: The data shown on [illegible]

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Date: 09-07-94 Phone: (505)667-5293

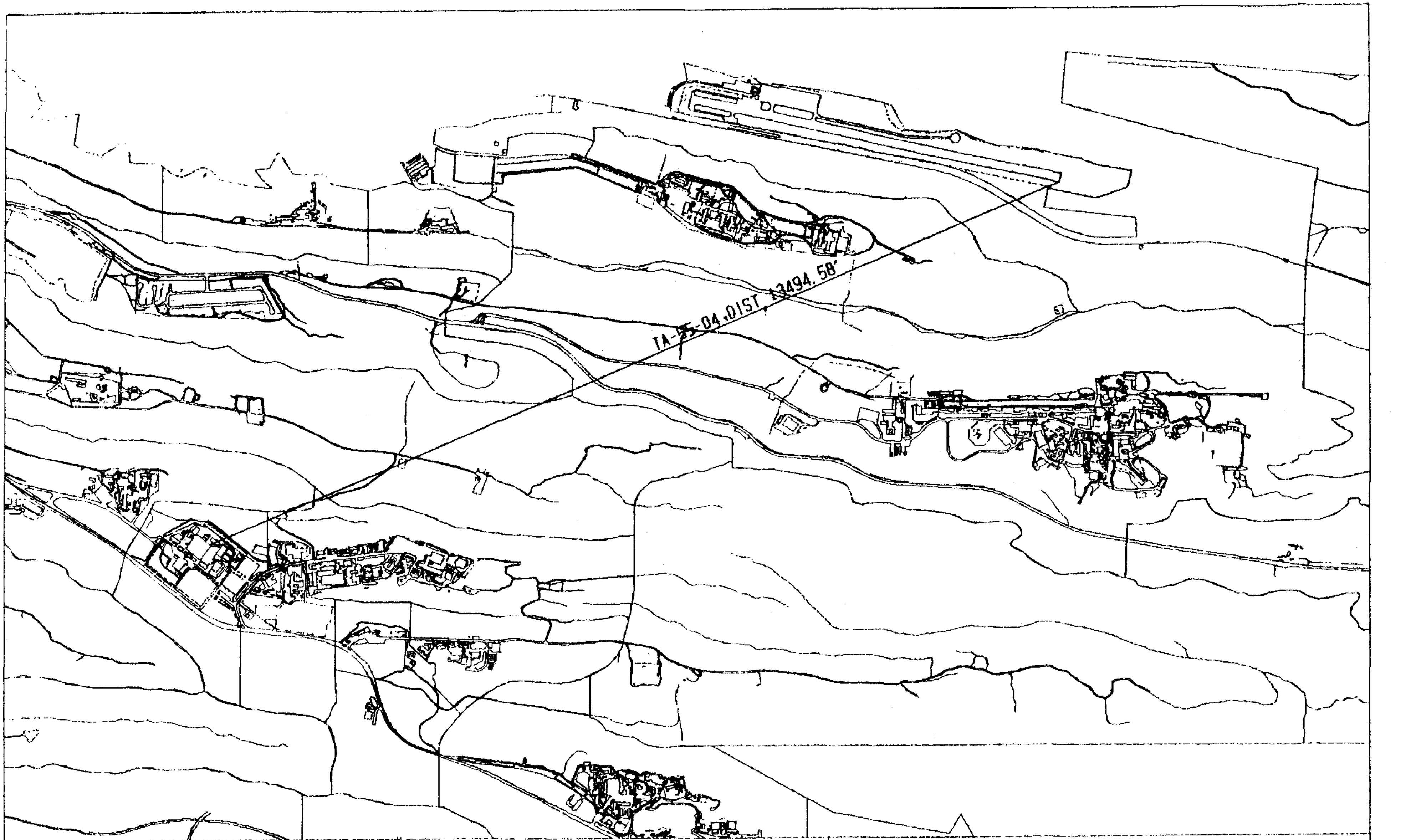

FIGURE N-2 FROM RUNWAY TO TA-55-04

Prepared for:
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RON SELVAGE

State Plane Coordinate System, New Mexico Central Zone, 1927 North American Datum

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500 0 2000 2000
FEET

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Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667-5293

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

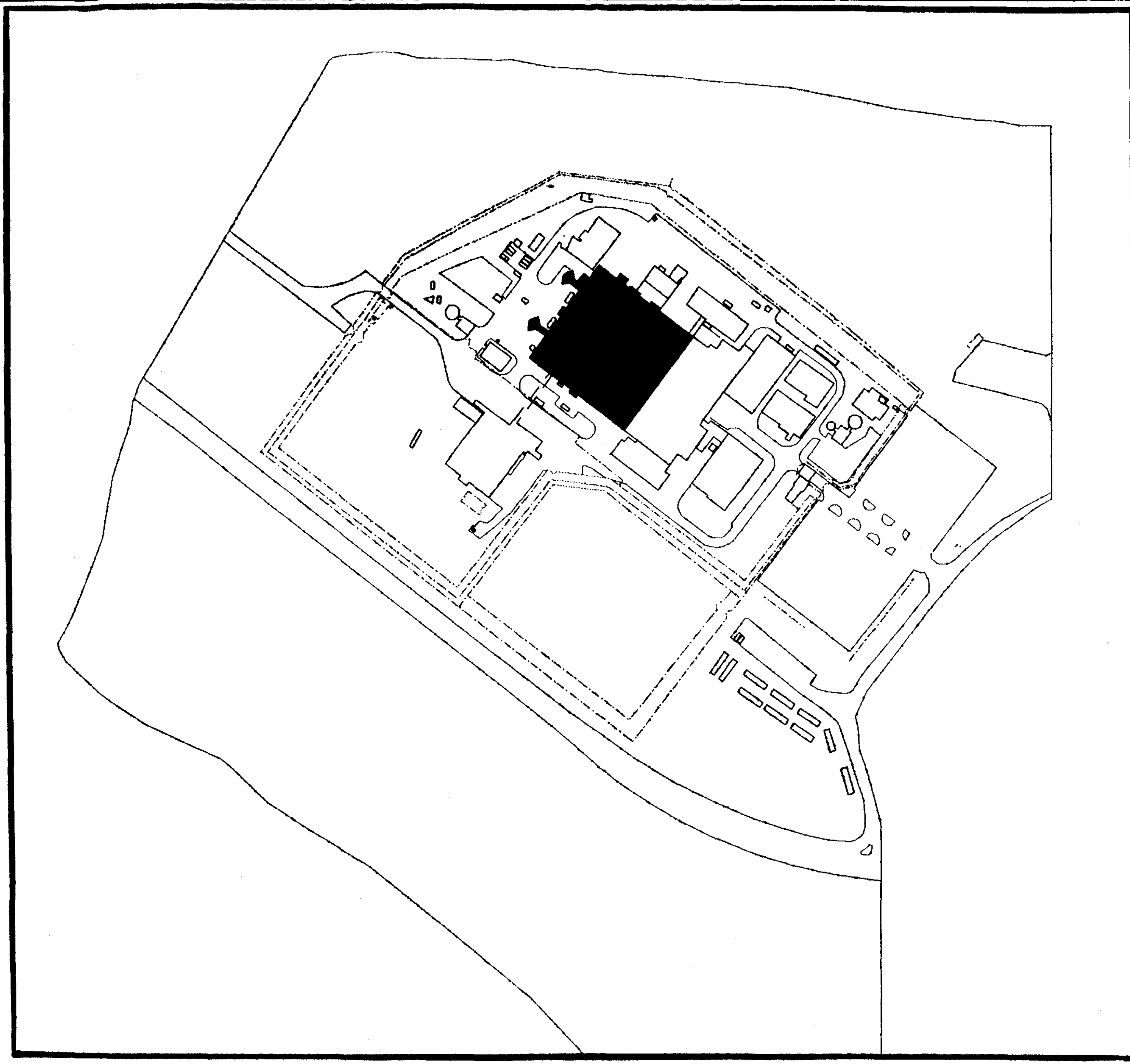

FIGURE
N-1 OUTLINE
TA-55-04

Prepared for:
LOS ALAMOS NATIONAL LABORATORY
RON SELVAGE

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

300 0 300 600
FEET

Note: The data shown on this map has not been checked for accuracy.

Prepared by:
Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667-5299

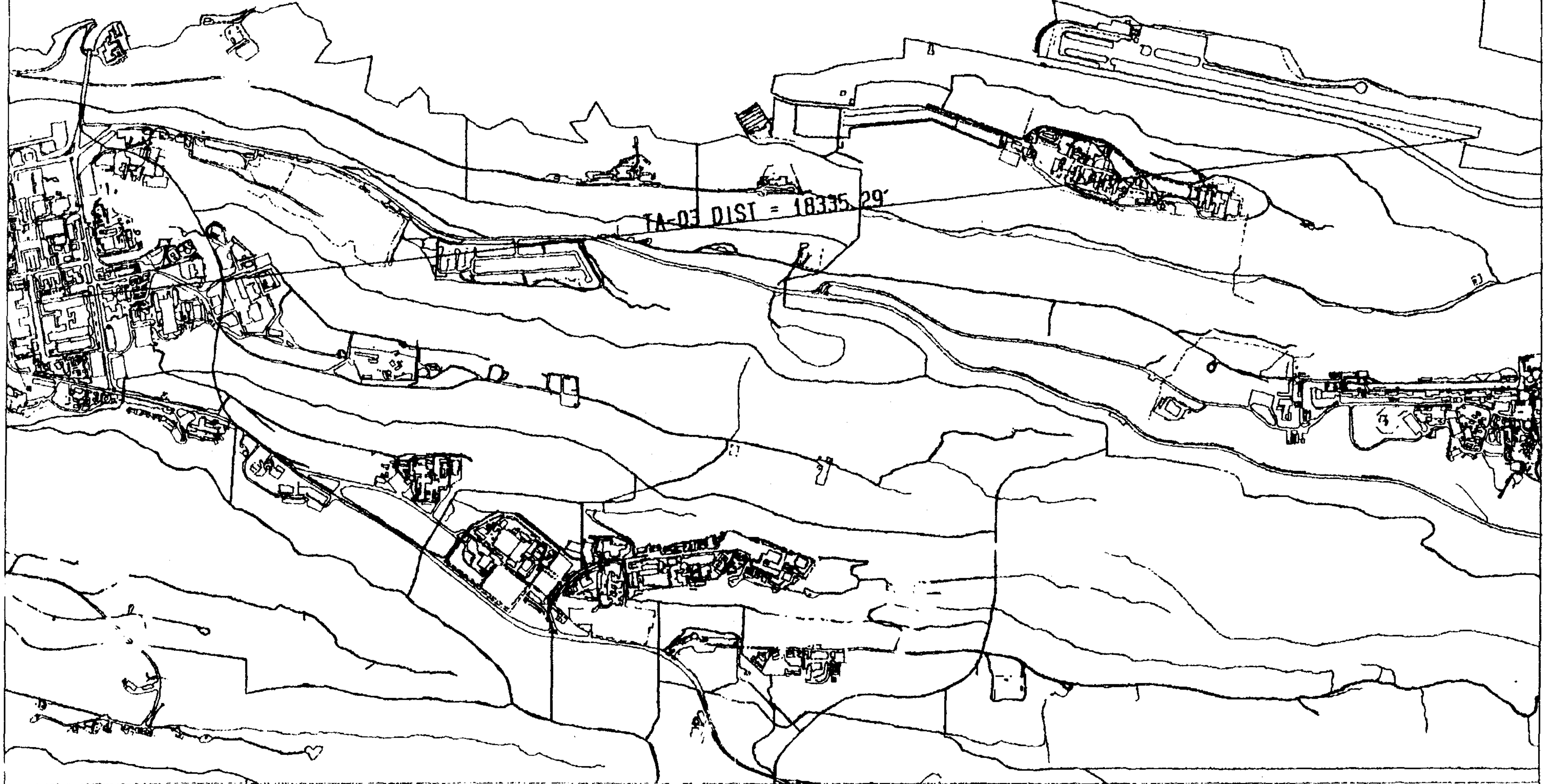

FIGURE A-2 FROM RUNWAY TO TA-03-29

Prepared for
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RON SELVAGE

State Plane Coordinate System, New Mexico Central Zone 1927 North American Datum

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2000 0 2000 4000
FEET

Prepared by: Drew Cummings
Johnson Controls Design Department
Date 09-07-94 Phone: (505)667-5293

LEGEND

BUILDING OF INTEREST
LABORATORY STRUCTURES
INDUSTRIAL FENCE
SECURITY FENCE

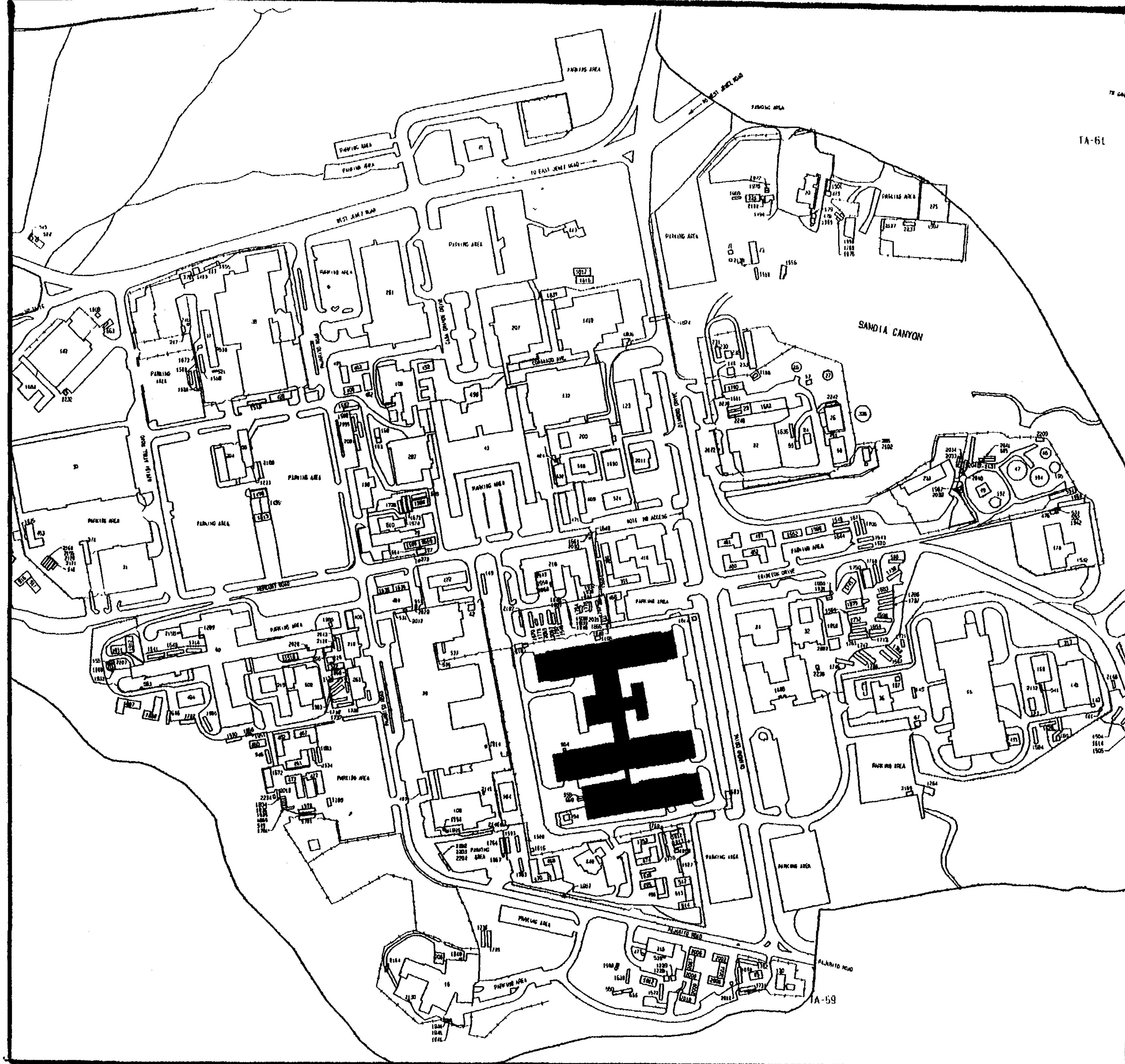

FIGURE
A-1 OUTLINE
TA-03-29

Prepared for:
LOS ALAMOS NATIONAL LABORATORY
KRISTIN NELSON

Prepared by:
Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667-5293

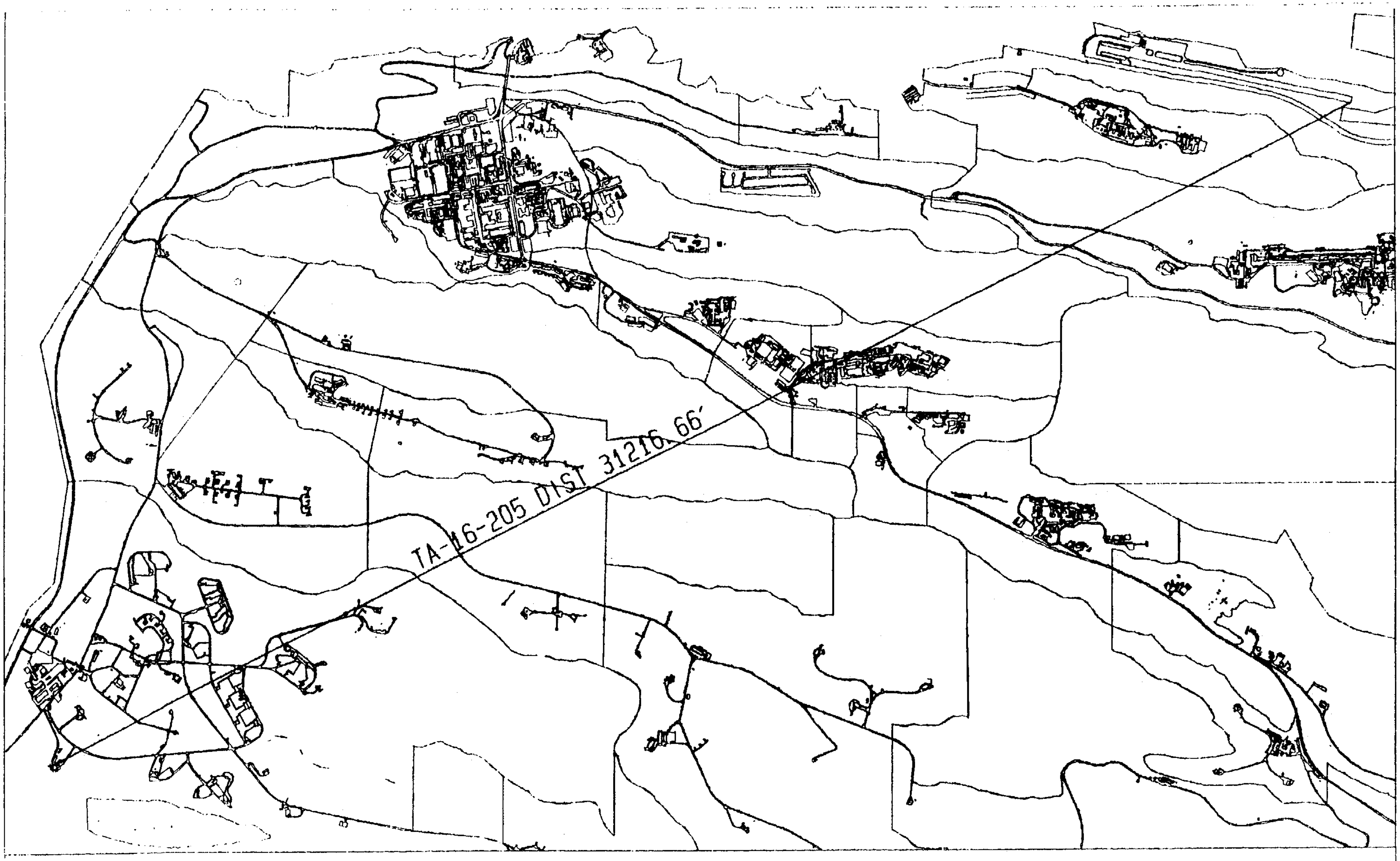

FIGURE B-2 FROM RUNWAY TO TA-16-205

Prepared for:
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DON SELVAGI

State Plane Coordinate System, New Mexico Central Zone 1927 North American Datum

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750 0 3000 6000
FEET

Prepared by Drew Cummings
Johnson Controls Design Department
Date: 09-07-94 Phone: (505)667 5293

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LEGEND

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- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

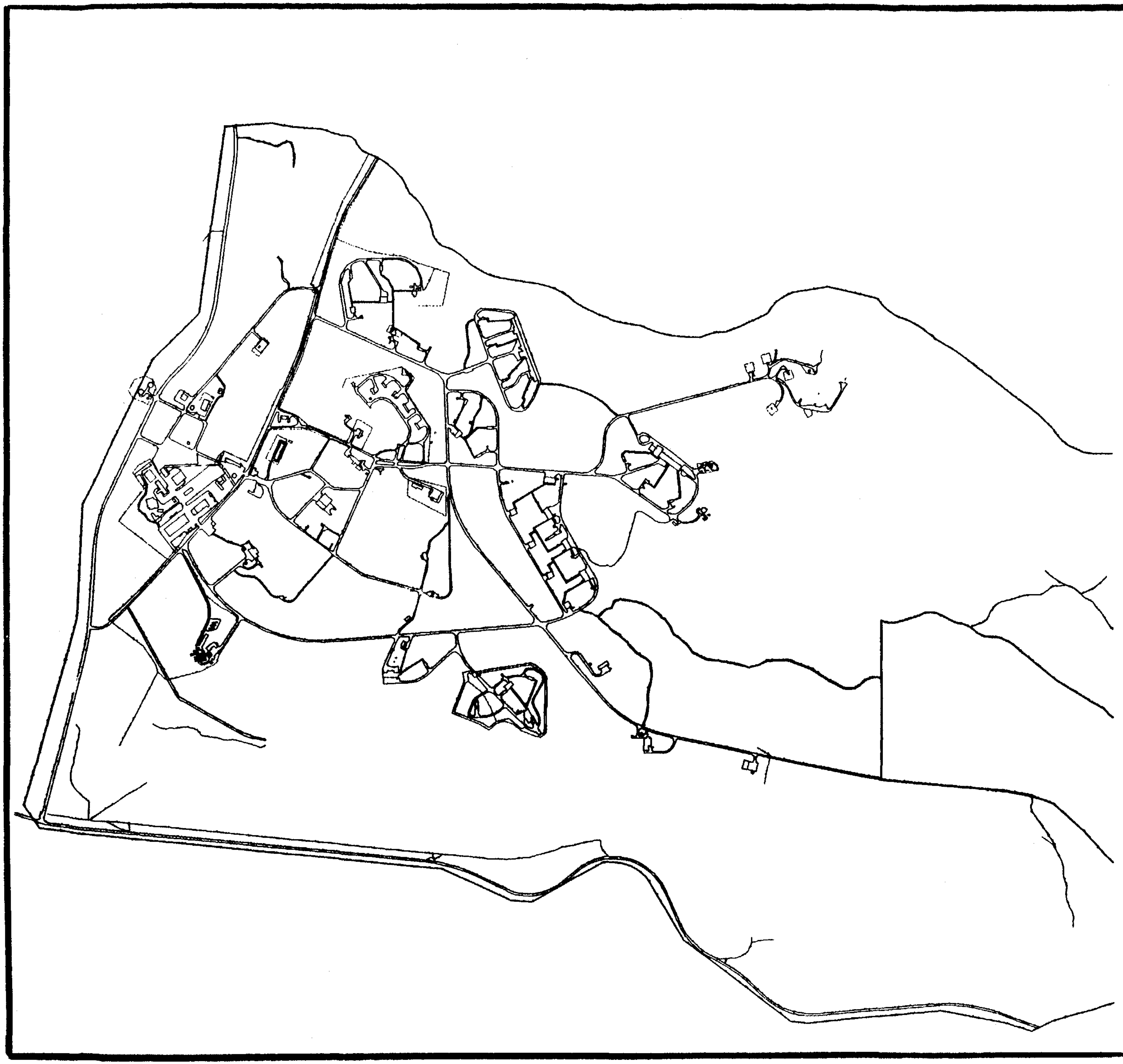

FIGURE
B-1 OUTLINE
TA-16-205

Prepared for:
LOS ALAMOS NATIONAL LABORATORY
KRISTIN NELSON

LEGEND

- BUILDING OF INTEREST
- LABORATORY STRUCTURES
- INDUSTRIAL FENCE
- SECURITY FENCE

State Plane Coordinate System, New Mexico Central Zone, 1927 North American Datum

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Johnson Controls Design Department
Date 09-07-94 Phone (505)667-5293