AIR FORCE HEALTH STUDY
(PROJECT RANCH HAND II)

AN EPIDEMIOLOGIC INVESTIGATION OF HEALTH EFFECTS IN AIR FORCE PERSONNEL FOLLOWING EXPOSURE TO HERBICIDES

MORTALITY UPDATE - 1989
15 MARCH 1989

WILLIAM H. WOLFE, COLONEL, USAF, MC
JOEL E. MICHALEK, Ph.D.
JUDSON C. MINER, COLONEL, USAF, BSC

Prepared for:
THE SURGEON GENERAL
UNITED STATES AIR FORCE
WASHINGTON, D.C. 20314

EPIDEMIOLOGY DIVISION
USAF SCHOOL OF AEROSPACE MEDICINE
HUMAN SYSTEMS DIVISION (AFSC)
BROOKS AIR FORCE BASE, TEXAS 78235

SAM/EKS-AY 890227

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAFSAM - TR - 89 - 5	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAF School of Aerospace Medicine 6b. OFFICE SYMBOL (If applicable) USAFSAM/EK	7a. NAME OF MONITORING ORGANIZATION The Surgeon General
6c. ADDRESS (City, State, and ZIP Code) Human Systems Divison (AFSC) Brooks Air Force Base, Texas 78235-5301	7b. ADDRESS (City, State, and ZIP Code) United States Air Force Washington, D.C. 20314
8a. NAME OF FUNDING / SPONSORING ORGANIZATION USAF School of Aerospace Medicine 8b. OFFICE SYMBOL (If applicable) USAFSAM/EK	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Aerospace Medicine Division (AFSC) Brooks Air Force Base, Texas 78235-5301	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 65306F; PROJECT NO. 2767; TASK NO. 00; WORK UNIT ACCESSION NO. 01

11. TITLE (Include Security Classification)
An Epidemiologic Investigation of Health Effects in Air Force Personnel Following Exposure to Herbicides - Mortality Update 1989

12. PERSONAL AUTHOR(S)
Wolfe, William H., Michalek, Joel E., Miner, Judson C.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Interim	FROM 1979 TO 1987	1989 March 15	128

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Epidemiologic Investigation; Air Force Health Study; Matched Cohort Design; Nonconcurrent Prospective Design; Mortality Study
06	05		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of the Air Force Health Study is to determine whether those individuals involved in the spraying of herbicides in Vietnam during the Ranch Hand operation have experienced any adverse health effects as a result of their participation in that program. The study is designed to evaluate both the mortality (death) and morbidity (disease) in these individuals over a 20-year period beginning in 1982.

The Baseline Mortality Report was released in June 1983, the Baseline Morbidity Report in February 1984. Follow-up mortality reports were released in 1984, 1985, and 1986. This study has not demonstrated health effects which can be conclusively attributed to herbicide or dioxin exposure.

(Continued)

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ OTIC USERS	UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL WILLIAM H. WOLFE, Col, USAF, MC	22b. TELEPHONE (Include Area Code) (512) 536-2604 22c. OFFICE SYMBOL USAFSAM/EK

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

(Continuation Block 19.)

This report contains analyses of cumulative deaths occurring up to 31 December 1987. These data show no statistical difference between the cumulative mortality of 1,261 Ranch Hands and that of 6,250 matched Comparisons and the entire population of 19,101 Comparisons. To date, 5.8% of the Ranch Hands, 6.02% of the matched Comparisons and 5.44% of the Comparison population have died.

The overall cumulative mortality of the Ranch Hands remains statistically indistinguishable from that of both their matched Comparisons and the entire Comparison population, although there is a statistically significant increasing trend in post-1983 death rates among Ranch Hand flying officers and a statistically significant increase in Ranch Hand digestive system deaths relative to the Comparison population; these findings are not suggestive of a herbicide effect and remain unexplained at this time. Ranch Hands are equivalent to all Comparisons in cumulative accidental, malignant neoplasm and circulatory system mortality.

Executive summary

An evaluation of data through 31 December 1987 (certified as of 15 June 1988) has found no statistical difference between the cumulative mortality of 1261 Ranch Hands and that of 6250 matched Comparisons and the entire population of 19101 Comparisons. The overall adjusted Ranch Hand mortality rate is 2.81 deaths per 1000 person-years and the corresponding rates for the matched Comparisons and the Comparison population are 2.74 and 2.87 deaths per 1000 person-years respectively. To date, 5.87% of the Ranch Hands, 6.02% of the matched Comparisons and 5.44% of the Comparison population have died.

Restriction to deaths occurring after 1983, however, shows a statistically significant increasing trend in the SMR, unadjusted for year of birth, during the years 1983 through 1987 among flying officers, flyers, officers and all personnel. The trends in flyers, officers and all personnel are attributed to the increasing trend among flying officers wherein the calendar year-specific SMR's were 0.00 in 1983, 0.59 in 1984, 0.69 in 1985, 2.80 in 1986 and 1.75 in 1987. This pattern is due to unusually low Ranch Hand death rates prior to 1986 and increased numbers of Ranch Hand circulatory and malignant neoplasm deaths during 1986 and 1987. However, Ranch Hand malignant neoplasm deaths in this stratum during 1986 and 1987 are not restricted to a particular anatomic site or cancer type. Additionally, current TCDD assay results suggest that flying officers were among the least exposed of all Ranch Hand personnel. These trends could not be analyzed with respect to the exposure index due to sparseness. These results remain unexplained at this time and continued surveillance is indicated to determine whether this trend continues.

This evaluation differs from previous statistical contrasts of Ranch Hand and Comparison mortality in that the mortality experience of the entire Comparison population has been determined as the standard for assessing Ranch Hand mortality. This expansion of the mortality study was prompted by an analysis of mortality through 31 December 1983 which revealed heterogeneity within the cohort of matched Comparisons.

All analyses in this update contrast Ranch Hand mortality with that of the matched Comparisons of previous reports as well as with the mortality of the entire Comparison population. The results of both assessments are similar, with the overall adjusted relative risks assessing Ranch Hand cumulative mortality with matched Comparisons and with all Comparisons estimated as 1.00 and 1.01, respectively.

Adjusted cumulative cause-specific analyses reveal group equivalence in accidental, malignant neoplasm and circulatory deaths. Digestive system deaths are statistically significantly more frequent in Ranch Hands (unadjusted SMR=2.7, P=0.01) relative to the Comparison population. However, these Ranch Hand digestive system deaths (6 to date) are too infrequent for adjusted analyses, and detailed tabulation by rank, occupation and anatomic site reveals no pattern suggestive of an herbicide effect. Continued surveillance is indicated.

Analyses of Ranch Hand mortality versus exposure to dioxin, as estimated by the Air Force exposure index, reveal no significant association between mortality and exposure.

In conclusion, the overall cumulative mortality of the Ranch Hands remains statistically indistinguishable from that of both their matched Comparisons and the entire Comparison population, although there is a statistically significant increasing trend in post-1983 death rates among Ranch Hand flying officers and a statistically significant increase in Ranch Hand digestive system deaths relative to the Comparison population; these findings are not suggestive of a herbicide effect and remain unexplained at this time. Ranch Hands are equivalent to all Comparisons in cumulative accidental, malignant neoplasm and circulatory system mortality.

TABLE OF CONTENTS

1. INTRODUCTION

This report updates the findings of the Air Force Health Study baseline mortality report [1] released on June 30, 1983. Other updates were released in 1984 [2], 1985 [3] and 1986 [4]. The reader is referred to the baseline report for information regarding the study design, the mortality determination process and previous findings.

This report differs from previous reports in that the entire Comparison population has been incorporated in the mortality determination. This expansion has allowed the application of statistical procedures that accommodate population death rates to compare observed and expected numbers of deaths with adjustment for calendar period as well as age at death, rank and occupation. Additionally, small increases in the number of Ranch Hands have occurred as additional Ranch Hands were recently determined to be eligible for inclusion in the study. As these new Ranch Hands were added to the study, newly matched Comparisons were added to the matched Comparison cohort. Thus, the group sizes in this report differ somewhat from those in previous mortality reports. These analyses also differ from those shown in previous reports because tour dates were determined for all Ranch Hands and their matched Comparisons, allowing the appropriate mortality contrasts referenced from date of tour as well as from date of birth.

Tour dates for unmatched Comparisons were randomly generated to permit analyses and report writing to take place while tour date determination for this expanded group continues. These artificial dates were produced by a random number generator and are uniformly distributed over the range November 1956 to October 1971. This range corresponds to the range of matched Comparison tour dates. Thus, while death rates referenced to tour date are only approximate for the unmatched Comparisons, they are considered adequate for reference with Ranch Hand rates. The effect of the use of these artificial tour dates for unmatched Comparisons is negligible, as evidenced by the near equivalence of Ranch Hand versus Comparison mortality contrasts both with and without the use of tour date information.

Changes in the Ranch Hand and matched Comparison cohort are documented in Table 1, which shows all additions to both groups since 1983. In Table 1, counts of matched Comparisons actually included in previous mortality reports are labeled with the heading C1-C5 and the total matched Comparison cohort is labeled C1-C10 because the Protocol specified that up to 10 Comparisons were to be matched to each Ranch Hand on date of birth, rank, race and occupation and that a random 5 from each match set were to be used as mortality Comparisons. At baseline, 1247 Ranch Hands were identified, to which 9982 Comparisons were matched. Of the matched 9982 Comparisons, five in each match set were randomly selected to produce a baseline mortality Comparison cohort of 6171 Comparisons. The total Comparison population numbers 19101 individuals, 10133 matched and 8968 unmatched to Ranch Hands.

TABLE 1

Ranch Hand and Comparison Counts, 1983 - 1988

Mortality Report	Ranch Hand	C1-C5	C1-C10	All Comparisons
Baseline 30 June 83	1247	6171	9982	19101
Update 27 July 84	1256	6171	9982	19101
Update 15 July 85	1257	6171	9982	19101
Update 26 Dec 86	1257	6171	9982	19101
Current Update	1261	6250	10133	19101

The increase in the C1-C5 cohort from 6171 to 6250 and the increase in the C1-C10 total matched cohort from 9982 to 10133 occurred when 151 Comparisons were matched to the 4 newly discovered Ranch Hands and 15 previously unmatched Ranch Hands in 1988.

Since the 1986 update, the mortality determination process has been extended to the entire Comparison population to address concerns that the mortality experience of the C1-C5 matched Comparison cohort might not be representative of the mortality of all matched Comparisons. This expansion of the Comparison group to the entire Comparison population occurred after concurrence by the Advisory Committee appointed by the Agent Orange Working Group. Their decision was motivated by data, shown later in this section, that suggested that the mortality experience of the C1-C5 Comparison cohort was, purely by chance, not representative of the mortality experience of the entire matched Comparison cohort.

This report, therefore, contrasts Ranch Hand mortality with that of the entire Comparison population of 19101 Comparisons who flew or serviced C-130 cargo aircraft in Southeast Asia during the same calendar period that the Ranch Hand unit was active in Vietnam. Except where necessary to relate to the December 1983 report, length of life is measured from the start date of the qualifying tour of duty, rather than from the birth date, as in previous reports. These new data have allowed the presentation of death rates per person-year, a new statistic in these mortality updates. To ease the transition from previous reports, Ranch Hand mortality is also contrasted with the C1-C5 subcohort of Comparisons, as in previously presented analyses. Throughout this report, C1-C5 refers to the 6250 matched Comparisons and "all Comparisons" refers to the entire population of 19101 Comparisons.

The analyses in this report are based on cumulative mortality as of 31 December 1987 (verified as of 15 June 1988). Table 2 shows summary counts, person-years and death rates by group (Ranch Hand, C1-C5, All Comparisons); Table 3 shows these summary statistics by group, rank and occupation. In Tables 2 through 6 and Table 8, the column headed "Rate (%)" shows percent dead ((number dead/number at risk) *100), a statistic displayed in previous mortality updates and now supplanted by death rate per 1000 person-years. Throughout this report person-years are measured from tour start date. In some tables, columns of death rates per 1000 person-years are simply headed by the word "Rate" (without the % symbol).

In the hypothetical case that the Ranch Hand mortality experience is the same as that of the Comparisons about 5% of the many statistical analyses shown in this report should be expected to produce P-values less than 0.05. The observation of significant results due to multiple testing on the same data, even when there is no group difference, is known as the multiple testing artifact and is common to all large studies. Unfortunately, there is no statistical procedure available to distinguish between those statistically significant results that arise because of multiple testing and those which may arise due to a herbicide effect. Hence, each significant result is scrutinized with regard to concomitant information to determine whether the result can be reasonably attributed to herbicide exposure.

A person-year is the length of time lived by one person in one year. The total number of person-years for a cohort is the total length of life lived by the cohort. Persons surviving to the time of data analysis contribute the time, in years, between the dates of entry into follow-up and data analysis. Persons known to have died before the date of data analysis contribute the time, in years, between the dates of entry into follow-up and death. In this study, the date of entry into follow-up is the date of the start of the first qualifying tour of duty. The date of data analysis is, effectively, 31 December 1987, the end of the 1987 calendar year. Throughout this report, person-years are rounded to the nearest year and are sometimes abbreviated as "P Y" in table headings.

TABLE 2

Summary Counts by Group, All Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	1261	74	5.87	24964	2.96
C1-C5	6250	376	6.02	126291	2.98
All Comp	19101	1039	5.44	413726	2.51

TABLE 2 Table 1, data

Summary Counts by Group, Rank and Occupation

Flying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	441	25	5.67	8736	2.86
C1-C5	2176	121	5.56	43842	2.76
All Comp	5245	319	6.08	110304	2.89

Enlisted Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	207	12	5.80	4112	2.92
C1-C5	1035	83	8.02	20771	4.00
All Comp	2833	202	7.13	60292	3.35

All Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	648	37	5.71	12848	2.88
C1-C5	3211	204	6.35	64612	3.16
All Comp	8078	521	6.45	170596	3.05

Nonflying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	26	1	3.85	512	1.95
C1-C5	124	6	4.84	2561	2.34
All Comp	286	15	5.24	6185	2.42

Nonflying Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	587	36	6.13	11604	3.10
C1-C5	2915	166	5.69	59117	2.81
All Comp	10737	503	4.68	236945	2.12

table1.dat

TABLE 2 (Cont'd)

Summary Counts by Group, Rank and Occupation

All Nonflyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	613	37	6.04	12116	3.05
C1-C5	3039	172	5.66	61679	2.79
All Comp	11023	518	4.70	243130	2.13

All Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	794	48	6.05	15716	3.05
C1-C5	3950	249	6.30	79888	3.12
All Comp	13570	705	5.19	297237	2.37

All Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	467	26	5.57	9248	2.81
C1-C5	2300	127	5.52	46403	2.74
All Comp	5531	334	6.04	116489	2.87

Occupation and race-specific mortality is summarized in Table 4. Some Ranch Hand death rates in Table 4 appear unusually high. For example, the Ranch Hand death rate among Black enlisted flyers is 13.46 and the corresponding rate for all Comparison deaths in this stratum is 4.40 deaths per 1000 person-years (SMR=3.05, P=0.02). These deaths are too infrequent to compute a confidence interval. The four Ranch Hand deaths in this stratum have occurred since 1980. One of the 4 deaths was a suicide, 1 was accidental, 1 was due to a digestive system disease and 1 was due to ill-defined causes. The increased Ranch Hand death rate in this stratum therefore remains unexplained but appears unrelated to herbicide exposure.

table2.dat

TABLE 4

Summary Counts by Group, Race-Specific Mortality

Nonblack Pilots

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	351	20	5.70	6937	2.88
C1-C5	1749	101	5.77	35169	2.87
All Comp	3419	231	6.76	70034	3.30

TABLE 4 (Cont'd) Table 2 stat

Summary Counts by Group, Race-Specific Mortality

Nonblack Navigators

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	82	5	6.10	1647	3.04
C1-C5	404	20	4.95	8184	2.44
All Comp	1774	87	4.90	39105	2.22

Nonblack Nonflying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	25	1	4.00	494	2.03
C1-C5	122	6	4.92	2522	2.38
All Comp	282	15	5.32	6098	2.46

Nonblack Enlisted Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	192	8	4.17	3815	2.10
C1-C5	960	72	7.50	19295	3.73
All Comp	2609	181	6.94	55523	3.26

Nonblack Nonflying Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	534	34	6.37	10557	3.22
C1-C5	2655	152	5.73	53828	2.82
All Comp	9701	444	4.58	214206	2.07

Black Pilots

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	6	0	0.00	115	0.00
C1-C5	13	0	0.00	269	0.00
All Comp	20	1	5.00	452	2.21

table2.dat

TABLE 4 (Cont'd)

Summary Counts by Group, Race-Specific Mortality

Black Navigators

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	2	0	0.00	38	0.00
C1-C5	10	0	0.00	219	0.00
All Comp	32	0	0.00	714	0.00

Black Nonflying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	1	0	0.00	19	0.00
C1-C5	2	0	0.00	39	0.00
All Comp	4	0	0.00	88	0.00

Black Enlisted Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	15	4	26.67	297	13.46
C1-C5	75	11	14.67	1475	7.46
All Comp	224	21	9.38	4769	4.40

Black Nonflying Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	53	2	3.77	1047	1.91
C1-C5	260	14	5.38	5289	2.65
All Comp	1036	59	5.69	22739	2.59

Deaths occurring during the calendar years 1986 and 1987 are shown in Tables 5 and 6. Corresponding tables for the years 1983, 1984 and 1985 are shown in the Appendix.

TABLE 5 Table 3, draft

Deaths During 1986
Summary Counts and Rates by Rank, Occupation and Group

Flying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	425	5	1.18	422	11.84
C1-C5	2069	4	0.19	2067	1.94
All Comp	4974	21	0.42	4962	4.23

Enlisted Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	197	1	0.51	197	5.08
C1-C5	963	8	0.83	958	8.35
All Comp	2659	18	0.68	2652	6.79

All Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	622	6	0.96	619	9.70
C1-C5	3032	12	0.40	3026	3.97
All Comp	7633	39	0.51	7614	5.12

Nonflying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	25	0	0.00	25	0.00
C1-C5	121	0	0.00	121	0.00
All Comp	277	2	0.72	276	7.24

table3.dat

TABLE 5 (Cont'd)

Deaths During 1986

Summary Counts and Rates by Rank, Occupation and Group

Nonflying Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	555	3	0.54	553	5.42
C1-C5	2776	13	0.47	2770	4.69
All Comp	10306	35	0.34	10290	3.40

All Nonflyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	580	3	0.52	578	5.19
C1-C5	2897	13	0.45	2891	4.50
All Comp	10583	37	0.35	10566	3.50

All Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	1202	9	0.75	1197	7.52
C1-C5	5929	25	0.42	5916	4.23
All Comp	18216	76	0.42	18180	4.18

table3.dat

TABLE 6

Deaths During 1987
Summary Counts and Rates by Rank, Occupation and Group

Flying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	420	4	0.95	419	9.54
C1-C5	2065	10	0.48	2061	4.85
All Comp	4953	27	0.55	4940	5.47

TABLE 6 (Cont'd)

Deaths During 1987
Summary Counts and Rates by Rank, Occupation and Group

Enlisted Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	196	1	0.51	196	5.11
C1-C5	955	3	0.31	954	3.15
All Comp	2641	10	0.38	2635	3.79

All Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	616	5	0.81	615	8.13
C1-C5	3020	13	0.43	3014	4.31
All Comp	7594	37	0.49	7576	4.88

Nonflying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	25	0	0.00	25	0.00
C1-C5	121	3	2.48	120	25.02
All Comp	275	4	1.45	273	14.65

Nonflying Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	552	1	0.18	551	1.81
C1-C5	2763	14	0.51	2756	5.08
All Comp	10271	37	0.36	10254	3.61

All Nonflyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	577	1	0.17	576	1.74
C1-C5	2884	17	0.59	2876	5.91
All Comp	10546	41	0.39	10527	3.89

Table 3, data

TABLE 6 (Cont'd)

Deaths During 1987
Summary Counts and Rates by Rank,
Occupation and Group

All Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
Ranch Hand	1193	6	0.50	1191	5.04
C1-C5	5904	30	0.51	5890	5.09
All Comp	18140	78	0.43	18102	4.31

2. C1-C5 VERSUS C6-C10 ANALYSES

During the analyses for the 1984 mortality update, Air Force statisticians received a mortality database on the entire matched Comparison cohort, consisting at that time of 9982 records. In each matched set, the Comparisons included in the previous mortality reports are referred to as the C1-C5 Comparisons. The remaining matched Comparisons are called the C6-C10 Comparisons. When Ranch Hand versus Comparison analysis results changed after introducing the new Comparisons, it was found that the C1-C5 Comparisons appeared statistically different, with respect to their mortality experience, from the C6-C10 matched Comparisons. The C1-C5 and C6-C10 Comparisons were contrasted via logrank tests and Mantel-Haenszel relative risks using 5-year age stratification within levels of rank and occupation. The results of those analyses, on data available for the 1984 update (cumulative deaths up to 31 December 1983, verified as of 15 April 1984) are shown in Table 7. Throughout this report the abbreviation for confidence interval is C I.

TABLE 7

Logrank Test Results Comparing C1-C5 with C6-C10 on Cumulative Deaths Occurring on or Before 31 December 1983 and Verified as of 15 June 1984, Survival Measured from Birth

Race	Occupation	Logrank Test	Logrank P-value	Mantel-Haenszel Relative Risk	Mantel-Haenszel 95% C I	Mantel-Haenszel P-value
Non-black	Pilots	-1.60	0.11	0.72	(0.26,2.00)	0.52
	Navigators	0.47	0.63	1.21	(0.29,4.96)	0.79
	Nonflying Officers					
	Enlisted Flyers	-1.53	0.13	0.70	(0.24,2.02)	0.51
	Nonflying Enlisted	2.15	0.03	1.55	(0.35,6.79)	0.56
Black	Pilots					
	Navigators					
	Nonflying Officers					
	Enlisted Flyers	1.59	0.11	4.38	(0.36,52.96)	0.25
	Nonflying Enlisted	0.45	0.65	1.24	(0.25,6.02)	0.14

These results suggested that nonblack enlisted nonflying Comparisons in the C1-C5 cohort were dying at a younger age than the corresponding nonblack enlisted nonflying C6-C10 Comparisons. The relative risk for this group, while elevated (RR=1.55), was not significantly different from unity. These analyses suggest that the C1-C5 Comparison cohort was representative of the C1-C10 matched cohort in all but the nonblack enlisted nonflying stratum. In the nonblack enlisted nonflying stratum, the C1-C5 mortality appeared worse than expected relative to the C6-C10 mortality and so Ranch Hand mortality in the stratum would appear more favorable than expected relative to their C1-C5 Comparisons. Based on these data, Air Force Principal Investigators recommended the expansion of the mortality study to the entire matched Comparison cohort. The Advisory Committee concurred that expansion was appropriate but asked that the mortality study include the entire Comparison population.

A contrast of the C1-C5 and C6-C10 Comparison mortality using current data was also carried out. Summary counts, person-years and death rates are shown in Table 8. Analytical results are shown in Table 9 with mortality measured from birth and from tour start date.

TABLE 8

Stratum-Specific Counts, Person-years and Death Rates
for C1-C5 and C6-C10 Comparisons
Person-years Computed from Tour Start Date

Nonblack Pilots

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	1749	101	5.77	35169	2.87
C6-C10	1175	92	7.83	23398	3.93

Nonblack Navigators

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	404	20	4.95	8184	2.44
C6-C10	310	13	4.19	6354	2.05

Nonblack Nonflying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	122	6	4.92	2522	2.38
C6-C10	43	1	2.33	897	1.11

Nonblack Enlisted Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	960	72	7.50	19295	3.73
C6-C10	723	72	9.96	14386	5.00

Nonblack Nonflying Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	2655	152	5.73	53828	2.82
C6-C10	1420	65	4.58	29264	2.22

TABLE 8 (Cont'd)

Stratum-Specific Counts, Person-years and Death Rates
for C1-C5 and C6-C10 Comparisons
Person-years Computed from Tour Start Date

Black Pilots

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	13	0	0.00	269	0.00
C6-C10	1	0	0.00	24	0.00

Black Navigators

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	10	0	0.00	219	0.00
C6-C10	9	0	0.00	197	0.00

Black Nonflying Officers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	2	0	0.00	39	0.00
C6-C10	0	0	0.00	0	0.00

Black Enlisted Flyers

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	75	11	14.67	1475	7.46
C6-C10	56	2	3.57	1162	1.72

Black Nonflying Enlisted Personnel

Group	Number at Risk	Number Dead	Rate (%)	Person-years	Rate Per 1000 Person-years
C1-C5	260	14	5.38	5289	2.65
C6-C10	146	8	5.48	2933	2.73

TABLE 9

Logrank Test Results Comparing C1-C5 with C6-C10 on Cumulative Deaths Occurring on or Before 31 December 1987 and Verified as of 15 June 1988, Survival Measured from Birth and from Tour Start Date

		Logrank				Mantel-Haenszel		
		From Birth		From Tour		Odds		
Race	Occupation	Test	P-value	Test	P-value	Ratio	95% C I	P-value
Non-black	Pilots	-2.24	0.02	-2.11	0.04	0.71	(0.32,1.57)	0.40
	Navigators	0.48	0.63	0.55	0.58	1.17	(0.37,3.70)	0.78
	Nonflying Officers	0.71	0.47	0.66	0.51	2.17	(0.25,18.5)	0.48
	Enlisted Flyers	-2.23	0.02	-2.12	0.03	0.71	(0.27,1.85)	0.49
	Nonflying Enlisted	1.57	0.11	1.42	0.16	1.26	(0.14,11.5)	0.83
Black	Pilots							
	Navigators							
	Nonflying Officers							
	Enlisted Flyers	2.05	0.04	2.09	0.04	4.64	(0.98,21.8)	0.05
	Nonflying Enlisted	-0.13	0.90	-0.17	0.86	0.93	(0.23,3.77)	0.92

It is noted that the previously statistically significant contrast for nonblack enlisted nonflying personnel is no longer significant although the C1-C5 to C6-C10 mortality odds ratio, 1.26, indicates a nonsignificant elevation of risk of death in the C1-C5 relative to the C6-C10 cohort in the nonblack nonflying enlisted personnel stratum. Additionally, the previously nonsignificant difference between C1-C5 and C6-C10 nonblack pilots is now statistically significant with logrank testing, whether survival is measured from birth (P=0.02) or from tour start date (P=0.04). Significant C1-C5 versus C6-C10 logrank differences are also seen in nonblack and black enlisted flyers. When only counts of death are considered, all rank and occupation-specific C1-C5 versus C6-C10 Mantel-Haenszel contrasts are not statistically significant, although the elevated C1-C5 versus C6-C10 odds ratio, 4.64, among black enlisted flyers is borderline significant (P=0.05). The negative logrank tests and odds ratios less than unity among nonblack pilots, nonblack enlisted flyers and black nonflying enlisted personnel indicate that C1-C5 personnel in these categories are living longer and dying in fewer numbers than their C6-C10 counterparts. These results support the conclusion that the C1-C5 and C6-C10 mortality experiences are not comparable.

Based on these results, the mortality determination was expanded to the entire Comparison population.

3. RANCH HAND VERSUS COMPARISON NONCAUSE-SPECIFIC ANALYSES

Survival contrasts were carried out between Ranch Hands and their C1-C5 matched Comparisons and between Ranch Hands and the entire population of Comparisons. Each analysis is presented with and without adjustment for the covariates of rank (officer, enlisted), occupation (flying, nonflying) and date of birth. All analyses are unadjusted for race due to the small proportion of blacks. A summary of the kinds of analyses carried out is shown in Table 10. Adjustments include date of birth (DOB), occupation (flying, nonflying), rank (officer, enlisted) and tour start date (tour date). Unadjusted contrasts of Ranch Hand and C1-C5 Comparisons reflect partial adjustment due to the matching of C1-C5 Comparisons to Ranch Hands on date of birth, rank, race and occupation. Such adjustment is simply indicated as "matching". Table 10 gives a summary of these methods.

TABLE 10

Analytical Method Summary

Contrast	Method	Adjustments
RH vs C1-C5	Two-sample unadjusted survival curves	Matching, survival time
	Two-sample adjusted survival curves	Rank, occupation, survival time
	Two-sample adjusted linear rank tests	DOB, race, rank, occupation, survival time
	Two-sample adjusted SMR	DOB, rank, occupation, tour date, survival time
	Two-sample unadjusted odds ratio	Matching
	Two-sample adjusted odds ratio	DOB, rank, occupation, tour date
RH vs All Comp	Two-sample unadjusted survival curves	Survival time
	Two-sample adjusted survival curves	Rank, occupation survival time
	Two-sample adjusted linear rank tests	DOB, rank, occupation survival time

TABLE 10 (Cont'd)

Analytical Method Summary

Contrast	Method	Adjustments
RH vs All Comp	Two-sample adjusted SMR	DOB, rank, occupation, tour date survival time
	Two-sample unadjusted odds ratio	None
	Two-sample adjusted odds ratio	DOB, rank, occupation, tour date
	One-sample unadjusted SMR	Tour date survival time
	One-sample adjusted SMR with fixed Comparison death rates	DOB, rank, occupation, tour date, calendar time survival time

The two-sample methods (linear rank tests, SMR [5] and odds ratio analyses) treat the Ranch Hands and Comparisons as samples from larger populations, even though they are actually populations rather than random samples. The adjusted SMR with fixed Comparison death rates [6] treats the Comparison population as a population rather than as a sample from a larger hypothetical population. This is the most appropriate method of analysis now that the entire Comparison population is available for reference with Ranch Hand mortality. The two-sample methods are repeated in the Ranch Hand versus All Comparison contrasts to ease the transition between this and previous mortality updates.

The Ejigou-McHugh odds ratio analysis [7] has been dropped and replaced by logistic regression because it has been recently shown [8] that the Ejigou-McHugh procedure may be viewed as a special case of conditional logistic regression [9] and because conditional logistic regression has been shown to yield the same results as logistic regression in these data. The Ejigou-McHugh method accommodates the matched design but does not otherwise adjust for the matching variables (race, rank, occupation and date of birth). Conditional logistic regression may be viewed as a generalization of the Ejigou-McHugh procedure in that it accommodates covariates and reduces to the Ejigou-McHugh procedure in matched designs with no additional covariates and when there is no mortality-by-covariate-by-group (Ranch Hand, Comparison) interaction. Additionally, conditional logistic regression allows the investigation of interactions whereas the Ejigou-McHugh procedure does not.

An attempt was made to replace the linear rank procedures with covariate adjusted contrasts via the proportional hazards model [10]. Chi-square tests of fit [11] and associated diagnostic plots were applied to assess modelling assumptions associated with the proportional hazards analysis. An application of the fully adjusted model to the Ranch Hand versus C1-C5 data failed because the date of birth covariate did not satisfy the proportional hazards assumption. The relevant diagnostic plot is shown in the Appendix. The proportional hazards assumption does hold, however, for group (Ranch Hand, Comparison), with or without adjustment for date of birth, hence the calculated logrank tests are appropriate summary statistics since they adjust for date of birth, rank and occupation via stratification.

Adjusted survival curves were calculated and plotted in Figures 1 through 10. In these plots, the Ranch Hand curve is a power of the respective Comparison curve, the power being the odds ratio estimated via application of the method of maximum likelihood from the proportional hazards model. Figures 1 through 5 show adjusted Ranch Hand and C1-C5 Comparison survival curves of the total cohort and in each of the four marginal strata: officers, enlisted, flying personnel and nonflying personnel. Figures 6 through 10 show the corresponding plots for Ranch Hands versus all Comparisons. In every plot, survival is measured from the start of the qualifying tour so the ordinate is interpreted as the proportion surviving since start of tour. The corresponding adjusted plots for survival measured from birth rather than from tour start date are shown in the Appendix. Also shown in the Appendix are nonparametric (Kaplan-Meier) plots [12] with survival measured from tour start date and from date of birth.

Figure 1

Adjusted Survival Curve Estimates
All Ranch Hands and C1-C5 Comparisons
Survival from Start of Tour

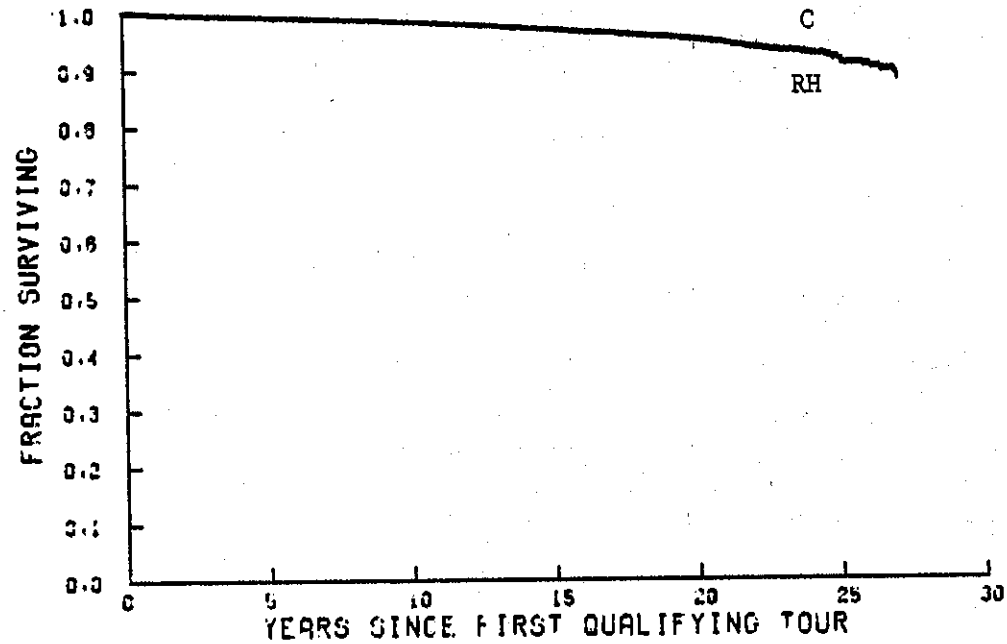


Figure 2

Adjusted Survival Curve Estimates
Ranch Hand and C1-C5 Comparison Officers
Survival from Start of Tour

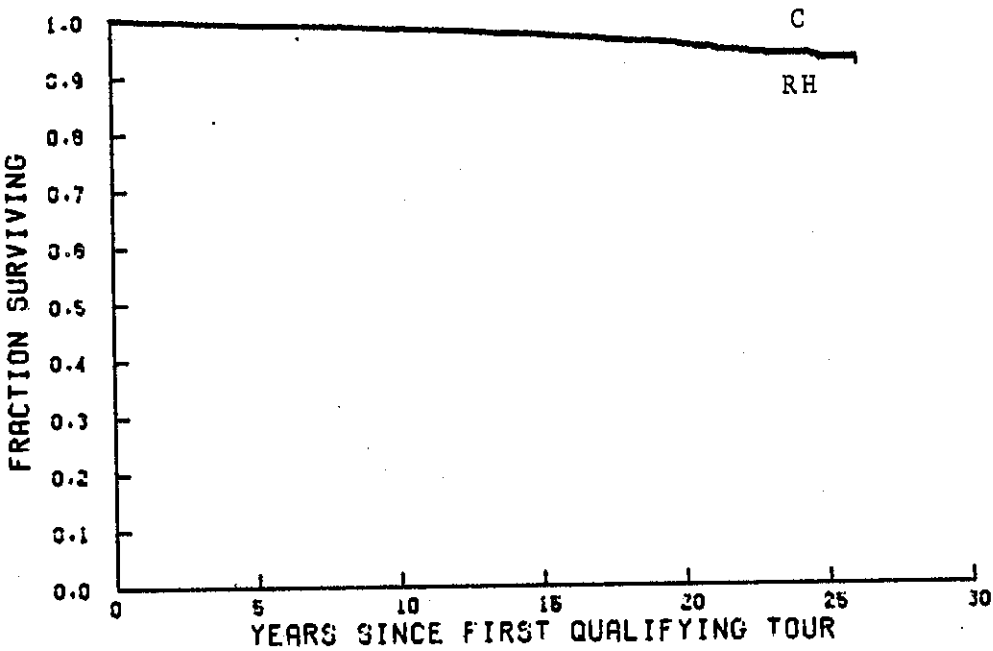


Figure 3

Adjusted Survival Curve Estimates
Ranch Hand and C1-C5 Comparison Enlisted Personnel
Survival from Start of Tour

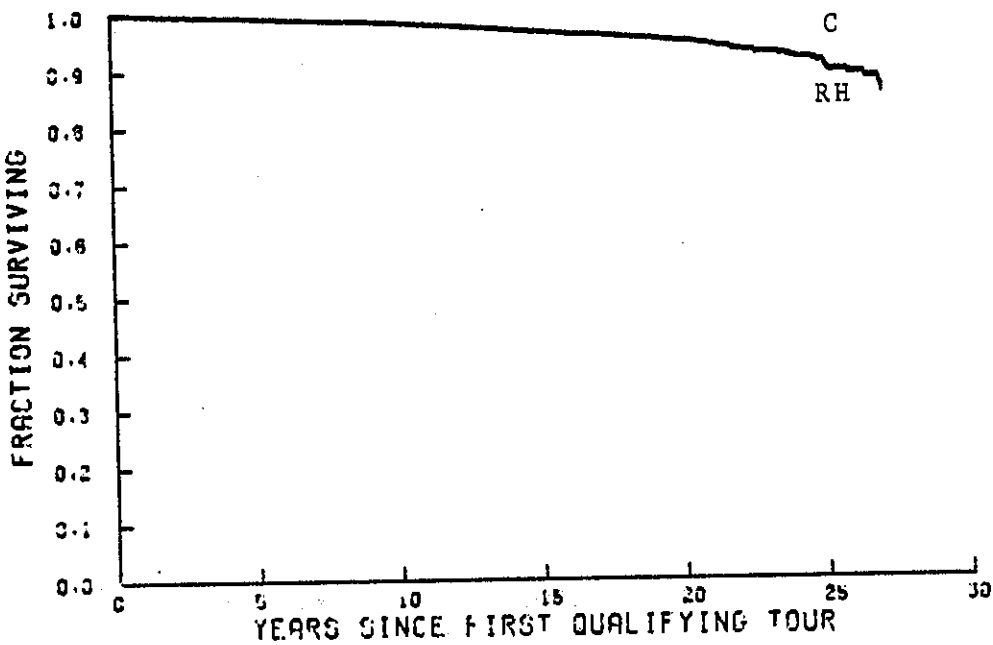


Figure 4

Adjusted Survival Curve Estimates
Ranch Hand and C1-C5 Comparison Flyers
Survival from Start of Tour

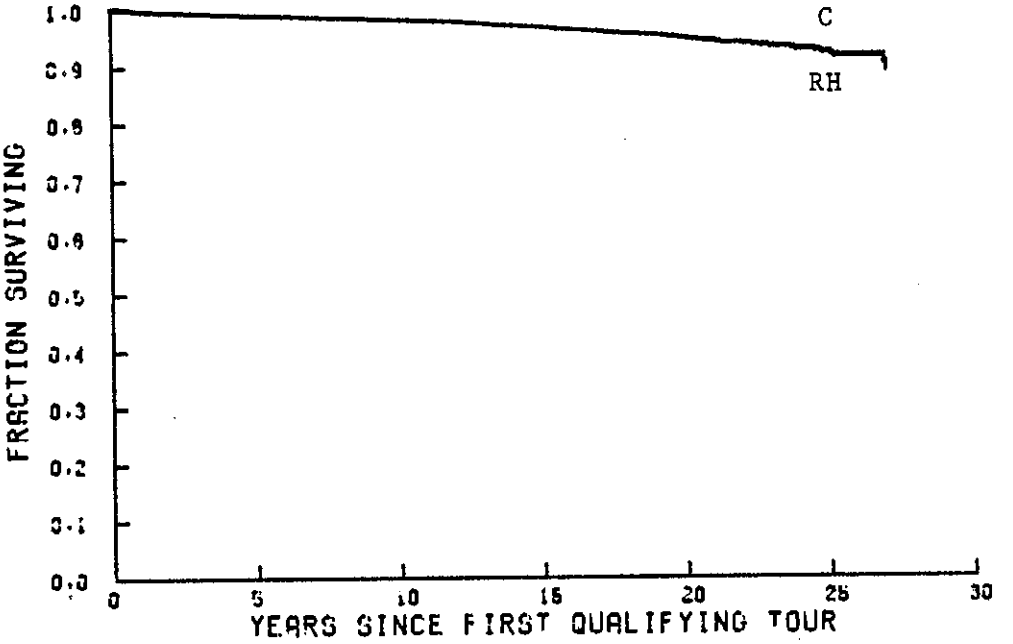


Figure 5

Adjusted Survival Curve Estimates
Ranch Hands and C1-C5 Comparison Nonflyers
Survival from Start of Tour

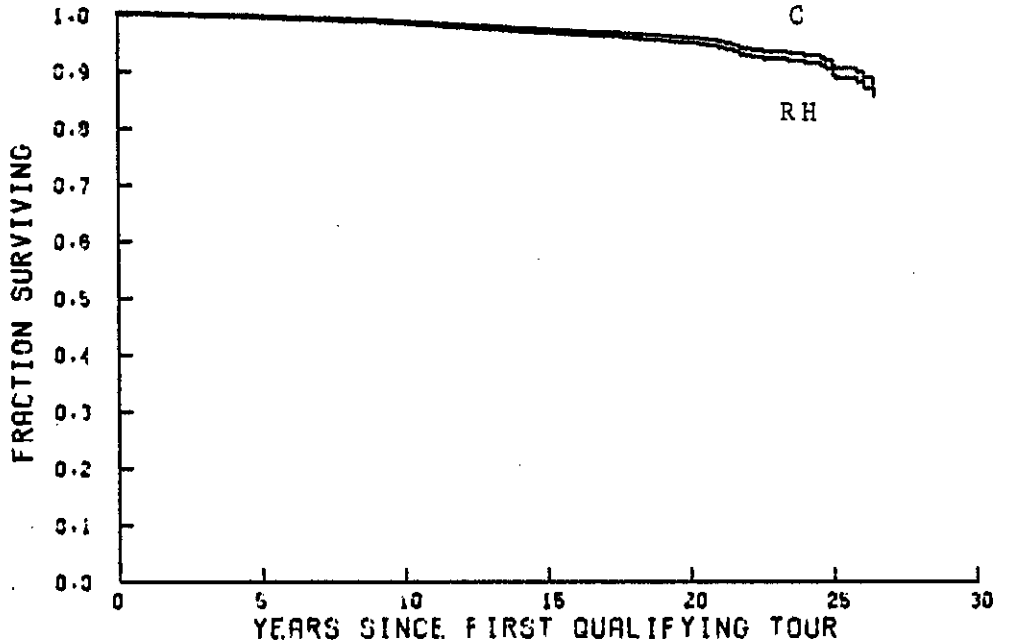


Figure 6

Adjusted Survival Curve Estimates
All Ranch Hands and All Comparisons
Survival from Start of Tour

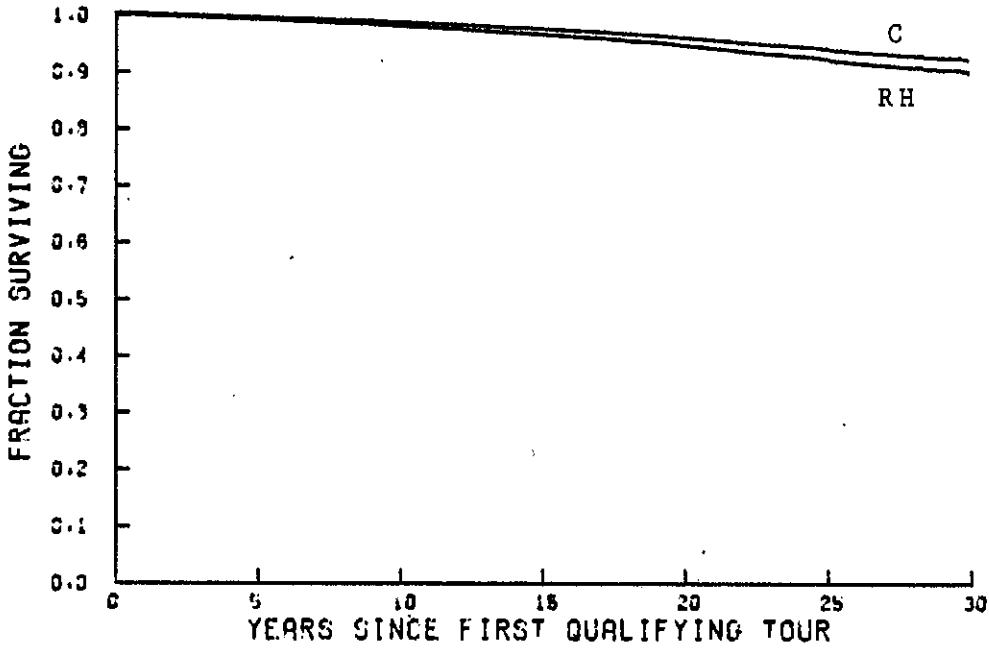


Figure 7

Adjusted Survival Curve Estimates
Ranch Hand and All Comparison Officers
Survival from Start of Tour

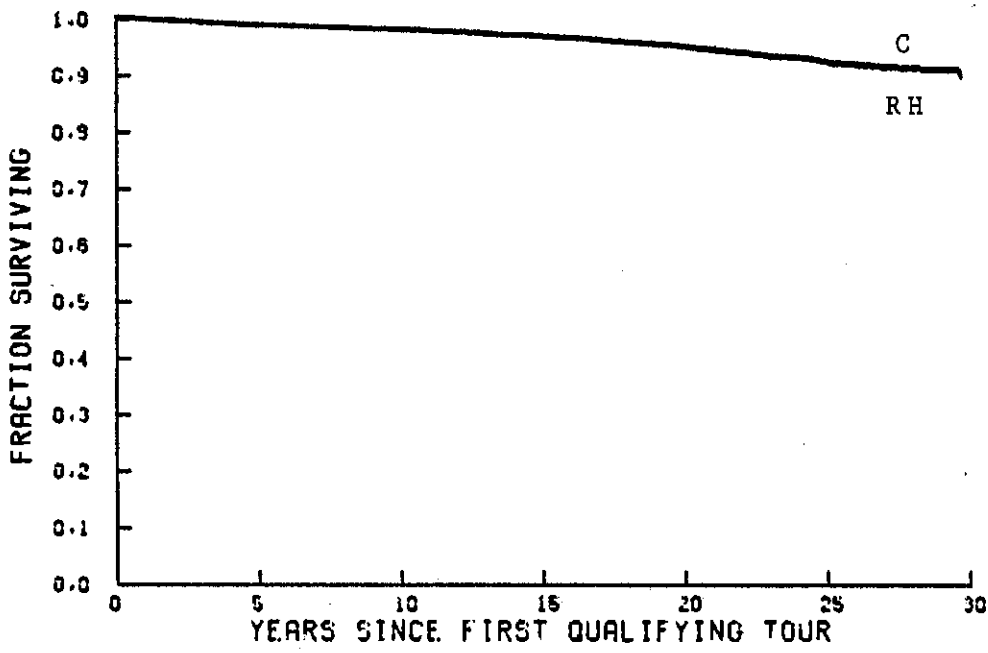


Figure 8

Adjusted Survival Curve Estimates
Ranch Hand and All Comparison Enlisted Personnel
Survival from Start of Tour

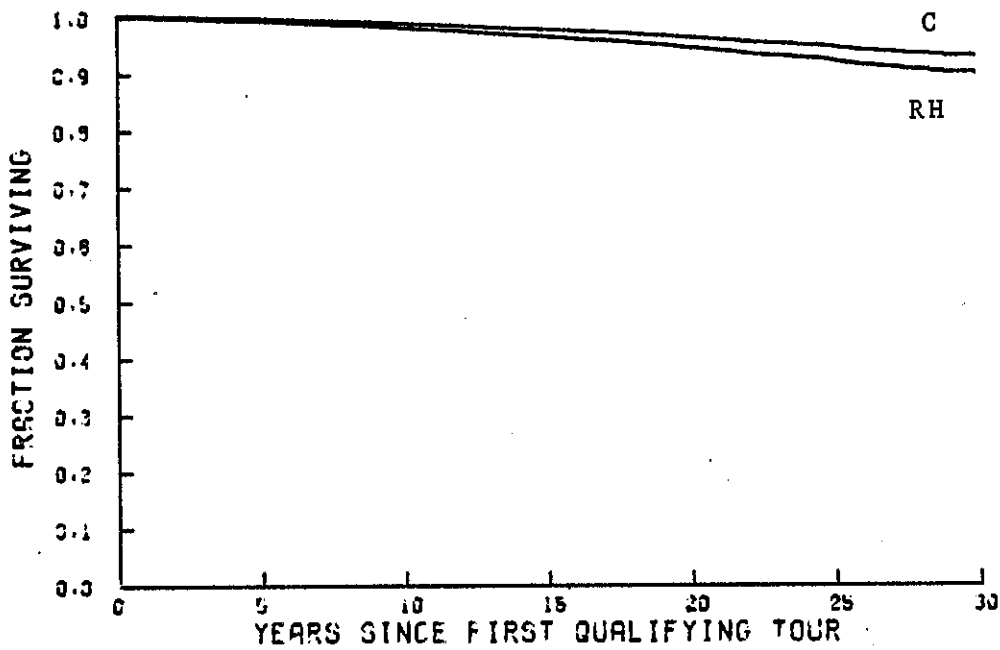


Figure 9

Adjusted Survival Curve Estimates
Ranch Hand and All Comparison Flyers
Survival from Start of Tour

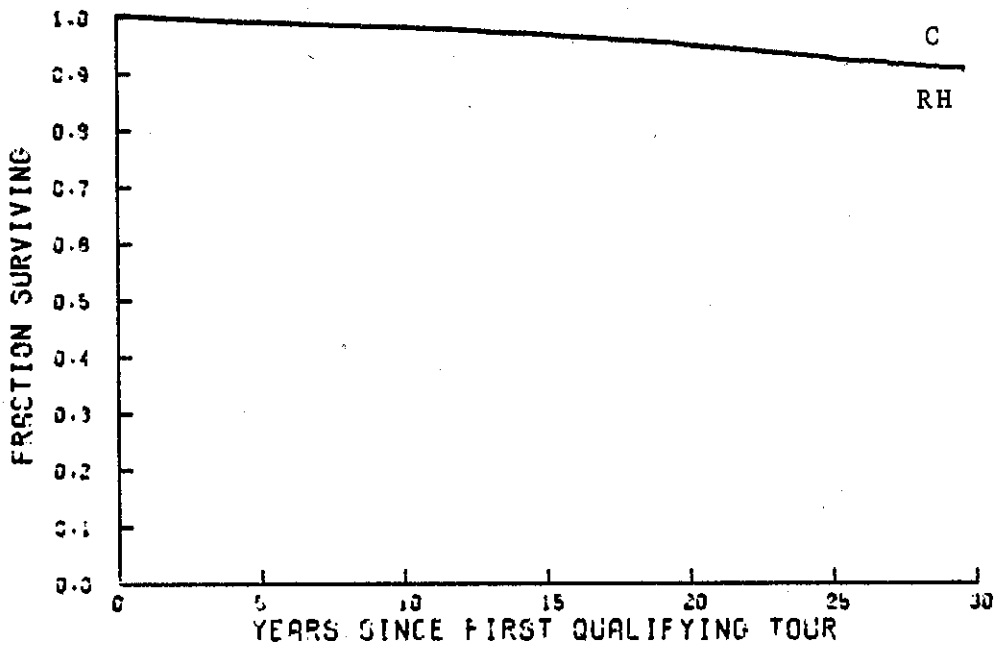
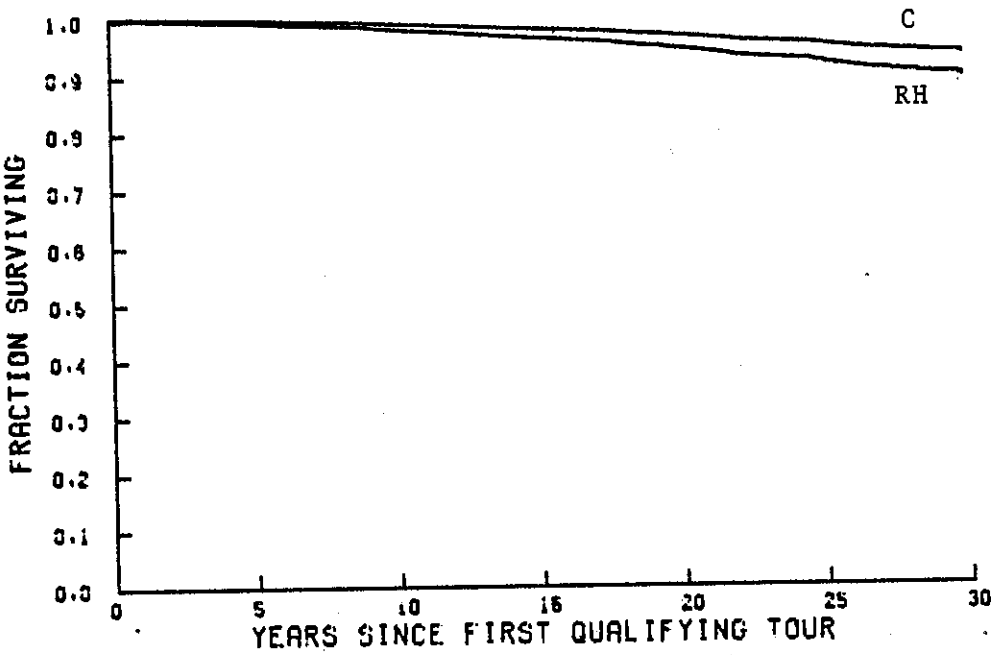


Figure 10

Adjusted Survival Curve Estimates
Ranch Hand and All Comparison Nonflyers
Survival from Start of Tour



The survival curves are so close together in Figures 1 through 4 and 7 and 9 that there appears to be only a single curve in each of these figures. This occurred because the adjusted Ranch Hand curve is the Comparison curve raised to the adjusted Ranch Hand versus C1-C5 odds ratio power and these odds ratios are nearly equal to unity. In general, the Ranch Hand and C1-C5 Comparison curves are closer together than the Ranch Hand and all Comparison curves because matching provides better adjustment than stratification.

The linear rank procedures (logrank and Wilcoxon tests) contrasting Ranch Hand with C1-C5 mortality and all Comparison mortality are shown in Table 11 with survival measured from tour start date. The corresponding results for survival measured from date of birth are shown in Table 12.

TABLE 11

Logrank and Wilcoxon Tests Contrasting
Ranch Hand and Comparison Mortality with
Survival Measured from Tour Start Date

	C1-C5 Comparison				All Comparison			
	Logrank		Wilcoxon		Logrank		Wilcoxon	
Group	Test	P-value	Test	P-value	Test	P-value	Test	P-value
Officer	0.31	0.75	0.26	0.80	0.21	0.83	0.16	0.87
Enlisted	0.07	0.94	0.11	0.91	0.89	0.37	0.96	0.34
Flying	-0.34	0.74	-0.40	0.69	-0.48	0.63	-0.52	0.60
Nonflying	0.68	0.49	0.74	0.46	1.73	0.08	1.79	0.07
All	0.29	0.83	0.22	0.83	0.73	0.47	0.74	0.46

TABLE 12

Logrank and Wilcoxon Tests Contrasting
Ranch Hand and Comparison Mortality with
Survival Measured from Date of Birth

	C1-C5 Comparison				All Comparison			
	Logrank		Wilcoxon		Logrank		Wilcoxon	
Group	Test	P-value	Test	P-value	Test	P-value	Test	P-value
Officer	0.00	1.00	-0.02	0.99	-0.35	0.73	-0.37	0.71
Enlisted	-0.26	0.79	-0.25	0.80	0.22	0.83	0.26	0.80
Flying	-0.66	0.51	-0.70	0.48	-1.08	0.28	-1.12	0.26
Nonflying	0.34	0.74	0.37	0.71	1.09	0.28	1.13	0.26
All	-0.21	0.83	-0.22	0.82	-0.18	0.85	-0.18	0.86

Table 11 suggests that nonflying personnel in the Ranch Hand group are dying sooner than their matched Comparisons (logrank = 0.68) when survival is measured from tour start date, but that the difference is not statistically significant (P=0.49). The same contrast for Ranch Hands versus all Comparisons is borderline significant (logrank = 1.73, P=0.08). The negative values of the logrank and Wilcoxon statistics for flyers in Table 11 indicate that Ranch Hands in this stratum are living longer than the Comparisons, but this is easily attributed to chance (P=0.74). The corresponding results in Table 12, for survival measured from date of birth, are generally nonsignificant with some reversals relative to Table 9. The results in Table 11 are more appropriate than those in Table 12, however. Table 12 is shown only for comparison with previous updates.

Unadjusted odds ratio estimates, confidence intervals and P-values, contrasting Ranch Hand and C1-C5 Comparison mortality overall and within each of the four marginal strata, are shown in Table 13. The corresponding results for Ranch Hand versus all Comparisons are shown in Table 14. The unadjusted odds ratio estimate for the Ranch Hand versus all Comparison contrast was carried out via the two-sample odds ratio estimate and also via the one-sample approach [6] treating the Comparison population as fixed, in which the odds ratio is the SMR, the ratio of the observed to the expected number of deaths.

TABLE 13

Unadjusted Odds Ratio Estimates Contrasting
Ranch Hand with C1-C5 Mortality

Stratum	Odds Ratio	95% C I	P-value
Officer	1.01	(0.65, 1.56)	0.97
Enlisted	0.96	(0.69, 1.32)	0.78
Flying	0.89	(0.62, 1.28)	0.54
Nonflying	1.07	(0.74, 1.54)	0.71
All	0.97	(0.75, 1.26)	0.84

TABLE 14

Unadjusted Odds Ratio Estimates Contrasting
Ranch Hand and All Comparison Mortality,
with Person-years Computed from Tour Start Date

	Two-sample Procedure			One-sample Procedure			
Stratum	Odds Ratio	95% C I	P-value	Obs	Exp	SMR	P-value
Officer	0.92	(0.61, 1.38)	0.68	26	26.5	0.98	0.92
Enlisted	1.17	(0.87, 1.59)	0.30	48	38.4	1.24	0.12
Flying	0.88	(0.62, 1.24)	0.46	37	39.2	0.94	0.72
Nonflying	1.30	(0.92, 1.84)	0.13	37	25.8	1.43	0.03
All	1.08	(0.85, 1.38)	0.52	74	62.7	1.18	0.15

Table 13 demonstrates a near equivalence of Ranch Hand and C1-C5 mortality without adjustment for covariates. The corresponding results in Table 14 are very similar with the exception that the Ranch Hand nonflying personnel are experiencing significantly more deaths than nonflying personnel in the Comparison population (SMR=1.43, P=0.03) in the unadjusted one-sample analysis.

In the corresponding adjusted two-sample analyses, odds ratios were determined by stepwise logistic regression with group (Ranch Hand, Comparison), date of birth, rank (officer, enlisted), occupation (flying, nonflying), tour start date and all pairwise products in the model. Each adjusted analysis was carried out with date of birth and tour start date entered as continuous variables and again with date of birth and tour date dichotomized as prior to or after 1 January 1935 and 1 October 1968. The cut point for date of birth was chosen to allow investigation of interactions discovered in the 1984 update; the cutpoint for tour start date is the median tour date in the combined Ranch Hand and Comparison database. Adjusted two-sample contrasts of Ranch Hand and C1-C5 mortality are summarized in Table 15. The corresponding summary of the two-sample Ranch Hand and all Comparison mortality is shown in Table 16.

TABLE 15

Adjusted Two-sample Odds Ratio Estimates Contrasting
Ranch Hand with C1-C5 Mortality

Odds Ratio	95% C I	P-value	Covariates and Interactions (P-value)
Dichotomized Date of Birth and Tour Start Dates			
1.00	(0.88, 1.14)	0.93	Rank (P<0.01) Occupation (0.34) Tour start (P<0.01) Date of birth (P<0.01) Occ by DOB (P<0.01)
Continuous Date of Birth and Tour Start Dates			
1.00	(0.87, 1.14)	0.96	Rank (P<0.01) Tour start (0.12) Date of birth (P<0.01)

Date of birth and tour start date are uncorrelated in these data (r-square = 0.0016), a fortunate circumstance that precludes concern about multicollinearity. The lack of correlation is most likely due to the rapid turnover of personnel during the war.

TABLE 16

Adjusted Two-sample Odds Ratio Estimates Contrasting Ranch Hands with All Comparisons

Dichotomized Date of Birth and Tour Start Dates

Odds Ratio	95% C I	P-value	Covariates and Interactions (P-value)
****	**********	****	Rank (P<0.01) Occupation (0.01) Tour start (0.37) Date of birth (P<0.01) Group by tour (0.01) Rank by tour (0.14) Occ by tour (P<0.01) Occ by DOB (P<0.01) Tour by DOB (P<0.01)

Continuous Date of Birth and Tour Start Dates

1.00	(0.88, 1.13)	0.96	Rank (P<0.01) Occupation (0.01) Tour start (0.17) Date of birth (P<0.01) Tour by DOB (0.03)

The group by tour by survival interaction in the discrete analysis is due to the change in the group by survival odds ratio with tour date (early, late). The presence of an interaction involving group (Ranch Hand, Comparison) precluded the specification of an odds ratio, confidence interval and P-values; these statistics are replaced by asterisks in Table 16. For veterans with early tours, the Mantel-Haenszel adjusted group by survival odds ratio is 1.10 and for late tours the adjusted odds ratio is 0.93. It is notable that the same interaction is not significant in the continuous analysis. This suggests that the just described interaction is spurious. In particular, if tour date is trichotomized to early, middle and late tours, the corresponding Mantel-Haenszel adjusted group by survival odds ratios are 0.90 for early tours, 1.23 for middle tours and 0.84 for late tours. This interaction remains unexplained at this time.

The two-sample [5] internally adjusted SMR analysis compares the mortality of two groups with adjustment for year of birth. These analyses are carried out as in previous updates, within each of the four rank and occupational strata as well as on the whole group. Survival is measured from tour start date in these analyses. The corresponding analyses with survival measured from birth are shown in the Appendix. Tables 17 through 21 show the two-sample SMR analyses for Ranch Hand versus C1-C5 mortality and Tables 22 through 26 show the corresponding analyses for Ranch Hand versus all Comparison mortality contrasts.

TABLE 17

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Officers
Survival from Start of Tour

SMR= 1.03 (P= 0.87)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1919	9	3	152	19.76	44	8	868	9.21
1920-1924	32	2	651	3.07	160	21	3217	6.53
1925-1929	43	3	867	3.46	289	22	5909	3.72
1930-1934	151	8	3108	2.57	645	39	13401	2.91
1935-1939	96	4	1969	2.03	467	20	9822	2.04
1940-1944	91	4	1725	2.32	505	12	9813	1.22
1945-1954	45	2	777	2.57	190	5	3373	1.48
Total	467	26	9248	2.81	2300	127	46403	2.74

TABLE 18

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Enlisted Personnel
Survival from Start of Tour

SMR= 0.99 (P= 0.93)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1914	4	2	77	26.00	12	4	278	14.41
1915-1919	9	2	185	10.80	53	14	1108	12.64
1920-1924	16	3	333	9.01	80	18	1677	10.73
1925-1929	41	4	851	4.70	215	35	4448	7.87
1930-1934	154	17	3030	5.61	755	70	15709	4.46
1935-1939	117	5	2368	2.11	577	35	11992	2.92
1940-1944	121	4	2486	1.61	616	24	12676	1.89
1945-1954	332	11	6386	1.72	1642	49	32002	1.53
Total	794	48	15716	3.05	3950	249	79888	3.12

TABLE 19

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Flyers
Survival from Start of Tour

SMR= 0.92 (P= 0.63)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1915-1919	9	4	136	29.34	45	10	865	11.56
1920-1924	35	2	720	2.78	175	25	3512	7.12
1925-1929	53	3	1079	2.78	353	29	7237	4.01
1930-1934	219	15	4435	3.38	972	71	19980	3.55
1935-1939	146	6	2954	2.03	712	36	14737	2.44
1940-1944	122	5	2380	2.10	668	23	13068	1.76
1945-1954	64	2	1144	1.75	286	10	5213	1.92
Total	648	37	12848	2.88	3211	204	64612	3.16

TABLE 20

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Nonflyers
Survival from Start of Tour

SMR= 1.09 (P= 0.63)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1914	5	2	99	20.27	14	5	325	15.38
1915-1919	8	1	179	5.59	50	11	1064	10.34
1920-1924	13	3	264	11.36	65	14	1382	10.13
1925-1929	31	4	639	6.26	151	28	3120	8.98
1930-1934	86	10	1703	5.87	428	38	9129	4.16
1935-1939	67	3	1383	2.17	332	19	7076	2.68
1940-1944	90	3	1831	1.64	453	13	9421	1.38
1945-1954	313	11	6019	1.83	1546	44	30162	1.46
Total	613	37	12116	3.05	3039	172	61679	2.79

TABLE 21

Two-sample Standardized Mortality Ratios
All Ranch Hand and C1-C5 Comparison
Survival from Start of Tour

SMR= 1.00 (P= 0.99)

Birth Year	Ranch Hand Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1914	5	2	99	20.27	14	5	325	15.38
1915-1919	17	5	315	15.86	95	21	1929	10.89
1920-1924	48	5	984	5.08	240	39	4894	7.97
1925-1929	84	7	1718	4.08	504	57	10357	5.50
1930-1934	305	25	6138	4.07	1400	109	29110	3.74
1935-1939	213	9	4337	2.08	1044	55	21814	2.52
1940-1944	212	8	4211	1.90	1121	36	22489	1.60
1945-1954	377	13	7163	1.81	1832	54	35375	1.53
Total	1261	74	24964	2.96	6250	376	126291	2.98

TABLE 22

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison Officers
Survival from Start of Tour

SMR= 1.01 (P= 0.96)

Birth Year	Ranch Hand Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1919	9	3	152	19.76	148	31	3095	10.02
1920-1924	32	2	651	3.07	573	76	12464	6.10
1925-1929	43	3	867	3.46	512	53	10469	5.06
1930-1934	151	8	3108	2.57	1221	73	25731	2.84
1935-1939	96	4	1969	2.03	1121	44	24354	1.81
1940-1944	91	4	1725	2.32	1563	47	32990	1.42
1945-1954	45	2	777	2.57	393	10	7386	1.35
Total	467	26	9248	2.81	5531	334	116489	2.87

TABLE 23

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison Enlisted
Survival from Start of Tour

SMR= 1.11 (P= 0.48)

	Ranch Hand				C1-C5 Comparison			
Birth Year	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1914	4	2	77	26.00	18	8	413	19.37
1915-1919	9	2	185	10.80	105	34	2167	15.69
1920-1924	16	3	333	9.01	274	61	5820	10.48
1925-1929	41	4	851	4.70	657	97	14196	6.83
1930-1934	154	17	3030	5.61	1921	168	41450	4.05
1935-1939	117	5	2368	2.11	1701	101	37164	2.72
1940-1944	121	4	2486	1.61	2425	70	53911	1.30
1945-1954	332	11	6386	1.72	6469	166	142115	1.17
Total	794	48	15716	3.05	13570	705	297237	2.37

TABLE 24

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison Flyers
Survival from Start of Tour

SMR= 0.90 (P= 0.54)

	Ranch Hand				C1-C5 Comparison			
Birth Year	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1919	9	4	136	29.34	140	35	2867	12.21
1920-1924	35	2	720	2.78	576	85	12361	6.88
1925-1929	53	3	1079	2.78	669	75	13799	5.44
1930-1934	219	15	4435	3.38	1790	136	37196	3.66
1935-1939	146	6	2954	2.03	1630	78	34818	2.24
1940-1944	122	5	2380	2.10	1928	70	40462	1.73
1945-1954	64	2	1144	1.75	1345	42	29094	1.44
Total	648	37	12848	2.88	8078	521	170596	3.05

TABLE 25

Two-sample Standardized Mortality Ratios
All Ranch Hand and Comparison Nonflyers
Survival from Start of Tour

SMR= 1.28 (P= 0.15)

	Ranch Hand				C1-C5 Comparison			
Birth Year	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1914	5	2	99	20.27	18	8	414	19.33
1915-1919	8	1	179	5.59	113	30	2394	12.53
1920-1924	13	3	264	11.36	271	52	5923	8.78
1925-1929	31	4	639	6.26	500	75	10867	6.90
1930-1934	86	10	1703	5.87	1352	105	29985	3.50
1935-1939	67	3	1383	2.17	1192	67	26701	2.51
1940-1944	90	3	1831	1.64	2060	47	46440	1.01
1945-1954	313	11	6019	1.83	5517	134	120406	1.11
Total	613	37	12116	3.05	11023	518	243130	2.13

TABLE 26

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison
Survival from Start of Tour

SMR= 1.06 (P= 0.63)

	Ranch Hand				C1-C5 Comparison			
Birth Year	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1914	5	2	99	20.27	22	9	512	17.59
1915-1919	17	5	315	15.86	249	64	5163	12.39
1920-1924	48	5	984	5.08	847	137	18284	7.49
1925-1929	84	7	1718	4.08	1169	150	24666	6.08
1930-1934	305	25	6138	4.07	3142	241	67181	3.59
1935-1939	213	9	4337	2.08	2822	145	61519	2.36
1940-1944	212	8	4211	1.90	3988	117	86902	1.35
1945-1954	377	13	7163	1.81	6862	176	149500	1.18
Total	1261	74	24964	2.96	19101	1039	413726	2.51

Adjusted one-sample analyses, summarized in Table 27, assess Ranch Hand mortality relative to all Comparison death rates in 5 year age and calendar time strata within each of the four rank and occupational strata (officer, enlisted, flying, nonflying) and over the entire Ranch Hand cohort with adjustment for rank and occupation.

Observed and Expected Deaths

TABLE 27

Lexis

[. lexis] table27 off.dat

Adjusted ~~One-Sample~~ Ranch Hand Contrasts with All Comparisons

allcases

Officers

SMR=0.95, 95% C I : (0.59,1.32), P=0.79

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1910-1914	1	22	0	0.22
1915-1919	8	130	3	1.26
1920-1924	32	651	2	4.79
1925-1929	43	867	3	3.92
1930-1934	151	3108	8	9.83
1935-1939	96	1969	4	3.81
1940-1944	91	1725	4	2.53
1945-1949	45	777	2	1.01
Total	467	9249	26	27.37

allcases
; 1. fo 1,2,3,4;1
; 2 nfo 5,6 2
; 3 fe 7,8 3
; 4 nfe 9,10 4

[. lexis] table27enl.dat Enlisted Personnel

SMR=1.05 95% C I : (0.75,1.35), P=0.73

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1910-1914	4	77	2	1.60
1915-1919	9	185	2	2.94
1920-1924	16	333	3	3.80
1925-1929	41	851	4	5.69
1930-1934	154	3030	17	12.82
1935-1939	117	2368	5	7.16
1940-1944	121	2486	4	4.05
1945-1949	321	6188	11	7.77
1950-1954	11	197	0	0.24
Total	794	15715	48	45.63

TABLE 27 (Cont'd)

Adjusted One-sample Ranch Hand Contrasts with All Comparison

[.lexis] table27fly.dat

Flyers

SMR=0.86, 95% C I : (0.58,1.13), P=0.35

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1915-1919	9	136	4	1.63
1920-1924	35	720	2	5.99
1925-1929	53	1079	3	5.83
1930-1934	219	4435	15	16.63
1935-1939	146	2954	6	7.04
1940-1944	122	2379	5	4.17
1945-1949	64	1144	2	1.90
Total	648	12847	37	43.19

[.lexis] table27nonfly.dat

Nonflyers

SMR=1.23, 95% C I : (0.83,1.63), P=0.21

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1910-1914	5	99	2	1.36
1915-1919	8	179	1	2.33
1920-1924	13	264	3	2.63
1925-1929	31	639	4	3.72
1930-1934	86	1703	10	6.66
1935-1939	67	1383	3	3.87
1940-1944	90	1831	3	2.65
1945-1949	302	5822	11	6.64
1950-1954	11	197	0	0.24
Total	613	12117	37	30.11

TABLE 27 (Cont'd)

Adjusted One-sample Ranch Hand Contrasts with All Comparison

[.keyes] table27all.dat

All Ranch Hands

SMR=1.01, 95% C I : (0.80, 1.26), P=0.95

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1905-1914	5	99	2	1.24
1915-1919	17	315	5	3.79
1920-1924	48	984	5	8.88
1925-1929	84	1718	7	9.60
1930-1934	305	6138	25	23.46
1935-1939	213	4337	9	11.09
1940-1944	212	4211	8	6.47
1945-1949	366	6966	13	8.80
1950-1954	11	197	0	0.24
Total	1261	24965	74	73.57

In the analysis on all Ranch Hands, summarized in the last panel of Table 27, there was no survival by rank by occupation interaction (P=0.48) and the Ranch Hand versus all Comparison mortality contrast did not vary significantly with rank (P=0.53) or occcupation (P=0.12).

The previous one and two sample adjusted contrasts (Tables 15 through 27), although fully adjusted for rank, occupation and year of birth, may not detect very recent trends. For example, inspection of Tables 5 and 6 and Appendix Tables 1, 2 and 3 suggests that Ranch Hand flyers are experiencing unusually high death rates relative to all Comparisons during 1986 and 1987. Therefore, chi-square tests for trend [6] were applied to all strata and all Ranch Hands to assess the presence of post-1983 trends in the SMR. These analyses were carried out twice, first with each of the years 1983 through 1987 separately contributing to the statistic and again with 1983 through 1985 collapsed to a single stratum and 1986 and 1987 collapsed to a second stratum. The second analysis with two strata was carried out after noting the increased SMR in flyers during 1986 and 1987. Table 28 shows the results for Ranch Hands versus C1-C5 Comparisons and Table 29 shows the results for Ranch Hands contrasted with all Comparisons. All of these analyses are conditioned on survival to 1 January 1983 and, due to data sparseness, are not adjusted for date of birth. The tests are two-tailed and will therefore detect upward or downward trends in the SMR. Test results for detecting upward trends in the SMR may be derived from these results by dividing the P-value by 2 when the data indicate an increasing trend and replacing the P-value by 1.00 when the data indicate a decreasing trend. These data were not assessed relative to the Air Force exposure index due to sparseness.

TABLE 28

Ranch Hand Mortality
Five Year Trend Analysis vs C1-C5 Comparison

Flying Officers

Chi-square (single year)=3.74 P=0.05
Chi-square (83-85,86-87)=7.54 P=0.01

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.61	0.00
1984	1	2.35	1.43	0.70
1985	1	2.35	2.05	0.49
1986	5	11.84	0.82	6.12
1987	4	9.54	2.03	1.97

Enlisted Flyers

Chi-square (single year)=0.34 P=0.56
Chi-square (83-85,86-87)=0.14 P=0.71

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	5.03	1.22	0.82
1984	0	0.00	1.22	0.00
1985	1	5.07	0.82	1.22
1986	1	5.08	1.64	0.61
1987	1	5.11	0.62	1.62

All Flyers

Chi-square (single year)=4.62 P=0.03
Chi-square (83-85,86-87)=6.50 P=0.01

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	1.60	1.84	0.54
1984	1	1.60	2.66	0.38
1985	2	3.21	2.87	0.70
1986	6	9.70	2.45	2.44
1987	5	8.13	2.65	1.89

TABLE 28 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs C1-C5 Comparison

Nonflying Officers

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.00	0.00
1984	0	0.00	0.00	0.00
1985	0	0.00	0.00	0.00
1986	0	0.00	0.00	0.00
1987	0	0.00	0.63	0.00

Nonflying Enlisted Personnel

Chi-square (single year)=0.26 P=0.61
Chi-square (83-85,86-87)=0.01 P=0.92

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.58	1.20	1.67
1984	0	0.00	1.79	0.00
1985	2	3.59	2.80	0.71
1986	3	5.42	2.60	1.15
1987	1	1.81	2.80	0.36

All Nonflyers

Chi-square (single year)=0.46 P=0.50
Chi-square (83-85,86-87)=0.00 P=0.96

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.43	1.20	1.67
1984	0	0.00	1.80	0.00
1985	2	3.44	2.81	0.71
1986	3	5.19	2.60	1.15
1987	1	1.74	3.41	0.29

TABLE 28 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs C1-C5 Comparison

All Officers

Chi-square (single year)=2.44 P=0.12
Chi-square (83-85,86-87)=5.73 P=0.02

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.61	0.00
1984	1	2.22	1.43	0.70
1985	1	2.22	2.05	0.49
1986	5	11.18	0.82	6.12
1987	4	9.01	2.65	1.51

All Enlisted Personnel

Chi-square (single year)=0.01 P=0.94
Chi-square (83-85,86-87)=0.08 P=0.77

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	3.96	2.40	1.25
1984	0	0.00	3.01	0.00
1985	3	3.98	3.62	0.83
1986	4	5.33	4.23	0.95
1987	2	2.68	3.42	0.58

All Personnel

Chi-square (single year)=1.41 P=0.24
Chi-square (83-85,86-87)=3.48 P=0.06

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	2.48	3.03	0.99
1984	1	0.83	4.44	0.22
1985	4	3.32	5.67	0.71
1986	9	7.52	5.06	1.78
1987	6	5.04	6.07	0.99

TABLE 29

Ranch Hand Mortality
Five Year Trend Analysis vs All Comparison

Flying Officers

Chi-square (single year)=4.89 P=0.03
Chi-square (83-85,86-87)=6.10 P=0.01

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	1.87	0.00
1984	1	2.35	1.70	0.59
1985	1	2.35	1.45	0.69
1986	5	11.84	1.79	2.80
1987	4	9.54	2.29	1.75

Enlisted Flyers

Chi-square (single year)=0.16 P=0.69
Chi-square (83-85,86-87)=0.09 P=0.76

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	5.03	1.03	0.97
1984	0	0.00	0.89	0.00
1985	1	5.07	0.89	1.13
1986	1	5.08	1.34	0.75
1987	1	5.11	0.74	1.35

All Flyers

Chi-square (single year)=4.75 P=0.03
Chi-square (83-85,86-87)=5.27 P=0.02

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	1.60	2.92	0.34
1984	1	1.60	2.60	0.38
1985	2	3.21	2.36	0.85
1986	6	9.70	3.17	1.89
1987	5	8.13	3.00	1.67

TABLE 29 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs All Comparison

Nonflying Officers

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.00	0.00
1984	0	0.00	0.09	0.00
1985	0	0.00	0.09	0.00
1986	0	0.00	0.18	0.00
1987	0	0.00	0.37	0.00

Nonflying Enlisted Personnel

Chi-square (single year)=0.01 P=0.93
Chi-square (83-85,86-87)=0.21 P=0.65

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.58	1.24	1.62
1984	0	0.00	1.88	0.00
1985	2	3.59	2.21	0.90
1986	3	5.42	1.88	1.59
1987	1	1.81	1.99	0.50

All Nonflyers

Chi-square (single year)=0.03 P=0.86
Chi-square (83-85,86-87)=0.13 P=0.71

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.43	1.26	1.59
1984	0	0.00	1.97	0.00
1985	2	3.44	2.30	0.87
1986	3	5.19	2.03	1.48
1987	1	1.74	2.24	0.45

TABLE 29 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs All Comparison

All Officers

Chi-square (single year)=4.22 P=0.04
Chi-square (83-85,86-87)=5.38 P=0.02

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	1.88	0.00
1984	1	2.22	1.79	0.56
1985	1	2.22	1.54	0.65
1986	5	11.18	1.96	2.55
1987	4	9.01	2.64	1.51

All Enlisted Personnel

Chi-square (single year)=0.02 P=0.89
Chi-square (83-85,86-87)=0.30 P=0.58

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	3.96	2.14	1.40
1984	0	0.00	2.72	0.00
1985	3	3.98	3.08	0.97
1986	4	5.33	3.07	1.30
1987	2	2.68	2.72	0.73

All Personnel

Chi-square (single year)=2.70 P=0.10
Chi-square (83-85,86-87)=4.31 P=0.04

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	2.48	3.88	0.77
1984	1	0.83	4.48	0.22
1985	4	3.32	4.68	0.85
1986	9	7.52	5.01	1.80
1987	6	5.04	5.13	1.17

In the Ranch Hand versus all Comparison trend analayses (Table 29), the increased SMR's specific to the calendar years 1986 and 1987 for flyers shown in Tables 5 and 6 are seen to produce an increasing trend from 1983 through 1987, with the respective SMR's being 0.34, 0.38, 0.85, 1.89, and 1.67. This trend is statistically significant (two tailed P=0.03, one tailed P=0.015) and is due to unusually low Ranch Hand death rates prior to 1986 and elevated Ranch Hand rates during 1986 and 1987. Inspection of Table 29 suggests that the trend within the flyers is due to an increasing trend in the SMR within the flying officer stratum, with no trend apparent within the enlisted flyer stratum. No trends are apparent or are detected in the nonflying or enlisted strata. The significant increasing trends in the officer statum (two tailed P=0.04, one tailed P=0.02) and all personnel (two tailed P=0.04, one tailed P=0.02) is due to the trend within the flying officer statum. The significant trend seen in the last panel of Table 29, for all Ranch Hands is due to the elevated SMR's specific to 1986 and 1987 (two tailed P=0.04, one tailed P=0.02) and is attributable to the trend within with flying officers. The Ranch Hand versus C1-C5 Comparison results are similar.

Inspection of Tables 35 and 36 and Appendix Tables 4, 5 and 6, which show counts of deaths during the calendar years 1983 through 1987 by cause, rank and occupation, shows that of the 5 flying officer Ranch Hand deaths during 1986, 3 were due to malignant neoplasm (SMR=3.92), 1 was a circulatory system death (SMR=1.68) and 1 was due to unknown causes (SMR not defined). Of the 4 deaths within the Ranch Hand flying officers occurring during 1987, 1 was accidental (SMR=6.00), 1 was due to a malignant neoplasm (SMR=0.98) and 2 were due to diseases of the circulatory system (SMR=2.62). The single Ranch Hand flying officer death during 1984 was due to circulatory system disease (SMR=2.35) and the single death occurring during 1985 was due to a malignant neoplasm (SMR=2.35). These patterns suggest that the observed trend may be attributed to increased numbers of Ranch Hand malignant neoplasm and circulatory deaths. Inspection of Tables 48, 49, 51 and 52 and Appendix Tables 7, 8, 9, 11, 12 and 13 shows that the observed Ranch Hand malignant neoplasm deaths during 1983 through 1987 among flyers or flying officers are not restricted to a particular anatomic site or morphological type.

With regard to exposures to herbicides and the contaminant TCDD (dioxin), an increasing trend within Ranch Hand flying officers is not expected because TCDD assay results in living Ranch Hands show that Ranch Hand flying officers were among the least exposed of all Ranch Hand personnel, with the heaviest exposures occurring in nonflying enlisted personnel.

The observed statistically significant increasing trend in the SMR among flying officers is of concern and emphasizes the importance of continued mortality surveillance. However, it appears to be due to recent elevations in Ranch Hand circulatory and malignant neoplasm death rates with no apparent pattern by anatomic site or morphology among those deaths due to malignant neoplasm. If herbicide exposure were having a direct effect on malignant disease, one would anticipate a clustering by site or type of cancer. Thus the implication of these observations is as yet unclear. Further, the trend is not expected relative to known TCDD body burdens among living Ranch Hands currently being assayed. The finding therefore remains unexplained at this time. The analyses shown in Tables 28 and 29 will be repeated in the next mortality report.

A lexis diagram of Ranch Hand officer deaths by age and calendar year period is shown in Figure 11. Follow-up time is indicated for each subject with a straight line beginning at his age and the beginning of his first qualifying tour and ending at his age at 31 December 1987 if he was still alive at that time. Follow-up lines for deceased subjects end with a box at the subjects age at death and date of death. The corresponding diagram without the follow-up lines is shown in Figure 12. Lexis diagrams for enlisted, flying and nonflying personnel, without follow-up lines, are shown in Figures 13 through 15.

Lexis diagrams provide another view of the data that permits a visual assessment of mortality clustering with respect to age and calendar time. A strong latency effect, for example, might be revealed by a cluster of deaths approximately 20 years after entry into follow-up. No such clusters are apparent in these data.

Figure 11

Lexis Diagram
Ranch Hand Officers