Monitoring Data Sufficiency -Appendix 1 for SEC-00028

Performing internal and external dose reconstructions requires worker monitoring data. Worker monitoring data includes data from members of the proposed class as well as data from workers outside the proposed class who were performing jobs with higher exposure potentials. Using worker monitoring data provides a means of calculating claimant-favorable and maximum potential radiation doses for class members who were unmonitored or have gaps in their monitoring records.

Calculating claimant-favorable and/or maximum potential radiation doses for unmonitored employees is only possible through sufficient data. Data sufficiency is determined through appropriate sampling, which involves choosing the correct monitoring locations and personnel with the highest exposure locations and activities, appropriate analytical techniques, and record keeping. In addition to sampling, analytical techniques, and record keeping, it is important to evaluate the exposure potential associated with activities that were non-production oriented, new, and/or short-lived, such as research and development activities.

In addition to the sampling, analytical, and record keeping information, NIOSH also evaluated other documentation related to Y-12. Historical Y-12 documents include detailed information about monitoring devices, sampling techniques, and analytical methods. In addition to historical document resources, further information supporting the adequacy of monitoring devices, sampling techniques, and analytical methods is presented in the Y-12 Site Profile (ORAUT-TKBS-0014-2 Rev. 00; ORAUT-TKBS-0014-6, Rev. 00; ORAUT-TKBS-0014-1, Rev. 00; ORAUT-TKBS-0014-3, Rev. 00; ORAUT-TKBS-0014-5, Rev. 01-A) and in *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 1 and 2* (ORAU Technical Report 2004-0888; ORAU Technical Report 2004-1406). The Y-12 Site Profile and in the *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee*: *Part 1 and 2* includes information supporting the proposition that activities and personnel associated with the highest exposure potentials were regularly monitored.

Documentation supports NIOSH findings that activities and personnel associated with the highest exposure potential were regularly monitored. However, given the importance of verifying coworker data sufficiency, NIOSH performed additional activities to verify data sufficiency; these additional activities focused on historical monitoring selection and data credibility and have been included in this evaluation. The additional data sufficiency verification activities included:

- Retrieval and review of Health Physics Progress Reports and additional monitoring related documents
- Interviews with plant workers employed during the subject timeframe
- Credibility, validity, and representativeness of data
- Statistical analysis of available personal monitoring data

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Table of Contents

Tables

Figures

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Monitoring Data Sufficiency –Appendix 1 for SEC-00028

1.0 Y-12 Health Physics Progress Reports

The Health Physics Progress Reports' general content and purpose are summarized in Section 4.0. The Y-12 Health Physics Progress Reports reflect an established Health Physics Program that was state-of-the-art and continually developing. Examination of the monitoring performed indicates a departmental effort to measure process and personal exposures associated with activities having the highest exposure potential at Y-12. Based on the Y-12 program information identified during document reviews, compliance with applicable standards was emphasized. Additional types of supporting information and documentation include personnel sampling protocols, Health and Safety/Health Physics procedures, personnel training, and recommendations made to increase worker safety (e.g., increased ventilation, personal protective equipment use, or new shielding requirements).

As indicated from the Y-12 Health Physics Progress Reports, all areas and activities were monitored on some frequency; production areas and specific jobs well known for exposure potential (see Section 5.0 of the Y-12 Evaluation Report, SEC-00028) were monitored constantly. The monitoring results for employees associated with known high exposure potential jobs were routinely documented in the reports. Contamination and exposure potentials associated with new and/or short duration research and developmental type activities were also assessed and documented. Long-term, non-uranium production activities such as the cyclotron work were given regular attention within the monitoring program and progress reports (see Section 5.0 of the Y-12 Evaluation Report, SEC-00028). The Y-12 Health Physics Progress Reports also clearly show that training and orientation sessions were provided by the Health Physics Department for all associate employees.

Information contained within the Y-12 Health Physics Progress Reports shows that monitoring was performed for Y-12 activities involving the highest exposure potentials for production operations and non-production research and development activities. This supports the assumption that it is appropriate to use the resultant monitoring data in the evaluation/calculation of maximum exposure potentials for the proposed class of Y-12 workers in this evaluation. It is notable, however, that the reports record recurrent elevated contamination levels associated with certain operations despite recommendations for engineering and/or operational control changes. This situation reflects organizational responsibilities in effect at the time; production supervisors and department heads ultimately possessed the authority for making decisions regarding implementation of the health physicists' recommended changes. While failures to expedite production refinements to minimize exposure potentials may have lead to increased doses to certain workers, the sufficiency of the monitoring data for calculating maximum possible doses received is not affected.

2.0 Y-12 Employee Interviews

NIOSH conducted interviews with former Y-12 Plant employees. The interview process included a short introduction to the EEOICPA process and the SEC-00028 Evaluation Report effort. Each person interviewed was asked to focus on Y-12 and the 1948 through1958 time period. Interview discussion was focused on the personnel monitoring selection process as well as determining how focused the program was on overall worker safety. Interviews conducted with the analytical laboratory employees focused on the quality control measures used at Y-12 and the handling of analytical data. Other

interviews were held specifically to gain knowledge of weapons assembly/disassembly operations during the proposed class time period.

In general, the employee interview responses were similar among those interviewed and to the information contained within the Y-12 Health Physics Progress Reports. The employee interview results also support the concept that it is appropriate to use the available monitoring data in the evaluation/calculation of maximum exposure scenario doses for proposed class of Y-12 workers in this evaluation. The health physicists interviewed were adamant that:

- Highest exposure activities were determined and carefully monitored (areas and employees)
- Expected clean areas (e.g. hallways, break areas) were routinely surveyed for contamination
- New, developmental, and/or research oriented work was always approached very cautiously and monitored thoroughly

Other interview results include:

- Of the employees interviewed that could remember, each stated that respirator use was required and implemented for specific
- One supervisor recalled that failure to use respirators when required was subject to reprimand
- With the exception of a single employee interviewed, all said that eating, drinking, and smoking was allowed only in designated areas
- Most of the workers interviewed recalled that containing contamination was a constant problem— Workers were constantly cleaning in an attempt to limit the spread of contamination
- Essentially, all interviewed remembered a management level (Carbide) emphasis on workplace safety— Regular safety meetings were held where workplace hazards were discussed and lost time accidents were reviewed

Many of the people interviewed confirmed the organizational responsibilities outlined in the Health Physics Progress reports as well as other reports. These generally included:

- Supervisor's were responsible for implementing safety requirements
- Health Physicists reported contamination and potential exposure readings and subsequently provided direction to supervisors regarding needed process changes, shielding, and respirator use e

3.0 Credibility, Validity, and Representativeness of Data

For this petition evaluation, NIOSH reviewed all of the available exposure data for Y-12 and then focused on key sets of exposure data to determine if those data are adequate for completing individual dose reconstructions for all members of the class. As such, the "credibility", "validity", and "representativeness" of the data sets must be determined. Based on a premise that members of the proposed class could have been associated with many, if not most plant activities, key data sets are defined as those required to assess sources of exposure and internal and external monitoring data for workers involved. The following discussions pertain to the available monitoring data with a focus on internal and external monitoring records from during, and soon after the proposed class time frame.

Credibility and validity of the data has been has been assessed by examining the following data characteristics:

- "Pedigree" of the data
- Original Y-12 methodology used to obtain the data

- Internal consistency of the data

These three aspects of the data set evaluations are discussed individually in the subsections that follow.

Assessments and discussions pertaining to the representativeness of key data have already been performed and presented in this report in Sections 5.0, 6.0 and 7.0. To complete the assessment, data sets were reviewed in terms of:

- The areas of the facility represented
- Application to the proposed class time period
- Types of workers and processes covered
- Quantity and representativeness of the highest exposed workers

Results of the assessments are that the available key data are sufficiently representative of the proposed class being evaluated and therefore appropriate for use in the calculation of radiation doses for members of the class.

3.1 Pedigree of the Data

NIOSH reviewed all of the available Y-12 exposure data to determine if the data are adequate for completing individual dose reconstructions for all members of the proposed class. Examination of the monitoring data "pedigree" involves determining the intent of the original exposure evaluations, the relation of the exposure monitoring to documented activities at the site during the proposed class time period, and the history of the data set(s) being used. As part of the data set history investigation, NIOSH must ensure that if secondary (not original) sources of data are used, these data are consistent with the original data set.

The intent of the Y-12 Health Physics Program was well documented. It is clear that the focus of the program was to determine and monitor all potential exposure areas and activities within the plant, minimize exposure potentials, and document compliance with applicable standards. This is evidenced by information available in a multitude of memos that have been obtained and reviewed (see Section 4.0), Health Physics Progress Reports (see sections 4.8, 6.5, and 1.0 above), and from worker interviews (2.0, above). NIOSH has obtained no information from any of the aforementioned sources that would indicate the Y-12 Health Physics program failed to adequately monitor known, or new/potential sources of exposure. Furthermore, NIOSH has no indication that results of these monitoring efforts were not properly documented and/or recorded in the monitoring records.

The history of the Center for Epidemiological Research (CER) data is also well known. The monitoring data contained within this CER database are a direct copy of the Y-12 Health Physics routine Monitoring Program record and is absolutely consistent with the original data. Information and data associated with non-uranium sampling and other non-routine activities at Y-12 are stored within the Delta View Imaging System (Section 4.8). Discussions with Y-12 personnel indicate that the Delta View system is used to ensure the capture of analytical results separate from those associated with the more routine processing activities. The Delta View Database resides with and is maintained by Y-12. Like the CER Database, the Delta View Database also represents original data. Copies of these data are available to NIOSH as needed and/or requested.

3.2 Methodology

Recognizing that radiation monitoring and analytical methods have varied significantly from site to site and over time, NIOSH evaluated the documented methodologies underlying the data (as available) to determine the data's suitability for dose reconstruction. This evaluation included assessing whether reliable corrective estimation procedures have been applied to the data and if so, whether or not they were appropriate.

Extensive documentation produced and preserved by the Y-12 Health Physics Department has allowed NIOSH to successfully accomplish the monitoring methodology assessment. Much of the information directly affecting data quality has been obtained, compiled, and summarized in the following documents:

- *TBD for the Y-12 Plant – Occupational Environmental Dose*, ORAUT-0014-4; October 11, 2005
- *TBD for the Y-12 Plant – Occupational Internal Dose*, ORAUT-0014-5; February 14, 2006
- *Technical Information Bulletin: External Radiation Monitoring at Y-12 During 1948-1949 Period, Rev. 01*, ORAUT-OTIB-0047; September 20, 2005
- *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 1—Gamma Radiation*

The types of information available from the proposed class time frame include radiation and analyte-specific sampling techniques, sampling devices used, sampling frequency, minimum detection limits, uncertainty and interferences, and calculations/conversions performed. Changes that occurred within these parameters over time have also been captured and presented in the abovementioned Y-12 documents.

In addition, available documentation describes a monitoring program that was continually improving. Despite its evolutionary nature, the sampling and measurement methodologies used at Y-12 from 1948 through 1957 represented the state of the art for the time. Y-12 correspondence describes frequent collaboration with ORNL and many other AEC facilities and Universities (e.g. University of Rochester) in their continued efforts to develop and improve external and bioassay monitoring methodology and procedures. Additionally, references to the use of National Council of Radiation Protection (NCRP) standards, AEC orders for exposure limits and other regulatory/administrative limits and control measures are prevalent in Y-12 documents, as are documentation regarding "special studies" which were conducted to test and improve methods being used.

NIOSH has concluded that sampling and analytical methodologies used during the proposed class timeframe produced data sufficient for use in dose reconstructions. Required adjustments resulting from method uncertainties are necessary to ensure that claimant-favorability have been documented in the abovementioned documents and in:

- *Technical Information Bulletin: Individual Dose Adjustment Procedure forY-12 Dose Reconstruction*, ORAUT-OTIB-0013
- *Technical Information Bulletin: Internal Dosimetry Coworker Data for Y-12*, ORAUT-OTIB-0029

3.3 Data Consistency

Evaluating data consistency involves comparing monitoring data references and primary data repositories. NIOSH has compared monitoring data references and primary data repositories as a spot check for data handling errors. Data handling errors include errors associated with transcription, data entry, and record maintenance. Data consistency was examined by comparing:

- Individual external monitoring results presented on documents captured within the Delta View imaging system were compared to results maintained in the Y-12 electronic record
- The number of urinalysis samples reported in Y-12 Health Physics Progress Reports were compared to the numbers of data records present in the Y-12 electronic record
- Monitoring result values reported in Y-12 Health Physics Progress Reports were compared to the Y-12 electronic record
- Uranium urinalysis results that were hand written on individual analytical record "punch cards" were compared to the Y-12 electronic record

3.3.1 Reported Analysis Totals and General Data References

A comparison of the number of uranium urinalyses performed as cited in the Health Physics Progress Reports to the number of urinalysis results contained in the CER Database indicates that there were typically more urinalyses reported than results entered into the Y-12 Electronic Record. However, interviews with two laboratory workers revealed that to their knowledge, it was always standard analytical procedure to include many additional quality control analyses such as blanks, standards, and matrix spikes. It was likely that these types of analyses were included in the totals cited in the reports, but not in the individual monitoring record. Additionally, interviews revealed that analysts would frequently perform more than one analysis (same and/or different analytical technique) from an individual sample as a quality control check. Unexpected discrepancies would warrant even more analyses and/or re-sampling. For example, one uranium urinalysis technician stated that during his two year tenure at Y-12, his routine procedure included performing fluorometric and gross alpha methods on nearly all samples as a quality control check to make sure potential exposures were not being missed.

Comparisons of external monitoring data also showed discrepancies between the number of film badges processed as recorded in the Y-12 Health Physics Progress Reports and the number of film badge results present in the Y-12 Database. These differences are due to the frequency of the exchange and processing activities.Y-12 summarized the film badge readings stored in the database into quarterly readings while the actual film badge exchange and processing rate was much more frequent: weekly in the early 1950s.

3.3.2 Reported Urinalysis Results

For the most part, Y-12 Health Physics Progress Reports report monitoring results in general terms that describe groups of workers. The Y-12 Health Physics Progress Report data are generally presented as ranges of exposures for workers and stress compliance with applicable standards. Therefore, the Y-12 Health Physics Progress Reports provide only limited opportunities for direct comparisons to individual monitoring results contained in the Y-12 Database. However, several data comparisons possibilities were identified. Results of these comparisons are described below.

Averaged uranium urinalysis results for the month of October 1953 were located for 22 Y-12 workers in a classified November 13, 1953 Y-12 Health Physics Progress Report. These results were compared to the Y-12 Database and the results are presented in Table 3-1.

With one exception, averages of results in the Y-12 record were identical to the average weekly excretion rates reported in the Y-12 Health Physics Progress Report. For one worker, worker # 13, three results were found in the Y-12 Database with values of 157, 152, and 2. The results of 152 and 2 were recorded for the same day. The average dpm/24hr for all three values is 104; excluding the 2 dpm/24 result yielded an average of 155, as reported in the November 13, 1953 Y-12 Health Physics Progress Report. It is assumed that the authors of the 1953 report decided it was appropriate to not use the questionably low result in their summary. Serving as the official record, it would be expected that the questionable result remain part of the Y-12 Database.

	Table 3-1: Headings and Data as Presented in Health Physics Report[1]			**Y-12 Database Results for October 1953 (Averaged)[3]**
Individual	**Number of Analyses During October**		**Average of Weekly Excretion Rates d/m/24hrs**	
1	2	2	212	212
2	2	2	167	167
3	2	2	736	736
4	2	2	127	127
5	2	2	110	110
6	2	2	101	101
7	3	2	89	89
8	2	2	143	143
9	3	2	88	88
10	3	2	88	88
11	2	2	181	181
12	2	2	210	210
13	2	2	155	104
14	3	3	241	241
15	2	2	110	110
16	1	1	458	458
17	2	2	78	78
18	2	2	126	126
19	3	2	344	344
20	2	1	2,100	2,100
21	3	1	199	199
22	2	1	352	352

Notes:
[1] It should be noted that data points were not individually labeled on the Health Physics Progress Report graphs. Therefore, minor transcription errors are inherent with the data interpretation process.
[2] Maximum Permissible Limit
[3] Results in dpm/24hour voiding

In addition to the individual monitoring results comparison, another comparison was made that graphed weekly 50th, 75th, and 90th percentile monitoring results reported in a July through December 1952 Y-12 Health Physics Progress Report. The 1952 Health Physics Progress Report was compared against weekly percentiles calculated from the Y-12 Database for the same July through December 1952 time period. The following table, Table 3-2, presents the results of the comparison.

Table 3-2: July- December 1952 Comparison of Percentiles Reported in Y-12 HP Reports Versus Percentiles Calculated from Y-12 Database[1]

	Percentiles					
	50th		75th		90th	
Week	HP Report July-December 1952	Y-12 Database	HP Report July-December 1952	Y-12 Database	HP Report July-December 1952	Y-12 Database
31	17	16	30	30	30	45
32	16	16	31	31	46	48.5
33	9.4	8	18	16	47	31
34	9	8	21	17	29	29
35	13	13	26	24	39	37
36	14	16	29	30	51	51
37	18	16	34	36	60	72
38	14	15	31	25	41	43
39	13	12	30	26.5	43	46
40	16	14	40	30.5	55	57
41	13	14.5	31	24.5	48	46
42	39	35	62	61	93	98
43	20	20	33	32.5	63	64
44	19	19	35	38	70	75.5
45	21	20	39	37	63	65
46	17	16	32	32	70	61
47	19	21	34	36	64	64
48	16	16.5	28	28	60	66
49	12	12	25	25	50	51
50	15	16	23	39	53	57
51	13	16	26	29	41	52
52	20	20	24	43.5	91	97

Note:
[1] Comparison of DPM/24 hours
DPM= disintegrations per minute

Results listed in Table 3-2 show that the monitoring results calculated from the Y-12 Database are consistent with those displayed graphically within the Y-12 Health Physics Progress Reports.

Two additional comparisons were performed using the Y-12 Health Physics Progress Reports. First, the January 1, 1952 through July 1, 1952 Health Physics Progress Report made reference to a percentage of urinalysis samples exceeding the maximum permissible limit (MPL) of 70 dpm/24 hour voiding (disintegrations per minute per 24 hour voiding period) and to a maximum urinalysis result (February 19, 1953). Page 30 of the January 1, 1952 through July 1, 1952 Health Physics Progress Report contains the following statement:

> "To date, 10 to 30 per cent of the total number of urine samples analyzed for enriched uranium have exceeded the MPL of 70 d/m/24-hour voiding. Efforts to decrease this number….."

It is assumed that the range of above-MPL results reflects the range of weekly or monthly assessments made within the six-month summary report period. Examination of the electronic record yielded a result of 18 % of the results for the six-month period being above the MPL.

Second, the November 1, 1950 through December 31, 1950 Y-12 Health Physics Progress Report stated that the highest excretion level of (enriched) uranium was 795 dpm/24hr. Querying the

electronic database for the highest uranium result for the same time period yielded the same result, 795 dpm/24hr.

3.3.3 Punch Cards Data Comparison

Data consistency was further examined by comparing data recorded on IBM punch cards to the Y-12 Database. The punch cards were used to record Y-12 employee monitoring information for decades. Interviews with Y-12 employees indicate that punch cards might have been used as early as 1948, but were certainly used as far back as the early 1950's. The cards were prepared with worker identification data and accompanied an individual's bioassay sample to the analytical laboratory. Sample information details were commonly recorded by hand directly onto the punch cards during the time of analysis. Typical identification-type information included on the punch cards included worker ID, sample date, sample volume, time interval, and work department. Also included and written directly on many of the punch cares was raw analytical count data.

Although to date, NIOSH has been unable to locate punch cards corresponding to the 1948 through 1957 time period, punch cards containing hand written sample details and analytical counts were located for analyses run in the mid-1970s. These later period punch cards were then used to check the consistency of the Y-12 Database in terms of the flow of data from the laboratory to its final entry into the Y-12 Database.

Thirty six punch cards containing worker identification, sample details, and raw analytical count data were selected for comparison to the Y-12 Database. The names, identification numbers, and sample information such as void times, sample size, and sample dates listed on the punch cards corresponded precisely with information stored in the Y-12 Database for all 36 cards. Comparing the raw analytical count data present on the punch cards to corresponding final results recorded in the Y-12 Database requires the application of a well documented mathematical algorithm. The mathematical algorithm requires sample specific parameters and analytical conditions. However, variables specific to analytical runs such as background measurements and plating recovery were not present on the punch cards, thus preventing a direct comparison of the data. Nevertheless, using plating recoveries and background numbers described as "typical" or "desired" from available Y-12 literature (McLendon, 1963) in the algorithm and then applying the numbers to the punch card data yielded results very close to the Y-12 Database.

3.3.4 External Monitoring Results

The consistency of external monitoring data was checked by comparing individual weekly monitoring results to quarterly and yearly results contained within the Y-12 Electronic Record. The weekly results were obtained from summary sheets maintained in the Delta View imaging system. Over 1,000 Delta View images were reviewed and resulted in a compilation of a nearly complete set of 1953 weekly results for 28 Y-12 employees. Of these 28 individuals identified, 12 had at least one positive weekly result. Querying theY-12 Electronic Database for records associated with the 28 identified workers yielded positive results for the same subset of 12 workers.

The following table, Table 3-3, compares the sums of the 1953 weekly Delta View results to sums of the quarterly results recorded in the Y-12 Electronic Database. Given the errors associated with this comparison, as described below the table, the data compare favorably and indicate strong consistency. Delta View beta results are identical to those recorded in the Y-12 Electronic Database for all but two

individuals for which the Electronic Database record is higher. These two discrepancies in the beta results could be caused by one or more of the errors described below Table 3-3.

Gamma results also compare favorably provided that the indicated 50mrem detection limit is added into the Delta View total. Similar to the beta results, it appears that the discrepancies are likely caused by the known errors listed below.

Table 3-3: Comparison of Delta View Results to Y-12 Database Results

Individual	DV Beta[1]	DB Beta[2]	DV Gamma[3]	DV + 50/*[4]	DB Gamma[5]
1	0	0	226	336	238
2	325	725	570	2,620	2,694
3	66	66	745	2,695	2,866
4	0	0	120	2,300	2,640
5	0	0	0	2,250	2,486
6	58	58	811	2,711	2,854
7	0	0	120	2,420	2,562
8	50	50	220	1,770	1,998
9	0	0	52	952	921
10	0	0	0	1,800	1,986
11	349	379	2,388	3,488	3,026
12	0	0	0	2,300	2,586

Notes:
[1] Delta View beta results – totals of the real numbers only
[2] Database beta results – totals of the four 1953 quarters
[3] Delta View gamma results – totals of the real numbers only
[4] Delta View real number gamma results plus 50 mrem for each * present (as denoted on the Delta View data sheets)
[5] Database gamma results – totals of the four 1953 quarters

Known errors/uncertainties inherent with this evaluation are as follows:

1. Each weekly summary consisted of names typed onto a table spanning two pages. Examining the images in the sequence provided by the Delta View system indicated a logical sequencing of a given week's first page with its respective second page. However, only the first page contains the date, therefore it is impossible to be certain that the second page of names is actually from the correct week.
2. Some of the results were very difficult and/or impossible to read. Best judgment was used in the data entry process.
3. Weeks "1" and "32" were missing, weeks "53" and "54" (an overlap into the next year) were partial - the second page of results could not be found.

4.0 Statistical Analysis of Monitoring Data

Analyses of external monitoring data were performed to further investigate the assertion that individuals selected for external monitoring prior to 1961 were workers with the highest exposure potential. In general, comparisons were made between pre-1961 monitoring data sets and 1961-1979 data sets. Personal external monitoring coverage prior to 1961 peaked out at approximately 20 % of the workforce. However, monitoring program changes implemented in 1961 resulted in essentially the entire workforce being monitored. This program change allows for exposure level comparisons

between the two time periods on a departmental and individual basis. Increases or decreases in exposure levels between the two time periods can then be used to support or refute the assertion that the highest exposure activities and personnel prior to 1961 were targeted for monitoring.

The following analyses were performed:

1. An examination of job titles and duties for two groups of workers selected regularly for monitoring before 1961 and used for regression analysis
2. Analysis of modified boxplots presenting distributions of beta and gamma doses prior to and after 1961
3. Analysis of beta and gamma doses by departments
4. An investigation of gamma doses in 1960 for workers with a quarterly doses greater than 10% of Radiation Protection Guidelines in 1961
5. Maximum internal and external monitoring results were compared between class members (plumbers, pipefitters and steamfitters) and non-class members with the job titles based on the gamma dose regression group and the beta dose regression group

4.1 Job Type Analysis of Y-12 Workers Selected for Regression Analysis

Members of the gamma dose and beta dose regression data groups were long-term employees of Y-12 who had been monitored regularly. Therefore, an analysis of their jobs provides insight into the types of workers who were selected for monitoring before blanket monitoring became policy in 1961. Because both groups had selection criteria that included regular monitoring before 1961 when fewer than 20% of the workers were generally monitored during any given year, there was necessarily an overlap of individuals between the two groups. Of the 147 gamma group members and the 182 beta group members, there were 113 individuals common to both groups.

Using a work history database acquired by ORAU from Y-12, all job titles with corresponding dates were obtained for each of the two groups of workers (ORAU Technical Report 2004-0888). Frequently, multiple job titles for an individual showed a progression of promotions as skills and seniority were gained. A recurring example was the progression from machine operator to specialty machinist to machinist and, occasionally, to supervisor of machining. For each individual in each group, the job held during the majority of the 1956 through 1960 time period was selected. This job was classified by type of activity (e.g., machining) and duties (worker, foreman, supervisor, or manager).

4.1.1 Gamma-Dose Regression Groups

The gamma dose regression group consisted of 147 Y-12 workers who had been monitored regularly both before and after 1961. The group was selected to investigate whether gamma dose potential in the earlier years was higher than in later years of the film badge period. Each of these 147 workers satisfied the criteria of possessing four quarters of gamma dose records per year for at least five years during each of the two time periods 1952 through 1960 and 1961 through 1970. The 5,686 quarterly doses for these workers between 1956 and 1965 were used for a regression analysis, the results of which were available for inferring gamma doses for unmonitored quarters before 1956 (ORAU Technical Report 2004-0888).

Table 4-1 presents the results of the job analysis for the gamma dose regression group. Among the 147 employees, 129 (88%) were involved in performing tasks that involved no management or supervisory components. Most of these 129 were machinists, chemical or production operators, or fire and security workers. Another 14 (10%) members of this group carried out some supervisory tasks, such as fire captains, laboratory, inspection, or production supervisors, or foreman. The foreman likely had similar exposure potential as their workers, and the supervisors may have had somewhat similar exposure as the workers they were supervising. Only four (3%) of the 147 individuals were managers, including one superintendent of utilities, one shift superintendent, and two assistant shift superintendents.

Table 4-1: Job Activities and Duties for 147 Long-Term Y-12 Workers Selected for Regression Analysis of Gamma Doses

Activity	Duties	Number of Workers
Fire and Security	Supervisor	5
Fire and Security	Worker	14
Inspection	Supervisor	1
Inspection	Worker	6
Laboratory Work	Supervisor	3
Laboratory Work	Worker	6
Machining	Worker	71
Management	Manager	4
Medical	Worker	1
Production	Foreman	4
Production	Supervisor	1
Production	Worker	28
Production Support	Worker	2
Research and Development	Worker	1

4.1.2 Beta-Dose Regression Groups

The beta dose regression group is a set of 182 Y-12 workers who had been monitored both before and after 1961 and worked in departments with beta-particle exposure potential. Members of this subgroup provided 4805 quarterly doses and had at least four quarterly film badges after 1960 and at least 24 before 1961. These quarterly doses provided the basis for a regression analysis the results of which can be used to estimate quarterly beta dose distributions for unmonitored quarters before 1956.

The table below, Table 4-2, presents the results of the job analysis for the beta dose regression group. Among the 182 employees, 156 (86%) were involved in performing tasks that involved no management or supervisory components. Most of these were machinists, chemical or production operators, or fire and security workers. Another 23 (13%) members of this group carried out some supervisory tasks, such as fire captains, laboratory, inspection, or production supervisors, or foreman. The foreman likely had similar exposure potential as their workers, and the supervisors may have had somewhat similar exposure as the workers they were supervising. Only 3 (2%) of the 182 individuals were managers, including one shift superintendent and two assistant shift superintendents.

Table 4-2: Job Activities and Duties for 182 Long-Term Y-12 Workers Selected for Regression Analysis of Beta Doses

Activity	Duties	Number of Workers
Crafts	Foreman	5
Fire and Security	Supervisor	5
Fire and Security	Worker	16

Table 4-2: Job Activities and Duties for 182 Long-Term Y-12 Workers Selected for Regression Analysis of Beta Doses

Activity	Duties	Number of Workers
Inspection	Supervisor	1
Inspection	Worker	9
Laboratory Work	Supervisor	4
Laboratory Work	Worker	5
Machining	Worker	65
Management	Manager	3
Medical	Worker	1
Production	Foreman	7
Production	Supervisor	1
Production	Worker	43
Production Support	Worker	17

4.2 Analysis Using Modified Boxplots

A modified version of a box plot was used to summarize the gamma and beta film badge doses. For each quarter the Kaplan-Meier (K-M) product limit estimate (PLE) of the empirical distribution function was calculated as described in Frome and Watkins.

A large number of the doses were recorded as zero. Each dose recorded as zero was treated as a left censored value at a detection limit of 30 mrem. The PLE adjusts for non-detects, which occurred in most of the quarters. A conventional boxplot is obtained by calculating the 25th quantile, xq25, and the 75th quantile, xq75, which define the ends of the box that contain the central 50 percent of the data. A modified boxplot is obtained by calculating the 25th and 75th quantiles using inverse interpolation from the PLE to take non-detects into account.

Large "outliers" for each quarter are identified by calculating the value of xq75 + 1.5*(xq75 - xq25), and all data points that exceed this value are shown in the box plot by a separate symbol, such as a “+”, for each outlier. Small "outliers" are identified by calculating the quarterly value of xq25 - 1.5*(xq75 - xq25), and all positive data less than this value are shown separately in the boxplot. The modified boxplots in this report show xq25 as a blue inverted triangle and xq75 as a green triangle, and the box connecting these quantiles is not drawn. The maximum dose is shown as a red circle, and the minimum dose is a red diamond when no left censored data were present. Each dose in a quarter that exceeded (on log scale) log(xq75) + 1.5*[log(xq75) - log(xq25)] is shown as a black plus sign (+) . All data points in a quarter that are less than (on log scale) log(xq25) - 1.5*[log(xq75) - log(xq25)] are also shown as plus signs, although these may be incomplete when there were a large number of zero doses. The percent zeros, percent positive outliers, number of film badge readings, and censoring adjusted K-M means are shown as part of the modified boxplot.

The adjusted cumulative dose is an estimate of the total dose adjusted for non-detects (zero doses), and is obtained by multiplying the K-M mean by the number of doses, i.e., cdosea=n*kmm. An estimate of missed dose (for monitored workers) is obtained by subtracting the cumulative dose from the adjusted cumulative dose.

4.2.1 Modified Boxplots for Gamma Dose

Each of the 426,621 beta doses recorded for Y-12 workers from 1952 to 1979 had a corresponding gamma dose for the same individual in that quarter. Because workers were selected for external dose monitoring before 1961 based mainly on potential exposure to beta particles, the gamma dose records contained a larger number of non-detects recorded as zeros or assigned the MDL (ORAU Technical Report 2004-0888).

Table 4-3 provides the summary statistics for all recorded gamma doses from 1952-1979. These statistics were used to produce the modified boxplot for Figure 1a. Plots with additional summary information by quarter are provided in Figure 1b.

Table 4-3: Product Limit Estimate Summary Stats for Y-12 Quarterly Gamma Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
52 Q1	111.7	9.8	24.9	48.6	84.1	825	0.902	21,151	23,010	30.1	7	206
52 Q2	360.8	18.6	21.3	485.4	593.9	1,702	2.466	88,616	91,282	35.2	0	253
52 Q3	392.6	15.9	28.2	412.0	623.0	1,945	2.295	118,466	120,921	26.6	0	308
52 Q4	294.0	15.7	15.9	138.0	558.6	2,174	2.638	108,027	113,484	47.2	0	386
53 Q1	503.0	21.6	394.6	638.0	648.2	1,066	0.368	73,034	73,941	20.4	0	147
53 Q2	454.1	32.2	64.1	598.1	692.5	3,601	1.765	70,245	71,294	22.3	0	157
53 Q3	531.3	38.1	24.6	658.1	704.1	3,834	2.486	78,851	80,226	30.5	0	151
53 Q4	240.4	21.6	11.5	23.0	494.5	4,901	2.789	73,747	80,294	65.3	0	334
54 Q1	176.8	19.2	10.1	20.2	110.0	3,279	1.772	51,293	58,698	74.4	0	332
54 Q2	334.5	46.1	12.4	24.8	590.0	5,629	2.863	64,846	68,572	60.5	0	205
54 Q3	259.6	30.6	11.2	22.4	441.7	2,915	2.723	48,387	52,439	66.8	0	202
54 Q4	113.5	12.6	8.5	16.9	25.4	3,062	0.814	43,231	56,410	88.5	55	497
55 Q1	54.8	3.7	8.6	17.1	25.7	840	0.814	14,964	28,770	87.6	52	525
55 Q2	116.0	9.4	9.2	18.3	27.5	1,987	0.814	48,008	60,900	81.9	83	525
55 Q3	91.6	10.3	9.4	18.9	28.3	1,732	0.814	42,831	42,869	79.3	79	468
55 Q4	111.1	12.6	9.7	19.3	29.0	2,000	0.814	44,150	44,218	77.1	80	398
56 Q1	67.1	5.6	17.7	24.3	44.0	1,207	0.674	22,629	30,061	71.2	58	448
56 Q2	54.0	5.1	17.8	21.8	35.0	1,456	0.500	20,628	26,568	57.5	53	492
56 Q3	82.8	5.0	11.9	35.5	90.8	1,229	1.507	47,537	51,088	40.4	0	617
56 Q4	155.5	6.2	35.0	103.0	246.5	955	1.447	94,559	96,410	19.5	0	620
57 Q1	118.7	3.6	60.4	108.5	160.9	654	0.726	67,018	67,066	10.3	0	565
57 Q2	77.8	4.5	16.5	31.7	94.5	835	1.292	43,388	46,291	29.1	0	595
57 Q3	82.8	5.3	13.8	28.4	92.7	1,219	1.411	51,771	55,310	32.3	0	668
57 Q4	40.8	2.3	17.2	21.1	30.7	695	0.433	19,691	27,662	57.2	79	678
58 Q1	67.3	2.8	21.5	36.2	87.5	660	1.039	43,686	47,379	25.1	0	704
58 Q2	145.1	5.9	27.7	95.0	213.5	1,920	1.514	98,587	100,699	15.0	0	694

Table 4-3: Product Limit Estimate Summary Stats for Y-12 Quarterly Gamma Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
58 Q3	149.5	6.1	47.6	114.4	188.5	1,527	1.021	101,176	103,006	13.5	1	689
58 Q4	103.5	3.9	24.6	66.3	144.2	1,170	1.311	77,125	81,558	23.9	0	788
59 Q1	155.1	4.2	68.6	129.0	205.7	1,015	0.815	129,967	130,904	5.2	0	844
59 Q2	69.9	4.5	15.5	35.2	97.3	2,540	1.363	59,686	59,695	43.9	1	854
59 Q3	73.7	2.7	19.1	41.4	98.3	645	1.214	63,420	66,993	23.1	0	909
59 Q4	102.6	3.3	29.1	71.1	139.5	1,290	1.160	103,781	108,038	20.3	0	1,053
60 Q1	66.5	2.6	13.4	28.1	86.0	1,227	1.378	70,910	76,342	27.8	0	1,148
60 Q2	88.3	3.3	21.5	57.3	109.4	1,905	1.207	95,706	97,483	11.1	1	1,104
60 Q3	104.5	2.9	32.9	73.8	152.8	737	1.139	109,523	110,248	4.0	0	1,055
60 Q4	126.7	3.4	44.2	94.8	179.7	685	1.039	123,400	124,800	7.0	0	985
61 Q1	21.2	0.8	3.9	10.5	20.1	1,810	1.210	65,293	112,381	78.3	35	5,301
61 Q2	55.6	0.7	32.2	40.6	57.4	1,276	0.429	306,096	307,190	0.6	267	5,525
61 Q3	31.3	0.8	10.8	18.6	33.3	2,173	0.836	171,408	171,962	1.0	40	5,494
61 Q4	61.3	0.7	34.9	46.7	67.1	1,413	0.484	340,995	341,134	0.1	147	5,565
62 Q1	21.6	0.5	4.9	5.9	20.1	1,050	1.044	120,281	120,593	0.1	52	5,583
62 Q2	62.0	0.8	32.9	44.6	65.3	1,231	0.509	331,680	331,824	0.0	182	5,352
62 Q3	52.0	0.8	22.5	40.4	62.6	1,114	0.758	280,127	280,488	0.2	58	5,394
62 Q4	46.6	0.7	19.5	27.4	52.4	1,018	0.732	247,703	248,238	0.3	46	5,327
63 Q1	24.7	0.7	2.7	5.4	27.3	1,187	1.721	105,379	134,763	58.3	2	5,456
63 Q2	26.5	0.6	10.4	15.0	19.5	1,518	0.467	99,473	146,704	56.7	602	5,536
63 Q3	26.3	0.9	0.9	5.4	25.5	1,315	2.461	108,221	145,939	66.4	0	5,549
63 Q4	21.6	0.4	10.4	15.7	22.6	447	0.576	49,709	117,958	78.4	187	5,461
64 Q1	33.8	0.8	20.9	24.2	25.6	757	0.150	72,041	185,123	82.5	897	5,477
64 Q2	34.7	0.6	23.5	25.5	27.8	1,517	0.126	69,631	184,396	82.7	566	5,314
64 Q3	41.1	0.7	11.4	23.4	46.5	1,077	1.040	209,747	220,296	13.6	11	5,360
64 Q4	24.8	0.7	5.3	12.7	23.8	978	1.106	82,049	127,026	72.6	62	5,122
65 Q1	26.5	0.5	8.1	15.7	30.3	511	0.983	111,109	133,480	35.4	35	5,037
65 Q2	24.1	0.7	3.9	10.6	22.8	691	1.301	87,080	107,823	41.8	17	4,474
65 Q3	26.2	0.7	5.7	12.6	24.0	907	1.066	113,778	113,839	0.0	47	4,345
65 Q4	40.0	0.6	23.6	31.0	38.6	737	0.364	173,468	173,440	0.2	317	4,336
66 Q1	21.3	0.7	2.4	7.6	19.7	543	1.552	67,798	92,293	61.5	5	4,333
66 Q2	28.0	0.8	4.9	11.1	24.4	629	1.195	102,181	121,492	41.0	38	4,339
66 Q3	38.5	0.9	9.1	18.3	37.4	830	1.051	169,574	169,400	0.0	40	4,400
66 Q4	32.5	1.0	6.1	15.0	26.5	1,900	1.096	122,730	145,762	37.5	71	4,485

Table 4-3: Product Limit Estimate Summary Stats for Y-12 Quarterly Gamma Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
67 Q1	25.9	1.3	4.9	10.4	19.9	3,812	1.044	76,794	116,938	76.2	106	4,515
67 Q2	26.7	1.3	5.1	13.3	23.7	5,000	1.134	98,902	123,167	45.3	51	4,613
67 Q3	21.7	0.5	5.3	11.0	22.2	751	1.064	98,485	103,140	8.6	26	4,753
67 Q4	19.2	0.6	4.0	9.0	20.1	1,053	1.199	68,166	92,102	47.3	20	4,797
68 Q1	18.7	1.5	1.6	5.0	15.5	5,000	1.663	81,812	91,331	23.1	6	4,884
68 Q2	57.1	0.8	42.4	49.1	61.0	3,670	0.270	283,443	284,015	1.2	186	4,974
68 Q3	15.2	0.6	4.1	9.9	18.9	751	1.139	22,956	79,222	91.4	16	5,212
68 Q4	40.2	0.4	24.5	38.5	48.3	528	0.503	212,177	212,779	0.7	112	5,293
69 Q1	26.3	0.4	12.5	20.5	31.0	668	0.675	134,360	141,967	8.5	76	5,398
69 Q2	28.0	0.4	11.8	19.7	31.1	392	0.716	147,749	153,048	6.3	92	5,466
69 Q3	40.4	0.7	13.3	23.5	47.9	786	0.950	234,179	239,774	6.7	43	5,935
69 Q4	30.4	0.9	10.3	20.6	31.5	3,288	0.832	170,450	178,813	10.1	87	5,882
70 Q1	32.3	0.6	9.3	20.4	36.1	715	1.002	189,516	194,575	6.2	35	6,024
70 Q2	15.6	0.2	4.7	10.6	18.8	485	1.024	90,148	93,631	5.4	10	6,002
70 Q3	39.2	0.8	16.8	29.1	44.9	3,750	0.728	249,184	255,153	5.7	72	6,509
70 Q4	32.3	0.5	10.5	22.2	33.8	1,197	0.868	196,580	215,506	18.8	93	6,672
71 Q1	34.0	1.8	17.9	20.9	30.9	11,700	0.405	229,838	229,806	0.2	527	6,759
71 Q2	13.5	0.3	3.2	7.3	12.3	525	1.003	76,631	91,220	26.0	106	6,757
71 Q3	34.0	0.4	15.3	27.2	41.1	375	0.730	223,804	225,386	1.3	68	6,629
71 Q4	22.0	0.4	7.8	14.6	24.4	762	0.846	135,543	144,232	9.7	82	6,556
72 Q1	21.9	0.4	8.1	14.0	18.4	852	0.611	124,792	142,898	23.4	382	6,525
72 Q2	17.5	0.4	4.3	10.9	20.1	484	1.150	55,931	112,000	75.3	35	6,400
72 Q3	14.2	0.5	4.0	9.9	18.8	389	1.149	21,047	90,923	92.4	19	6403
72 Q4	15.8	0.5	5.1	11.4	19.8	468	1.011	28,924	97,865	89.6	43	6,194
73 Q1	16.4	0.4	3.4	8.7	17.6	512	1.224	66,793	103,500	58.0	38	6,311
73 Q2	19.5	0.6	7.1	15.5	23.4	650	0.880	38,983	118,209	88.9	54	6,062
73 Q3	17.7	0.4	4.3	9.1	17.4	525	1.039	83,297	104,076	35.2	73	5,880
73 Q4	15.1	0.9	5.4	11.7	21.2	542	1.016	11,442	81,510	96.4	14	5,398
74 Q1	45.2	0.8	11.6	26.3	56.6	856	1.175	235,519	239,470	5.3	5	5,298
74 Q2	19.4	0.5	3.4	8.6	19.8	501	1.303	84,142	103,965	39.6	13	5,359
74 Q3	22.9	0.5	7.6	13.5	22.9	484	0.817	114,266	122,836	13.0	115	5,364
74 Q4	15.3	0.4	3.3	8.8	18.0	343	1.268	42,413	79,774	70.9	8	5,214
75 Q1	16.5	0.6	4.9	8.6	15.5	1,420	0.854	74,796	85,272	20.8	110	5,168
75 Q2	15.1	0.6	3.5	8.7	18.0	972	1.214	26,105	74,247	88.2	16	4,917

Table 4-3: Product Limit Estimate Summary Stats for Y-12 Quarterly Gamma Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
75 Q3	12.7	0.6	2.4	8.1	16.6	297	1.422	13,982	56,934	91.3	1	4,483
75 Q4	11.7	0.5	2.4	6.6	14.1	680	1.316	14,336	53,118	89.4	5	4,540
76 Q1	16.6	0.4	5.8	10.8	18.0	449	0.844	51,882	76,659	44.7	66	4,618
76 Q2	13.1	0.4	2.7	6.6	13.7	487	1.191	26,068	60,326	82.7	24	4,605
76 Q3	19.3	0.4	6.1	11.5	20.0	352	0.877	62,505	88,240	45.9	59	4,572
76 Q4	13.3	0.7	4.2	9.8	19.1	311	1.127	8,298	62,430	95.2	3	4,694
77 Q1	11.6	0.3	3.1	6.6	13.2	670	1.086	25,108	57,223	74.2	19	4,933
77 Q2	11.4	0.3	3.4	7.9	14.9	133	1.093	16,451	57,239	81.2	0	5,021
77 Q3	18.4	0.5	4.7	10.8	19.7	566	1.070	60,666	93,067	53.9	44	5,058
77 Q4	9.5	0.3	2.2	4.9	10.4	656	1.145	19,482	46,569	71.9	25	4,902
78 Q1	9.6	0.3	2.3	4.8	9.4	618	1.046	26,033	48,067	61.3	30	5,007
78 Q2	15.5	0.4	4.7	9.4	16.8	697	0.937	51,821	78,632	50.0	42	5,073
78 Q3	41.0	0.5	21.2	31.7	48.1	553	0.606	204,670	213,282	8.3	73	5,202
78 Q4	9.9	0.3	1.7	4.4	10.8	828	1.358	22,757	52,024	77.4	7	5,255
79 Q1	9.8	0.3	2.3	5.3	11.4	210	1.185	19,325	50,656	77.1	12	5,169
79 Q2	12.2	0.3	2.9	7.6	16.3	383	1.286	21,318	67,246	83.4	1	5,512
79 Q3	17.7	0.6	3.8	10.2	19.1	714	1.203	39,582	91,969	85.6	43	5,196
79 Q4	16.2	0.5	4.5	9.5	18.5	582	1.043	31,283	88,922	87.5	41	5,489

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

The red solid line in the figure below is the geometric mean (GM) of the prediction density used to estimate doses for unmonitored quarters before 1956 (ORAU Technical Report 2004-0888). The horizontal blue line segments mark values of 10% of the Radiation Protection Guidelines. The vertical green dashed line identifies the first quarter of 1961 when all workers were monitored. As was found for the beta doses, there was a distinct drop in the gamma dose distribution once complete monitoring was initiated. This drop can be seen in the 25th, 50th, and 75th percentiles in Figure 1a and in the KM means in Figure 1b. Maximum doses remained constant in the time periods before and after 1961.

Figure 1a: Modified Boxplot for Gamma Doses, 1952-1979

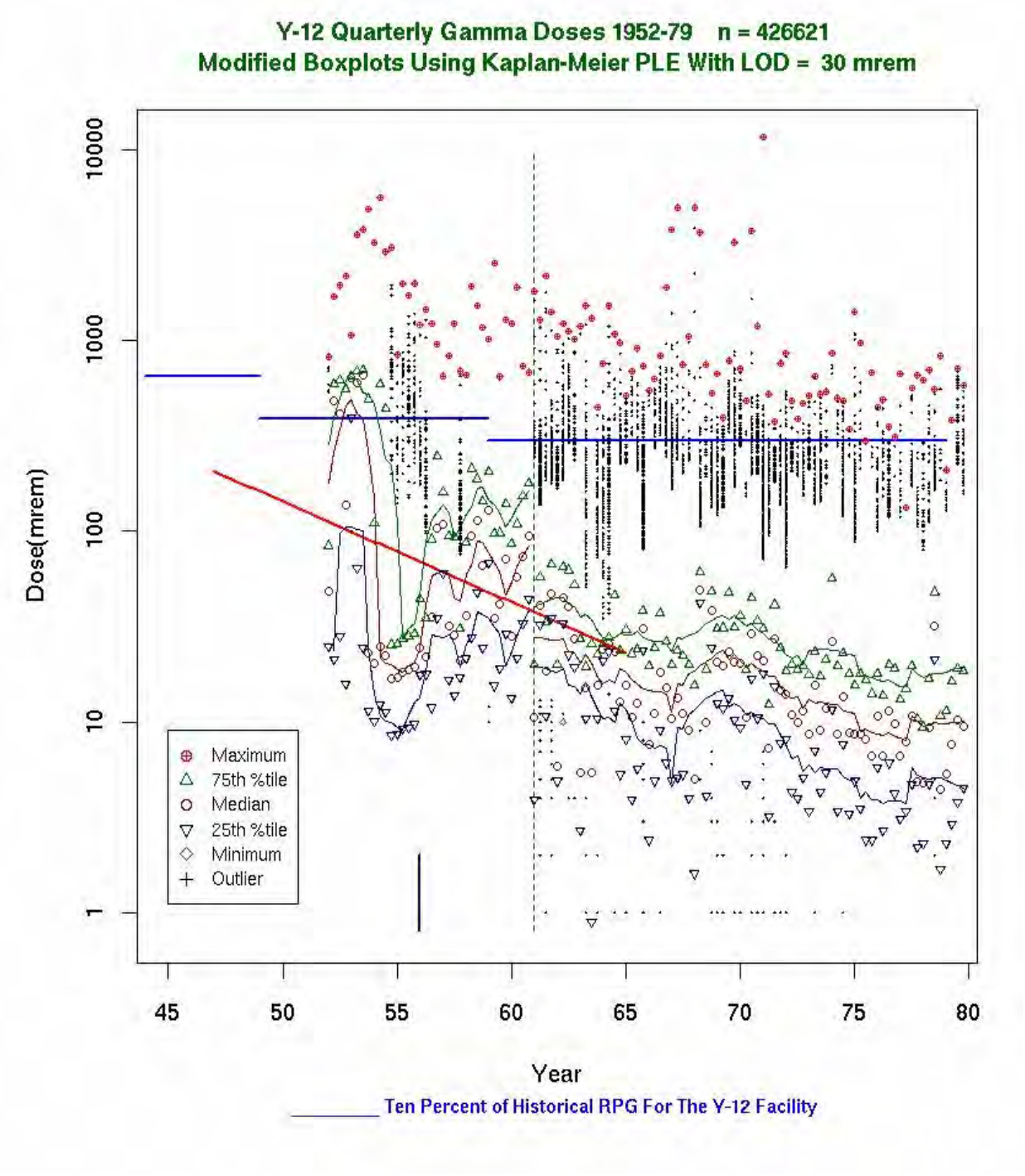
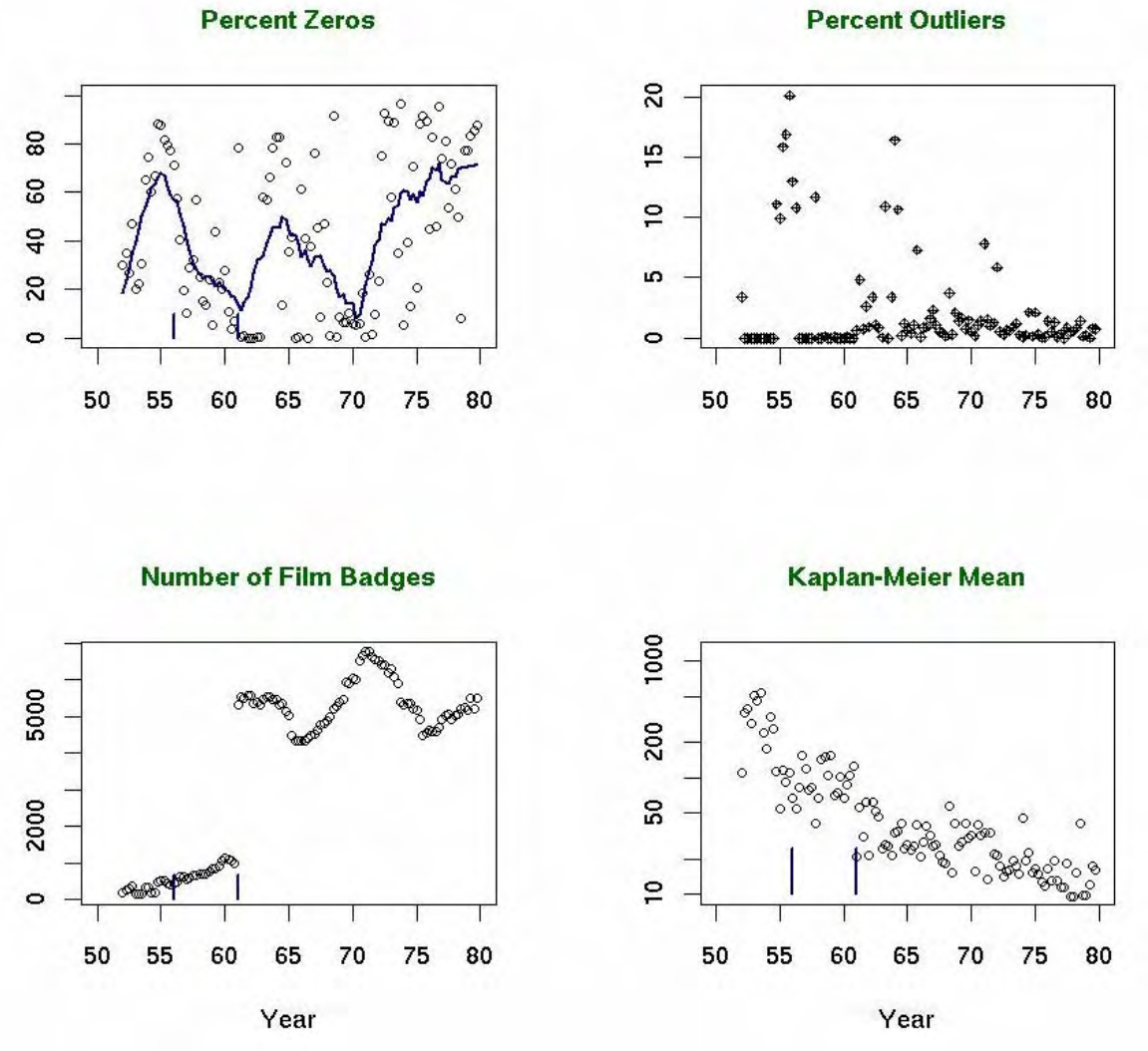


Figure 1b. Additional Summary Information for Gamma Doses, 1952-1979

Y-12 Quarterly Gamma Doses



4.2.2 Modified Boxplots for Beta Dose

All of the summary statistics used to obtain the modified boxplots for each quarter in Figure 1a are listed in Table 4-4 below. Figure 1b gives additional summary information by quarter in separate plots for the percent of the quarterly doses that were recorded as zero, the percent of positive outliers, the total number of quarterly doses, and the quarterly K-M means. Note that when a lognormal distribution is used to describe a quarterly dose distribution, rsdy = [log(xq75) - log(xq25)] / 1.35 provides an outlier resistant nonparametric estimate of the standard deviation of log(dose) which is equivalent to the log(GSD).

In Figure 1a the horizontal blue line segments mark values of 10% of the Radiation Protection Guidelines, which changed somewhat over this time period. Seventy-five percent of the beta doses each quarter were found to be lower than 10% of the Radiation Protection Guidelines except for 1954 through 1958 when some of the quarterly dose 75th percentiles were slightly larger. Beginning in 1961, when monitoring was extended to all workers regardless of exposure potential, there was a

precipitous drop in the 75th, 50th, and 25th percentiles of dose, which indicated that the newly monitored workers generally had doses far lower than the workers who were selected to be monitored before 1961. Maximum quarterly doses remained fairly constant from 1953 through 1970, verifying that workers with the highest exposure potential were already being monitored before 1961monitored. Dose distributions from 1961 and later were highly skewed toward very low doses, pulling the boundary for outliers to much lower values, which resulted in additional high outliers. These outliers can be seen in the long stretches of black crosses beginning in 1961 when monitoring for all workers began. The number of film badge readings that each quarterly box plot was based on, shown in Figure 1b, was generally about 1000 or less before 1961 and about 5000 or more afterwards.

Table 4-4: Product Limit Estimate Summary Stats for Y-12 Quarterly Beta Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
52 Q1	115.0	14.0	10.7	21.3	118.0	1,530	1.783	19,347	23,690	70.4	0	206
52 Q2	345.2	43.2	10.2	20.4	102.0	3,780	1.707	81,755	87,336	73.5	1	253
52 Q3	247.7	26.7	9.5	19.1	28.6	2,625	0.814	69,033	76,292	78.6	64	308
52 Q4	220.1	26.8	9.0	18.0	27.0	2,988	0.814	75,317	84,959	83.4	56	386
53 Q1	381.1	71.3	9.0	18.1	27.1	4,605	0.814	52,360	56,022	83.0	24	147
53 Q2	334.8	62.3	8.9	17.8	26.8	3,712	0.814	48,604	52,564	84.1	25	157
53 Q3	418.9	57.2	11.0	22.0	436.2	2,750	2.729	60,160	63,254	68.2	0	151
53 Q4	413.3	31.0	21.8	291.1	510.8	3,989	2.339	134,586	138,042	34.4	0	334
54 Q1	411.3	40.4	29.3	227.4	294.5	4,615	1.711	133,986	136,552	25.6	0	332
54 Q2	717.6	77.8	19.0	266.5	841.3	6,961	2.811	144,686	147,108	39.5	0	205
54 Q3	771.0	72.3	20.5	585.0	898.0	5,892	2.803	153,518	155,742	36.6	0	202
54 Q4	968.3	45.6	247.9	613.8	1,318.0	5,311	1.238	479,014	481,245	15.1	0	497
55 Q1	986.3	42.8	399.6	655.5	1,132.5	7,046	0.772	516,922	517,808	5.7	3	525
55 Q2	816.5	32.7	197.1	723.9	978.7	5,065	1.188	426,285	428,662	15.0	0	525
55 Q3	629.0	32.5	238.4	494.0	657.0	4,439	0.751	291,540	294,372	20.1	8	468
55 Q4	1,102.9	63.0	499.5	815.0	1,242.0	8,522	0.675	438,953	438,954	20.4	12	398
56 Q1	861.5	33.7	426.0	651.0	1,038.0	4,470	0.660	385,636	385,952	4.5	1	448
56 Q2	681.8	32.5	195.0	447.0	832.0	3,828	1.075	335,407	335,446	0.2	0	492
56 Q3	745.3	28.0	319.8	495.0	917.0	4,419	0.781	459,847	459,850	0.2	0	617
56 Q4	557.1	25.3	216.0	338.0	600.0	5,234	0.757	345,393	345,402	0.3	12	620
57 Q1	975.2	37.9	471.9	688.5	1,098.8	9,524	0.627	550,937	550,988	0.4	7	565
57 Q2	682.1	25.3	234.9	432.0	921.0	3,393	1.013	405,847	405,850	0.2	0	595
57 Q3	517.0	20.6	193.1	299.0	664.0	3,621	0.916	345,365	345,356	0.1	0	668
57 Q4	475.1	17.1	194.7	303.5	569.4	3,028	0.796	322,130	322,118	0.0	1	678
58 Q1	465.9	16.2	194.7	282.0	619.0	3,017	0.858	327,976	327,994	0.0	0	704
58 Q2	322.4	15.3	66.5	198.0	408.0	3,674	1.345	223,153	223,746	4.8	0	694
58 Q3	413.7	15.0	154.5	307.0	549.9	3,084	0.941	284,655	285,039	3.2	0	689

Table 4-4: Product Limit Estimate Summary Stats for Y-12 Quarterly Beta Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
58 Q4	318.0	11.8	61.2	204.5	470.0	2,755	1.511	249,632	250,584	7.9	0	788
59 Q1	289.7	10.8	54.2	182.0	422.0	2,245	1.521	242,922	244,507	9.2	0	844
59 Q2	304.1	11.4	64.8	201.0	425.5	2,532	1.395	259,124	259,701	4.4	0	854
59 Q3	369.6	18.8	57.6	203.6	471.0	5,956	1.558	334,555	335,966	8.9	0	909
59 Q4	373.4	18.7	45.9	177.5	485.8	10,407	1.749	391,002	393,190	12.3	0	1,053
60 Q1	279.7	12.6	32.0	108.0	354.0	5,109	1.782	319,784	321,096	6.0	0	1,148
60 Q2	391.6	17.7	44.8	165.3	468.0	5,910	1.739	431,590	432,326	3.9	0	1,104
60 Q3	464.6	18.9	55.4	230.8	590.3	3,840	1.753	489,680	490,153	2.7	0	1,055
60 Q4	398.5	17.2	49.4	177.5	518.2	3,628	1.742	392,300	392,522	1.4	0	985
61 Q1	125.0	4.0	11.3	22.9	86.8	4,475	1.512	625,940	662,625	45.8	29	5,301
61 Q2	112.9	4.0	4.9	14.0	58.0	4,379	1.828	600,191	623,772	39.8	17	5,525
61 Q3	101.4	3.3	7.5	15.4	59.5	4,069	1.531	550,282	557,092	10.9	41	5,494
61 Q4	94.1	3.4	5.6	13.8	51.6	4,534	1.651	495,874	523,666	46.4	42	5,565
62 Q1	92.2	2.9	7.8	18.3	63.8	2,555	1.560	494,696	514,753	30.0	28	5,583
62 Q2	136.6	4.8	10.6	24.2	78.9	4,266	1.490	717,376	731,083	19.5	87	5,352
62 Q3	112.7	3.5	15.9	24.4	64.2	2,986	1.036	567,228	607,904	43.5	343	5,394
62 Q4	84.8	3.1	12.4	21.9	28.6	3,700	0.618	392,191	451,730	68.0	793	5,327
63 Q1	80.6	3.0	17.3	24.3	36.4	4,800	0.550	374,051	439,754	62.0	736	5,456
63 Q2	70.7	2.6	1.8	9.4	30.8	2,519	2.108	363,997	391,395	59.3	4	5,536
63 Q3	95.4	3.4	17.2	23.6	56.7	5,825	0.886	485,017	529,375	42.3	380	5,549
63 Q4	66.8	2.2	9.9	18.1	47.3	3,047	1.161	329,266	364,795	48.2	122	5,461
64 Q1	73.3	2.5	14.1	19.2	40.2	40,54 0	.777	350,941	401,464	58.3	484	5,477
64 Q2	83.9	2.6	18.2	24.5	60.7	3,368	0.891	399,539	445,845	43.9	249	5,314
64 Q3	91.7	3.1	16.2	27.1	51.1	3,034	0.853	482,032	491,512	10.6	417	5,360
64 Q4	76.6	3.4	11.0	16.9	26.1	3,810	0.644	329,985	392,345	78.1	633	5,122
65 Q1	58.8	2.0	7.4	15.8	27.7	3,424	0.976	252,975	296,176	62.3	379	5,037
65 Q2	61.3	2.5	8.7	15.6	36.4	2,924	1.056	258,853	274,256	27.6	197	4,474
65 Q3	51.9	2.6	6.4	12.8	26.6	5,290	1.059	209,635	225,506	29.6	223	4,345
65 Q4	43.3	1.8	9.1	16.5	25.4	2,726	0.756	144,097	187,749	68.9	317	4,336
66 Q1	64.3	2.9	10.5	20.5	41.4	5,290	1.019	269,756	278,612	13.8	158	4,333
66 Q2	63.2	2.8	9.1	18.6	35.6	5,290	1.012	260,308	274,225	23.7	223	4,339
66 Q3	72.2	3.2	10.5	21.6	50.8	5,290	1.173	297,393	317,680	32.1	95	4,400
66 Q4	63.5	2.2	10.0	23.0	39.4	1,894	1.017	270,808	284,798	19.4	192	4,485
67 Q1	57.8	2.4	11.1	16.9	38.9	5,290	0.929	237,292	260,967	37.9	203	4,515

Table 4-4: Product Limit Estimate Summary Stats for Y-12 Quarterly Beta Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
67 Q2	64.3	2.6	9.5	19.9	43.4	5,290	1.127	279,823	296,616	25.7	139	4,613
67 Q3	42.0	1.9	5.3	12.2	25.0	5,290	1.142	161,328	199,626	67.9	174	4,753
67 Q4	50.8	2.0	6.2	15.2	31.4	5,290	1.202	219,480	243,688	42.4	143	4,797
68 Q1	55.0	2.6	5.7	13.5	27.8	5,290	1.180	239,455	268,620	52.3	200	4,884
68 Q2	28.6	1.5	5.4	10.6	20.7	5,290	0.995	100,474	142,256	74.9	183	4,974
68 Q3	48.1	1.7	7.9	16.0	27.3	2,663	0.916	196,730	250,697	73.8	336	5,212
68 Q4	49.8	1.8	7.9	15.6	26.4	2,932	0.896	206,283	263,591	74.9	394	5,293
69 Q1	36.1	1.2	5.9	13.6	24.3	1,162	1.046	142,308	194,868	75.7	245	5,398
69 Q2	37.7	1.7	6.0	11.8	22.5	3,986	0.977	168,895	206,068	58.1	280	5,466
69 Q3	31.7	1.8	4.1	9.9	19.4	5,290	1.148	135,328	188,140	80.9	196	5,935
69 Q4	30.8	1.8	2.8	8.7	15.4	4,660	1.264	148,342	181,166	64.1	187	5,882
70 Q1	40.3	2.9	3.1	7.2	17.5	8,120	1.283	202,042	242,767	76.5	213	6,024
70 Q2	18.7	0.7	3.0	7.2	15.1	1,514	1.202	82,310	112,237	57.9	96	6,002
70 Q3	47.1	2.5	5.4	11.4	20.1	7,200	0.982	250,084	306,574	77.7	474	6,509
70 Q4	54.3	2.5	4.6	13.1	24.4	5492	1.238	317,080	362,290	57.7	297	6,672
71 Q1	31.9	1.4	5.6	11.5	21.2	1,961	0.987	137,896	215,612	90.7	303	6,759
71 Q2	29.2	1.0	3.9	7.9	17.0	1,647	1.102	161,979	197,304	53.9	301	6,757
71 Q3	18.6	0.9	3.7	7.1	15.4	1,462	1.060	64,122	123,299	92.8	172	6,629
71 Q4	19.0	0.8	3.0	5.6	13.3	1,354	1.112	84,144	124,564	78.2	217	6,556
72 Q1	26.0	1.4	2.8	6.6	15.3	3,675	1.257	134,384	169,650	65.9	182	6,525
72 Q2	43.1	1.3	6.6	14.6	26.3	3,330	1.021	227,823	275,840	60.0	305	6,400
72 Q3	29.3	0.9	7.6	15.7	24.3	1,071	0.862	106,216	187,608	86.0	254	6,403
72 Q4	33.4	1.1	7.4	14.3	25.4	1,151	0.920	133,502	206,880	83.2	291	6,194
73 Q1	31.9	1.0	6.1	13.5	21.9	1,019	0.943	134,159	201,321	83.5	308	6,311
73 Q2	35.9	1.4	9.2	16.1	23.9	2,542	0.710	140,266	217,626	85.1	356	6,062
73 Q3	26.3	1.0	4.7	10.9	21.9	1,872	1.134	93,431	154,644	85.8	129	5,880
73 Q4	24.7	1.1	6.9	14.0	20.6	1,158	0.811	62,573	133,331	92.1	190	5,398
74 Q1	41.7	2.0	5.6	13.0	22.6	2,210	1.037	155,407	220,927	89.6	252	5,298
74 Q2	34.2	1.3	6.0	14.3	23.5	1,350	1.005	124,507	183,278	82.0	230	5,359
74 Q3	29.1	1.1	6.2	13.5	21.4	1,231	0.922	96,214	156,092	84.9	221	5,364
74 Q4	27.8	1.2	5.9	13.5	23.1	2,145	1.018	81,935	144,949	88.6	162	5,214
75 Q1	34.1	1.2	5.6	14.4	25.1	1,281	1.118	122,052	176,229	79.8	123	5,168
75 Q2	36.8	1.3	5.1	12.7	24.0	1,207	1.148	138,448	180,946	72.9	133	4,917
75 Q3	30.8	1.2	4.9	11.9	24.5	1,953	1.189	101,723	138,076	70.7	67	4,483

Table 4-4: Product Limit Estimate Summary Stats for Y-12 Quarterly Beta Doses, 1952-1979

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
75 Q4	32.2	1.1	4.8	12.0	24.6	1,624	1.217	112,104	146,188	66.2	67	4,540
76 Q1	51.6	1.1	24.3	38.5	47.7	1,730	0.501	235,526	238,289	4.4	273	4,618
76 Q2	22.1	1.0	4.5	11.2	20.4	1,655	1.125	67,747	101,770	66.3	54	4,605
76 Q3	24.9	1.1	4.0	9.1	17.0	1,555	1.079	86,799	113,843	59.4	134	4,572
76 Q4	25.8	1.1	6.2	14.5	22.4	1,670	0.950	66,632	121,105	84.5	108	4,694
77 Q1	20.4	0.8	3.4	8.5	17.8	1,206	1.221	68,629	100,633	65.9	56	4,933
77 Q2	15.3	0.4	4.3	9.5	18.2	1,553	1.062	45,505	76,821	59.4	1	5,021
77 Q3	28.7	1.2	6.2	11.7	19.9	2,300	0.861	120,537	145,165	43.0	251	5,058
77 Q4	21.7	0.9	3.1	7.3	16.9	1,383	1.246	78,504	106,373	62.0	63	4,902
78 Q1	26.2	1.0	4.4	10.2	19.2	1,433	1.096	109,993	131,183	40.7	132	5,007
78 Q2	27.6	1.2	3.5	8.5	18.5	1,673	1.245	116,223	140,015	50.2	110	5,073
78 Q3	27.7	1.4	4.8	10.7	19.0	1,708	1.022	90,346	144,095	89.0	169	5,202
78 Q4	25.9	1.1	3.7	9.1	20.7	1,660	1.287	107,413	136,104	55.9	56	5,255
79 Q1	30.0	1.0	5.6	12.8	23.5	1,638	1.064	123,970	155,070	51.9	110	5,169
79 Q2	41.9	1.2	7.7	17.7	34.9	1,587	1.119	214,347	230,953	23.2	90	5,512
79 Q3	27.7	1.1	5.9	11.8	21.8	1,621	0.969	99,901	143,929	70.4	151	5,196
79 Q4	39.6	1.5	5.9	13.7	24.9	1,622	1.072	177,670	217,364	59.0	183	5,489

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

The red solid line seen in Figure 2a is the GM of the prediction density used to estimate doses for unmonitored quarters before 1956. The horizontal blue line segments mark values of 10% of the Radiation Protection Guidelines. The vertical green dashed line identifies the first quarter of 1961 when all workers were monitored. When complete monitoring began, the dose distributions dropped dramatically. Workers with higher exposure potential, who had been monitored previously, were joined after 1961 by workers with lower exposure workers added to the monitoring program. In department 2619, for example, the dose distribution fell in 1961 and remained low, although maximum quarterly doses were fairly constant for several years. Higher doses workers who had previously been monitored became outliers in the lower dose distribution.

Figure 2a. Modified Boxplot for Beta Doses, 1952-1979

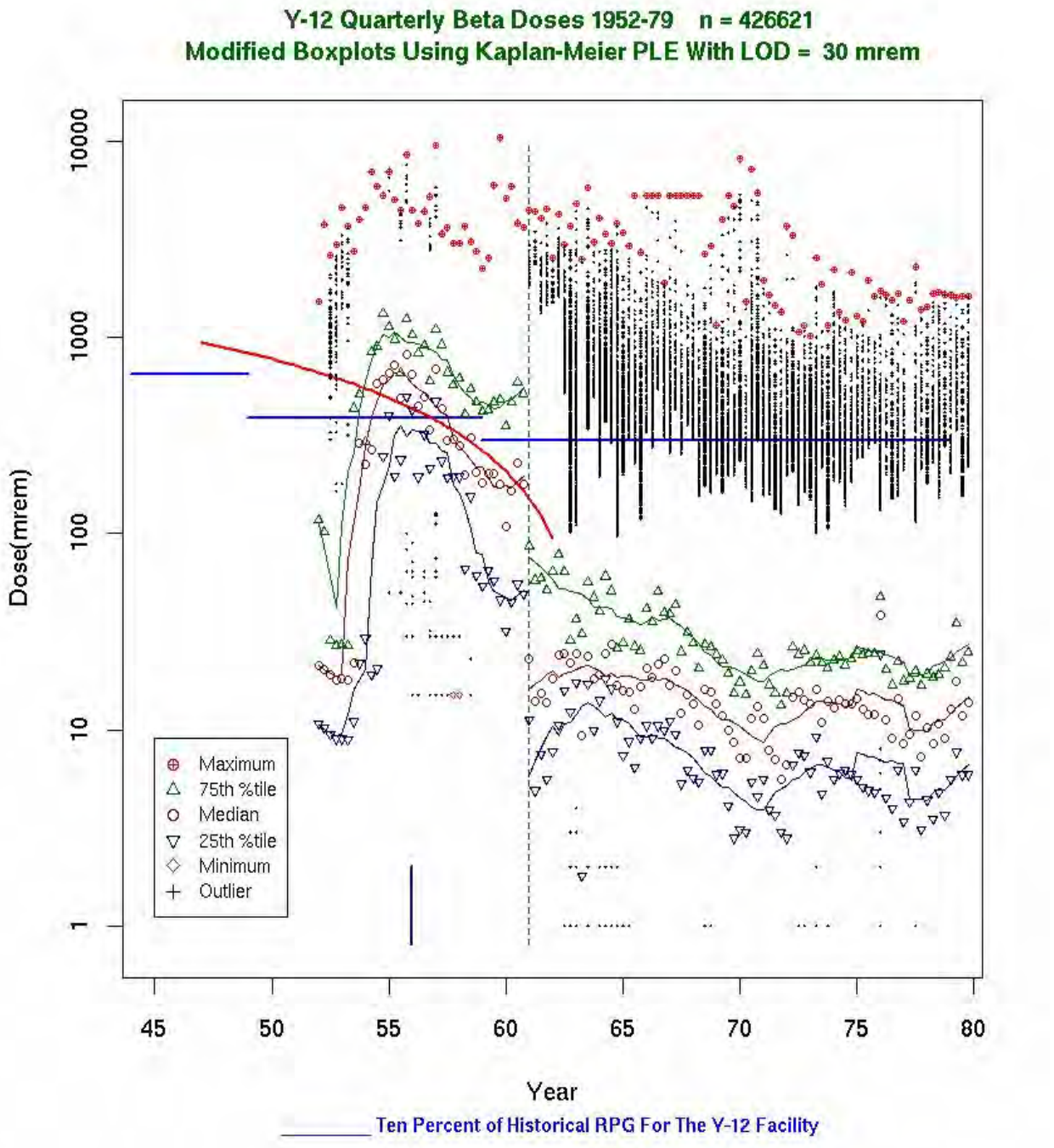
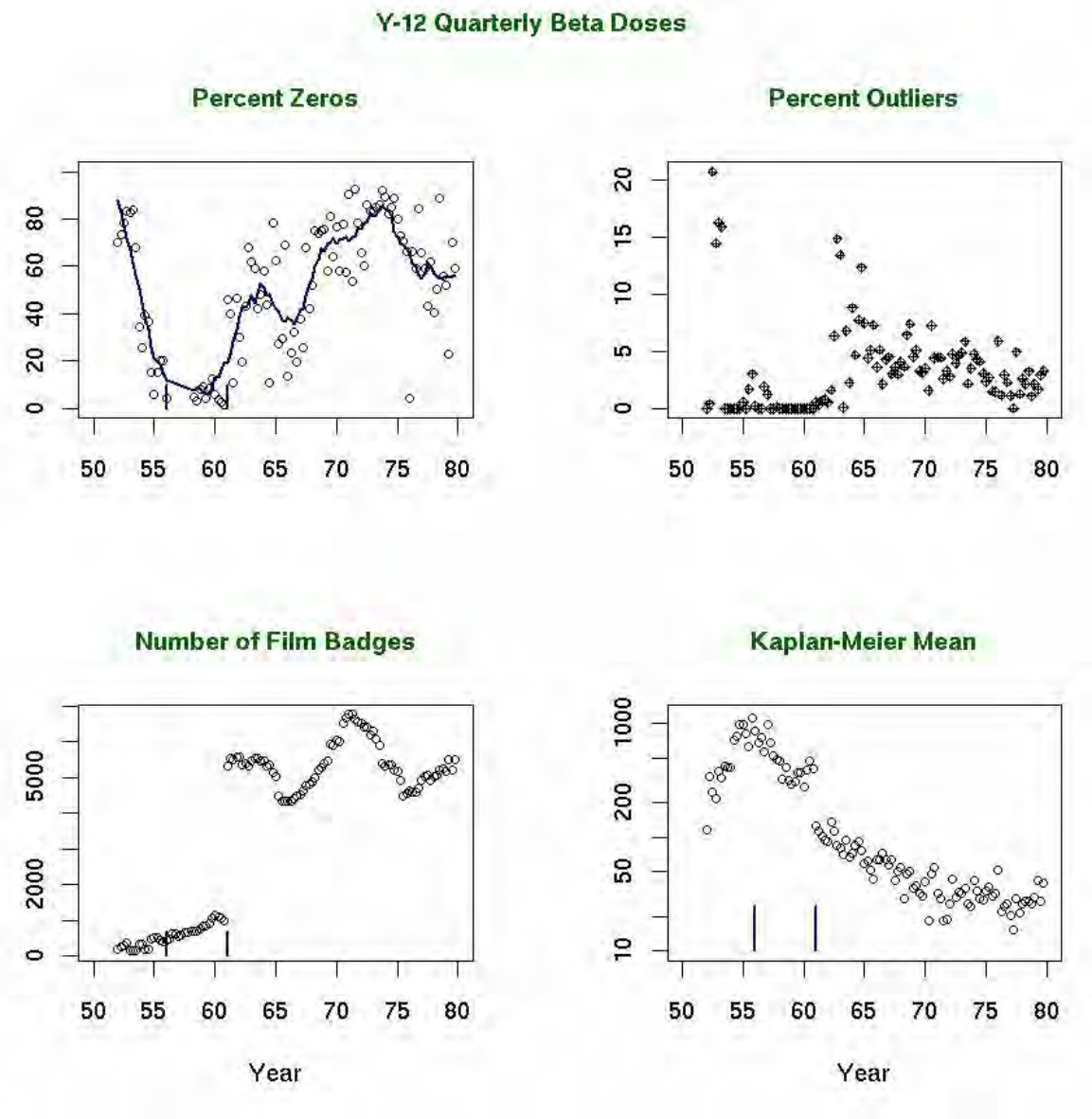


Figure 2b. Additional Summary Information for Beta Doses, 1952-1979



4.3 Analysis by Departments

To compare the change in average dose by department in the years after all workers began to be monitored to the immediately proceeding years, the summary statistics that follow were calculated by department for all beta and gamma doses during this period.

4.3.1 Departmental Gamma Doses

The following table is partitioned into three parts. Departments in Part A and Part B were determined by whether the mean dose in 1961 through 1965 was less than or greater than 60 mrem, which was one percent of the quarterly Radiation Protection Guidelines for beta dose. Departments in Part C

were in the process of being closed out in 1960 or 1961. After complete monitoring began in 1961, the highest quarterly mean dose accrued by workers in department 2722 was 107.8 mrem. This can be compared to the quarterly Radiation Protection Guidelines values of 3,000 mrem in 1960 and 1,250 mrem today. Although individuals may have had higher doses, workers with high dose potential were carefully monitored to be sure that they did not exceed the Radiation Protection Guidelines.

Table 4-5A: Y-12 Gamma Doses Ordered by Adjusted Mean Dose, 1961-1965

Part A. Departments with quarterly gamma mean for 1961-1965 less than 30 mrem (MDL)

Dept.	NW 56-60[1]	NM 56-60[2]	M% 56-60[3]	Mean 56-60[4]	A Mean 61-65[5]	Mean 61-65[6]	N 61-65[7]
2051	182	0	0.0	NA	16.9	8.3	155
2137	118	0	0.0	NA	17.8	11.7	103
2073	360	0	0.0	NA	18.0	12.5	303
2157	151	0	0.0	NA	18.0	12.4	353
2301	1,715	215	12.5	65.0	18.0	11.0	44
2102	99	0	0.0	NA	18.2	13.5	96
2065	349	0	0.0	NA	18.7	13.1	633
2060	303	0	0.0	NA	18.8	13.0	493
2090	613	20	3.3	15.9	18.8	13.3	539
2141	176	0	0.0	NA	18.8	12.9	163
2146	630	0	0.0	NA	19.0	12.9	821
2046	269	0	0.0	NA	19.2	12.6	247
2098	52	0	0.0	NA	19.2	11.8	65
2115	70	0	0.0	NA	19.2	12.9	116
2068	594	0	0.0	NA	19.3	14.0	614
2101	90	0	0.0	NA	19.3	13.3	74
2133	196	0	0.0	NA	19.9	13.6	125
2067	569	0	0.0	NA	20.1	13.9	586
2017	269	2	0.7	0.0	20.2	14.1	242
2002	430	0	0.0	NA	20.3	14.0	208
2069	245	0	0.0	NA	20.3	14.8	472
2163	273	0	0.0	NA	20.6	14.9	275
2148	275	0	0.0	NA	20.8	16.8	68
2140	246	0	0.0	NA	21.0	14.3	148
2093	511	491	96.1	14.4	21.3	15.7	464
2107	433	0	0.0	NA	21.5	15.2	373
2149	7	0	0.0	NA	21.5	16.0	424
2139	353	0	0.0	NA	22.0	16.7	300
2041	180	0	0.0	NA	22.1	17.3	160
2142	1,695	1	0.1	0.0	22.1	16.0	1,917
2094	170	0	0.0	NA	22.3	16.2	150
2096	436	0	0.0	NA	22.5	16.7	233
2151	692	0	0.0	NA	22.5	17.9	359
2091	2,679	85	3.2	11.9	22.7	17.5	2,022
2085	77	0	0.0	NA	22.8	17.6	63
2014	5,215	8	0.2	80.0	23.0	17.2	4,110
2057	595	0	0.0	NA	23.0	17.2	793
2001	2,252	2	0.1	0.0	23.1	17.2	2,254
2136	51	0	0.0	NA	23.1	16.9	69
2346	54	3	5.6	22.0	23.1	18.3	358
2066	501	0	0.0	NA	23.2	17.7	744
2743	433	0	0.0	NA	23.2	17.6	284

Table 4-5A: Y-12 Gamma Doses Ordered by Adjusted Mean Dose, 1961-1965

Part A. Departments with quarterly gamma mean for 1961-1965 less than 30 mrem (MDL)

Dept.	NW 56-60[1]	NM 56-60[2]	M% 56-60[3]	Mean 56-60[4]	A Mean 61-65[5]	Mean 61-65[6]	N 61-65[7]
2742	727	0	0.0	NA	23.5	17.2	1,152
2015	4,791	2	0.0	0.0	23.7	17.4	4,127
2695	608	0	0.0	NA	23.7	17.3	2,038
2345	80	32	40.0	19.8	24.0	18.7	810
2070	944	0	0.0	NA	24.2	18.6	1,101
2100	52	0	0.0	NA	24.3	20.6	14
2700	268	0	0.0	NA	24.4	18.2	443
2059	210	0	0.0	NA	24.6	20.0	322
2143	904	1	0.1	0.0	24.7	18.8	784
2200	406	50	12.3	15.7	24.7	18.5	735
2058	328	0	0.0	NA	24.9	21.2	32
2006	346	0	0.0	NA	25.1	19.8	288
2342	45	0	0.0	NA	25.1	19.8	574
2664	219	0	0.0	NA	25.1	19.4	98
2665	1,188	657	55.3	78.5	25.1	19.5	597
2145	754	0	0.0	NA	25.2	21.1	125
2077	4,008	219	5.5	29.6	25.3	19.4	2,665
2095	59	0	0.0	NA	25.5	20.6	27
2616	2,298	40	1.7	26.5	26.4	21.5	1,187
2685	2,265	3	0.1	12.7	26.5	26.5	119
2011	184	0	0.0	NA	26.6	24.8	79
2687	2,081	12	0.6	46.1	27.1	20.8	2,023
2343	64	0	0.0	NA	27.2	21.8	619
2216	614	1	0.2	0.0	28.3	24.0	472
2071	394	0	0.0	NA	28.5	26.7	421
2161	250	0	0.0	NA	28.5	24.4	367
2144	357	0	0.0	NA	29.0	25.9	82
2260	386	7	1.8	18.6	29.1	25.8	112
2044	531	304	57.3	156.9	30.0	25.0	212
2682	1,319	0	0.0	NA	30.5	27.1	408
2009	92	0	0.0	NA	30.6	28.2	34
2204	148	124	83.8	37.1	31.2	25.2	233
2158	4,352	125	2.9	99.6	31.8	27.4	4,139
2230	1,270	125	9.8	11.5	33.2	29.3	226

Notes:
[1] Number of quarters worked, 1956-1960
[2] Number of quarters monitored, 1956-1960
[3] Percent of worked quarters that were monitored, 1956-1960
[4] Mean dose, 1956-1960
[5] Mean dose adjusted for zeros by left-censoring methods, 1961-1965
[6] Mean dose with zeros, 1961-1965
[7] Number of quarterly doses, 1961-1965

Table 4-5B: Y-12 Gamma Doses Ordered by Adjusted Mean Dose, 1961-1965

Part B. Departments with quarterly gamma mean for 1961-1965 greater than 30 mrem

Dept.	NW 56-60[1]	NM 56-60[2]	M% 56-60[3]	Mean 56-60[4]	A Mean 61-65[5]	Mean 61-65[6]	N 61-65[7]
2128	571	209	36.6	59.4	33.9	30.3	246

Table 4-5B: Y-12 Gamma Doses Ordered by Adjusted Mean Dose, 1961-1965

Part B. Departments with quarterly gamma mean for 1961-1965 greater than 30 mrem

Dept.	NW 56-60[1]	NM 56-60[2]	M% 56-60[3]	Mean 56-60[4]	A Mean 61-65[5]	Mean 61-65[6]	N 61-65[7]
2257	860	0	0.0	NA	34.8	30.5	201
2344	81	30	37.0	72.8	35.8	30.9	910
2003	7,535	110	1.5	31.3	35.9	33.8	2,862
2018	5,153	27	0.5	29.6	35.9	30.8	6,105
2164	36	0	0.0	NA	37.2	37.2	174
2038	379	0	0.0	NA	39.9	38.1	756
2703	5,218	4,636	88.8	72.4	43.5	40.2	2,332
2638	683	52	7.6	155.3	44.3	40.8	395
2637	247	0	0.0	NA	47.1	43.0	1,454
2055	33	2	6.1	0.0	48.1	46.7	1,403
2701	1,639	1,459	89.0	145.0	49.6	46.2	2,399
2793	820	786	95.9	92.6	50.5	48.2	677
2162	50	18	36.0	17.1	51.1	47.6	246
2108	572	122	21.3	65.4	53.9	52.3	304
2618	1,551	1,077	69.4	110.4	57.5	54.4	1,912
2233	1,636	844	51.6	59.0	74.8	73.3	783
2617	3,761	878	23.3	69.0	76.6	75.0	3,427
2619	3,258	365	11.2	149.6	77.0	75.0	1,943
2259	409	305	74.6	127.5	80.9	79.0	305
2702	738	717	97.2	280.2	83.2	81.5	1,038
2776	1,187	106	8.9	20.6	91.7	90.7	866
2718	65	0	0.0	NA	92.6	90.3	43
2722	257	251	97.7	183.5	108.5	107.8	545

Notes:
[1] Number of quarters worked, 1956-1960
[2] Number of quarters monitored, 1956-1960
[3] Percent of worked quarters that were monitored, 1956-1960
[4] Mean dose, 1956-1960
[5] Mean dose adjusted for zeros by left-censoring methods, 1961-1965
[6] Mean dose with zeros, 1961-1965
[7] Number of quarterly doses, 1961-1965

Table 4-5C: Y-12 Gamma Doses Ordered by Adjusted Mean Dose, 1961-1965

Part C. Quarterly gamma dose statistics for departments no longer operating after 1960

Dept.	NW 56-60[1]	NM 56-60[2]	M% 56-60[3]	Mean 56-60[4]	A Mean 61-65[5]	Mean 61-65[6]	N 61-65[7]
2026	88	0	0.0	NA	NA	NA	0
2056	185	0	0.0	NA	NA	NA	0
2088	32	0	0.0	NA	NA	NA	0
2159	1,723	32	1.9	62.4	NA	NA	0
2160	106	2	1.9	105.0	NA	NA	0
2205	60	53	88.3	18.6	NA	NA	0
2231	743	159	21.4	156.1	NA	25.0	2
2681	1,069	0	0.0	NA	NA	7.0	2
2683	749	0	0.0	NA	NA	NA	0
2690	111	0	0.0	NA	NA	NA	0
2692	182	3	1.6	109.3	NA	NA	0
2791	1,333	208	15.6	109.7	NA	NA	0

Table 4-5C: Y-12 Gamma Doses Ordered by Adjusted Mean Dose, 1961-1965

Part C. Quarterly gamma dose statistics for departments no longer operating after 1960

Dept.	NW 56-60[1]	NM 56-60[2]	M% 56-60[3]	Mean 56-60[4]	A Mean 61-65[5]	Mean 61-65[6]	N 61-65[7]
2792	714	528	73.9	29.0	NA	NA	0
2799	65	0	0.0	NA	NA	NA	0

Notes:
[1] Number of quarters worked, 1956-1960
[2] Number of quarters monitored, 1956-1960
[3] Percent of worked quarters that were monitored, 1956-1960
[4] Mean dose, 1956-1960
[5] Mean dose adjusted for zeros by left-censoring methods, 1961-1965
[6] Mean dose with zeros, 1961-1965
[7] Number of quarterly doses, 1961-1965

4.3.2 Departmental Beta Doses

There were 426,621 beta doses recorded for Y-12 workers from 1952 to 1979 including non-detects recorded as zeros. Before 1961 there were 101,139 quarterly records, which included 15,508 (15.3%) monitoring records and an additional 85,631 working quarters that were not monitored. Unmonitored quarters were obtained from a file of Y-12 work history records that included job start date, job termination date, job title and department for each worker and each change of job title.
Table 4-6 presents the summary statistics listed above for beta doses for each Y-12 departments in operation during this time period, ordered from smallest to largest adjusted mean dose for 1961-65. Changes in the number of working quarters, reflecting the number of workers assigned to a department, can be found in Table 4-6 by comparing values in column NW56-60 to the column N61-65. To provide an indication of the consistency of the workers assigned to a department, the %same column gives the percent of workers assigned to a department in 1961 who were also in that department in 1960. Departments where %same is absent had no assigned workers in 1961. The %same would inevitably be lowered for departments who had large increases or decreases in the number of workers as projects ended or began. Note that even with some change in department personnel, the exposure potential would remain similar when the activity, machining for example, was the same.

The following table, Table 4-6, is partitioned into three parts. Departments in Part A and Part B were determined by whether the mean dose in 1961 through 1965 was less than or greater than 60 mrem, which was one percent of the quarterly Radiation Protection Guidelines for beta dose. Departments in Part C were in the process of being closed out in 1960 or 1961. Among the 83 departments in Part A, in which beta dose potential was extremely low, two points are evident: (1) in the majority of these departments very few working quarters were monitored (63 of these departments had less than one percent monitoring), and (2) individuals who were selected for monitoring before 1961 generally were exposed to beta particles since means for 1956 through 1960 when monitoring occurred were generally greater than 100 mrem. These two points provide solid evidence that workers not being monitored before 1961 had low potential for beta-particle exposure.

Working in the 17 departments in Part B may have provided higher potential of beta-particle exposure. Five of these departments (2055, 2162, 2164, 2637, and 2718) were not initiated until late 1960 or early 1961. Department 2233 ceased to exist after 1961 and was growing smaller in 1961, and department 2638 had no assigned workers in 1961. Mean dose for 1961-65 in department 2776 was less than three percent of Radiation Protection Guidelines. Among the remaining departments in Part

B, the following points are apparent: (1) 70% or more of the working quarters were selected for monitoring in 1956 through 1960, and (2) mean dose from 1956-60 was greater than the mean in 1961-65 except for department 2618, which was about 15% lower. Only in departments 2701 before 1961 and 2722 and 2618 before and after 1961 were mean doses at least 10% of the Radiation Protection Guidelines, which was the level at which monitoring was required. These departments had approximately 90%, 98%, and 70% of working quarters monitored in 1956 through 1960.

The mean beta dose assigned to unmonitored quarters before 1960 based on regression methods is about 500 mrem. Therefore, only in department 2618 may a worker have had an unmonitored quarter in which the assigned doses would likely be below the mean for 1961 through 1965. If "scaling" based on doses after 1960 is applied to assigned doses for unmonitored quarters as was done for gamma doses, this would most likely adjust the assigned doses upward for workers with higher exposure potential (ORAUT-PROC-0042).

All of the 14 departments in Part C were being closed down during 1960, and eight of them had fewer than 200 working quarters during the five years of 1956 through 1960. In departments 2792 and 2205 three-fourths or more of the working quarters were monitored before 1961. Only 12 individuals were assigned to department 2159 in 1960, and after 1959 these tradesmen were already being transferred to other departments before blanket monitoring was planned. Workers in department 2231 were engaged in laboratory work with little potential exposure to external radiation. The higher mean doses from 1956 through 1960 for departments 2791 and 2793, which were engaged in similar tasks, demonstrate that the workers with exposure potential were being selected for monitoring.

Table 4-6B: Y-12 Beta Doses 1956-1965 Order by Adjusted Mean Dose, 1956-1960

Part B. Departments where quarterly beta mean for 1961-1965 was greater than 60 mrem

Dept.	NW 56-60[1]	NM 56-60[2]	M 56-60 (%)[3]	Mean 56-60[4]	A Mean 61[5]	Mean 61-65[6]	N 61-65[7]
2164	36	0	0	NA	73.3	68.3	174
2718	65	0	0	NA	75.2	72.9	43
2619	3,258	365	11.2	746.9	90	84.6	1,943
2637	247	0	0	NA	100.4	94.6	1,454
2664	219	0	0	NA	125.5	123.4	98
2776	1,187	106	8.9	412.3	148.2	146.6	866
2259	409	305	74.6	291.7	176.8	175.1	305
2162	50	18	36	49.2	200.8	199	246
2793	820	786	95.9	347.1	213.9	212.6	677
2701	1,639	1,459	89	502.5	223.7	221.8	2,399
2638	683	52	7.6	105.5	244.7	241.3	395
2055	33	2	6.1	257	275.7	275	1,403
2703	5,218	4,636	88.8	467.1	318.3	317.3	2,332
2702	738	717	97.2	1,200.6	441	440.1	1,038
2233	1,636	844	51.6	283.4	466.1	465	783
2722	257	251	97.7	677.6	500.7	500.3	545

Notes:
[1] Number of quarters worked, 1956-1960
[2] Number of quarters monitored, 1956-1960
[3] Percent of worked quarters that were monitored, 1956-1960
[4] Mean dose, 1956-1960
[5] Mean dose adjusted for zeros by left-censoring methods, 1961-1965
[6] Mean dose with zeros, 1961-1965
[7] Number of quarterly doses, 1961-1965

Table 4-6C: Y-12 Beta Doses 1956-1965 Order by Adjusted mean dose, 1956-1960							
Part C. Beta dose statistics for departments no longer operating after 1960							
Dept.	**NW 56-60[1]**	**NM 56-60[2]**	**M 56-60 (%)[3]**	**Mean 56-60[4]**	**A Mean 61[5]**	**Mean 61-65[6]**	**N 61-65[7]**
2026	88	0	0.0	NA	NA	NA	0
2056	185	0	0.0	NA	NA	NA	0
2088	32	0	0.0	NA	NA	NA	0
2159	1723	32	1.9	97.1	NA	NA	0
2160	106	2	1.9	0.0	NA	NA	0
2205	60	53	88.3	199.8	NA	NA	0
2231	743	159	21.4	569.8	NA	5.0	2
2681	1,069	0	0.0	NA	NA	1.0	2
2683	749	0	0.0	NA	NA	NA	0
2690	111	0	0.0	NA	NA	NA	0
2692	182	3	1.6	309.7	NA	NA	0
2791	1,333	208	15.6	1030.1	NA	NA	0
2792	714	528	73.9	677.2	NA	NA	0
2799	65	0	0.0	NA	NA	NA	0

Notes:
[1] Number of quarters worked, 1956-1960
[2] Number of quarters monitored, 1956-1960
[3] Percent of worked quarters that were monitored, 1956-1960
[4] Mean dose, 1956-1960
[5] Mean dose adjusted for zeros by left-censoring methods, 1961-1965
[6] Mean dose with zeros, 1961-1965
[7] Number of quarterly doses, 1961-1965

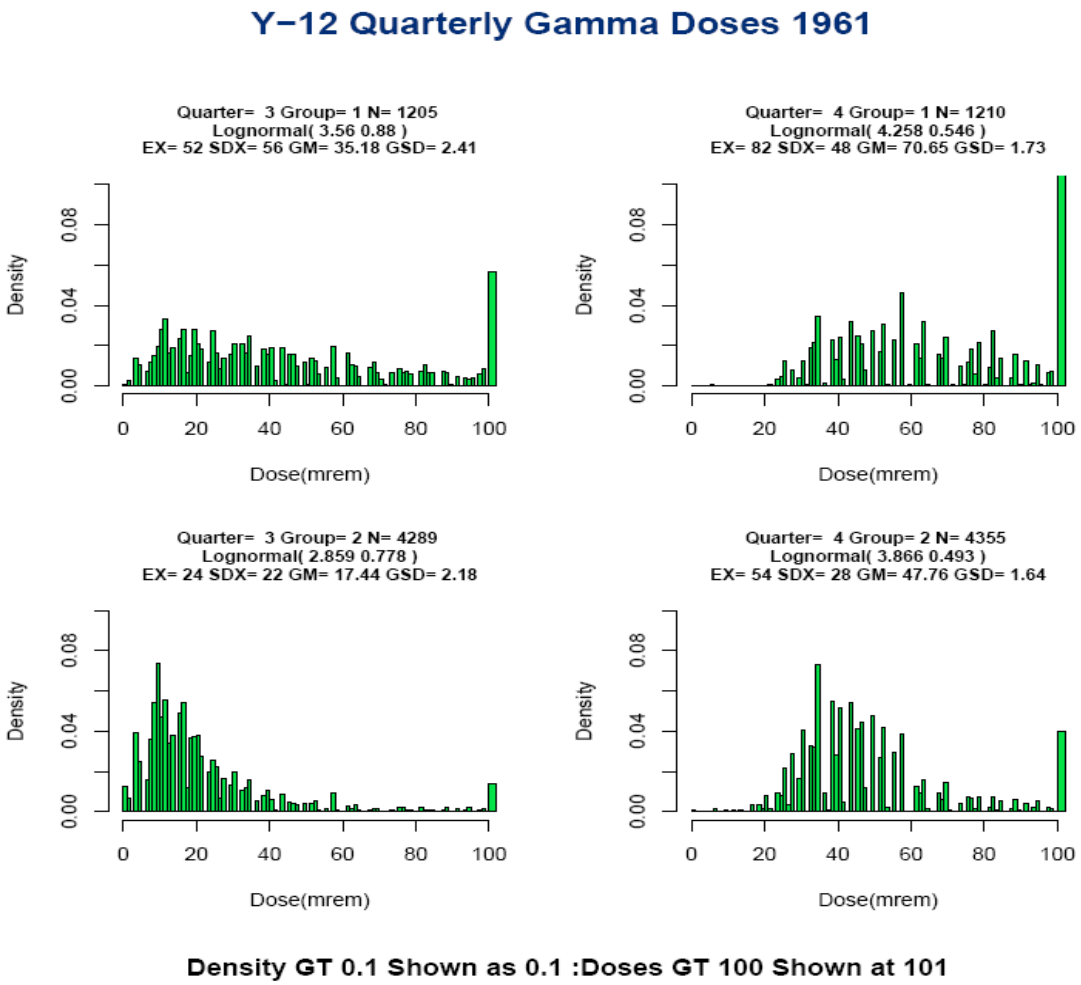
4.4 Comparing 1961 Gamma Dose Distributions of Workers Monitored Versus Not Monitored in 1960

In 1961 the Y-12 facility adopted a policy that required monitoring all workers for external radiation exposure. Before this time the Y-12 policy was to select workers for external monitoring if they had potential for exposure to 10 percent or more of the Radiation Protection Guidelines. An assessment of the 1961 gamma doses to appraise whether workers with higher exposure potential had indeed been selected to be monitored before 1961 is presented below. Since workers monitored before 1961 were picked because of higher dose potential, the distribution of the doses in 1961 for previously monitored individuals should be higher than the distribution of doses for workers who were first monitored in 1961. Therefore, the 1961 doses were separated into two groups partitioned by each worker's monitoring status in 1960. "Group 1" consisted of 1961 workers who were chosen to be monitored in 1960, and "Group 2" included those employees who were not monitored in 1960.

Figure 3 provides an initial look at the1961 third and fourth quarter gamma doses of the two groups of workers. Because Group 2 was approximately four times the size of Group 1, histograms based on percents rather than counts were used to facilitate a comparison of doses for the two groups. The top two graphs (Group 1) show relatively fewer doses in the lower dose range and distinctly more doses above 100 mrem than the corresponding Group 2 doses below. The statistics above each plot were based on a lognormal model with EX indicating the expected value of the doses, SDX the standard deviation, GM the geometric mean, and GSD the geometric standard deviation. The indicated parameters derived from each the lognormal models are the natural logarithms of the geometric mean

and geometric standard deviation. These statistics further verify that the average doses were higher for workers who had been selected for monitoring in 1960.

Figure 3. Histograms for Y-12 Quarterly Gamma Doses in 1961 for Two Groups of Workers Partitioned by Monitoring Status in 1960



Statistics for 1961 quarterly gamma doses are presented in Table 4-7 for the two groups of Y-12 workers. The percentiles, Kaplan-Meier means, and adjusted cumulative doses were calculated taking into account doses recorded as zero, which indicated film badge readings below the minimum detectible level (MDL). These statistics were derived using non-parametric left-censored methods with the non-detectible doses (recorded as zero) designated to have an upper limit of 30 mrem. Because there were very few zero doses in quarters two (Q2), three (Q3), and four (Q4) of 1961, the left-censored methods had little impact on the calculated statistics, as can be seen by comparing the directly calculated cumulative doses to the adjusted cumulative doses in Table 4-7. However, in the first quarter (Q1) of 1961 the percents of non-detectible doses were 53 and 86 for the previously monitored and newly monitored groups, respectively, which substantially increased the adjusted cumulative doses, percentiles, and Kaplan-Meier means, particularly for Group 2. In every quarter of 1961 the 25^{th}, 50^{th} (median), and 75^{th} percentiles for Group 1 workers were higher than those for Group 2. Further, except for Q1, medians for previously monitored individuals were higher than the

75th percentiles for the newly monitored, verifying that workers who were selected to be monitored in 1960 had higher exposure potential.

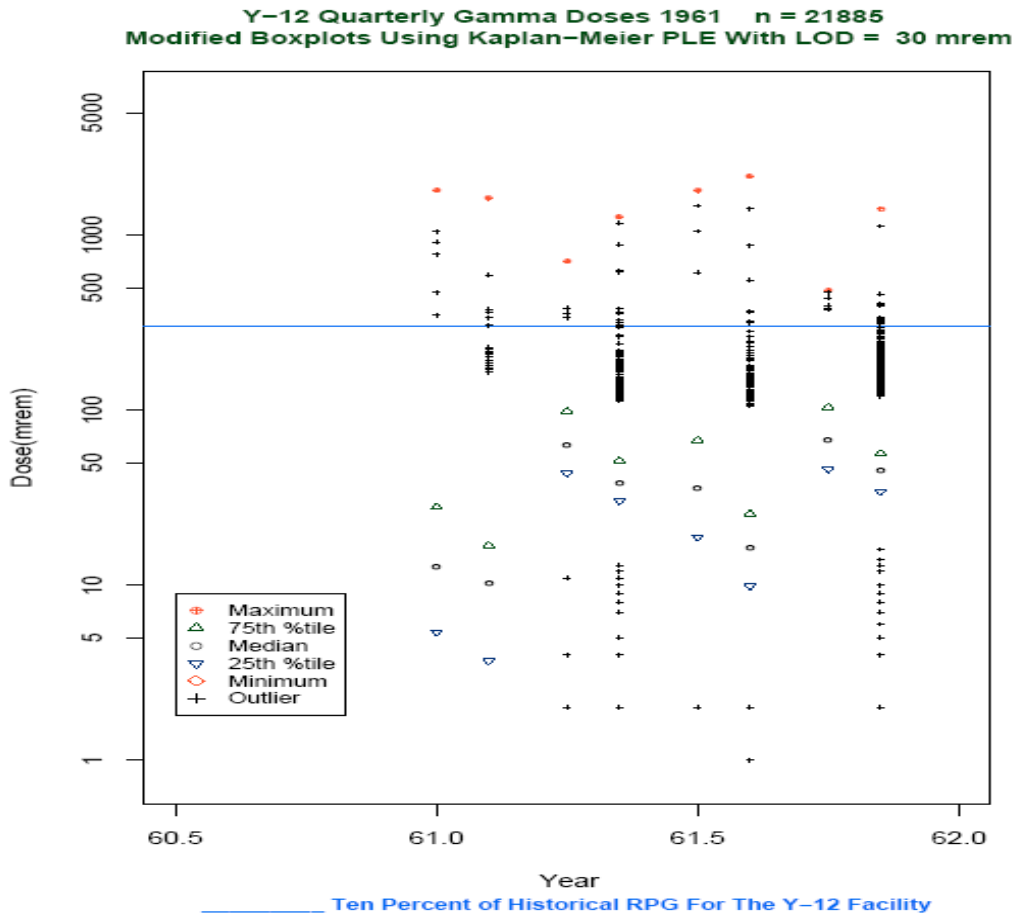
A modified version of a boxplot was used to summarize the gamma-ray doses for the two groups. The statistics in Table 4-7 are shown as modified boxplots in Figure 4. In this figure, xq25 is shown as a blue inverted triangle and xq75 as a blue upright triangle, and the box connecting these quantities is not drawn. The maximum dose is shown as a red bull's eye, and the minimum dose as a red diamond when no left censored data were present. Each dose in a quarter that is larger (on a log scale) than log(xq75) + 1.5 × [log(xq75) – log(xq25)] is shown as a black plus sign (+). All data points in a quarter that are smaller (on a log scale) than log(xq25) + 1.5 × [log(xq75) – log(xq25)] are also shown as plus signs, although these may be incomplete when there are a large number of zero doses. In each of the four pairs of box plots in Figure 1, the left-hand plot is for Group 1 during the quarter and the right-hand for Group 2. In addition, a horizontal line is shown at 300 mrem, corresponding to 10 percent of the quarterly Radiation Protection Guidelines dose in 1961, and it is clear that fewer than a dozen workers from either group had doses above this level in any quarter. Because Group 1 contained approximately 1200 workers each quarter and Group 2 more than 4000, at most one-half of one percent of the doses for either group in any quarter were above 10 percent of the Radiation Protection Guidelines.

Table 4-7: Descriptive Statistics for 1961 Y-12 Quarterly Gamma Doses for Two Groups of Workers Partitioned by Monitoring Status in 1960

	Quarter							
	Q1		Q2		Q3		Q4	
Group	**1[a]**	**2[b]**	**1**	**2**	**1**	**2**	**1**	**2**
25th Percentile	5.4	3.7	43.8	30.4	18.9	9.9	46.2	34.4
Median	12.8	10.2	63.4	38.5	35.8	16.3	67.2	45.1
75th Percentile	27.8	16.8	98.2	51.3	67.1	25.5	103.7	56.4
max dose	1810	1,621	710	1276	1791	2173	483	1,413
K-M Mean[c]	38.4	15.8	84.5	47.3	52.4	25.4	82.6	55.4
Cumulative Dose[d]	39,350	25,943	103,323	202,773	63,123	108,285	99,962	241,033
Cumulative Dose, Adjusted[e]	47,078	64,385	103,428	203,437	63,142	108,941	99,946	241,267
% Below MDL[f]	53.1	85.9	0.5	0.7	0.1	1.2	0.0	0.1
N[g]	1,226	4,075	1,224	4,301	1,205	4,289	1,210	4,355

Notes:
[a] Y-12 workers selected to be monitored in 1960
[b] Y-12 workers not monitored in 1960
[c] Kaplan-Meier mean; product-limit estimate of the mean using censored data methods with an upper limit of 30 mrem for doses recorded as 0
[d] Dose accumulative by adding all recorded quarterly doses for the group
[e] Cumulative dose adjusted upward by using left-censored methods with an upper limit of 30 mrem for doses recorded as 0
[f] Percent of records recorded as 0 to indicate below MDL
[g] Number of quarterly doses for the group

Figure 4. Modified Box Plots for Y-12 Quarterly Gamma Doses in 1961 for Two Groups of Workers Partitioned by Monitoring Status in 1960



Altogether 65 workers, including 35 in Group 1 and 30 in Group 2, had at least one quarterly dose greater than 300 mrem. Group 1 workers were known to have higher exposure potential since they had been selected for monitoring in 1960. Group 2 workers were not expected to have potential for higher exposure, although these 30 individuals received a quarterly dose above 300 mrem in 1961 when all workers began being monitored. Information was gathered to investigate why these 30 workers had not been selected for monitoring in 1960. Collected data included hire dates, dates of change for job titles and departments, monitoring data for earlier years, and all quarterly gamma doses for 1961 through 1965.

4.4.1 Analysis of "Why Not Monitored?" Group for Gamma Doses

The 30 Group 2 workers who were not monitored at Y-12 in 1960 and had a quarterly doses greater than 300 mrem in 1961 will be referred to as the "why not monitored?" group. Results of this investigation are presented in Table 2. For those individuals whose annual gamma dose was above 1200 mrem, which was 10 percent of yearly Radiation Protection Guidelines, each quarterly dose for 1961 and the highest quarterly dose for 1962 are also given in the table.

The total number of workers in Group 2 was approximately 300 greater during the remainder of 1961 than in Q1, indicating that new employees were likely hired during Q1. Hire dates revealed that four of the "why not monitored?" group were not employed at Y-12 in 1960, and two addition members worked only part of 1960. Among the remaining 24 individuals, eighteen had only one quarter with

dose above 300 mrem. Dates of change for job titles and departments uncovered five more members of the "why not monitored?" group who changed departments in the second half of 1960 or early in 1961, which may have resulted in increasing their exposure potential. Seven group members had been monitored during the late 1950s and were found to have low gamma doses at that time, with the exception of one quarterly dose of 337 mrem.

For the remaining 12 members of the "why not monitored?" group, the explanation of why they were not selected for monitoring in 1960 is less obvious. However, in 1961 eight of these 12 workers had only one quarterly dose above 300 mrem and an annual dose below 10 percent of the yearly Radiation Protection Guidelines. The highest quarterly dose in 1962 for six of these eight workers was below 300 mrem; one chemical operator and one development mechanic had a quarterly dose in 1962 above this limit. Among the four workers with annual doses in 1961 above 1200 mrem, one was a welder with three quarterly doses each below 80 mrem and a Q3 dose of 1413. The final three individuals were all development mechanics who appeared to have quarterly doses that were consistently above 300 mrem.

The dose assignment methodology for unmonitored quarters before 1961 includes a scaling factor based on an individual's doses after 1961 (ORAUT-PROC-0042). For the scaling factor to be applied, the worker must have been monitored for at least five quarters during the period from 1961-1965 and must have routine duties and work location essentially the same during the 1950s and early 1960s. This scaling factor would be implemented to adjust doses derived for each unmonitored quarter before 1961 for all of the approximately 4000 Y-12 workers (including members of the "why not monitored?" group) who met the two criteria. In particular, the development mechanics, chemical operator, and welder, for whom there is no clear explanation of why they were not monitored before 1961, would also receive claimant favorable doses due to the scaling factor adjustment. It is notable that out of over 5000 Y-12 workers only six (about one-tenth of one percent) may have been overlooked when selecting workers to be monitor in 1960.

Table 4-8A: Job and 1961 Gamma Dose Information for Y-12 Workers Not Selected for Monitoring in 1960 and Having a Quarterly Dose above 300 mrem in 1961

Annual 1961 Dose	Highest 1961 Dose	Job Title	Department	Comments	Monitoring Quarters 1961-1965[a]
Not a Y-12 employee during all of 1960					
1518	1413	Machinist	2703	First Hired 04-10-61 1961 Doses Quarter 2=41 Quarter 3=64 Quarter 4=1413 All 4 Doses for 1962-Below 80 Group 2 Max Quarter 4 dose	16
1198	1170	Coop. Student	2619	First Hired 01-09-61	11
1163	871	Assembler	2722	First Hired 01-31-61	20
614	362	Machinist	2003	First Hired 10-03-60	20
516	460		2077	Hired 01-16-61	17

Table 4-8A: Job and 1961 Gamma Dose Information for Y-12 Workers Not Selected for Monitoring in 1960 and Having a Quarterly Dose above 300 mrem in 1961

Annual 1961 Dose	Highest 1961 Dose	Job Title	Department	Comments	Monitoring Quarters 1961-1965[a]
Not a Y-12 employee during all of 1960					
		Electrician			
501	322	Lab Trainee	2259	Hired 03-01-60 High Dose in Quarter 4	13

Notes:

[a] Number of quarters of monitoring data from 1961-1965. Any worker with at least five monitored quarters in 1961-1965 (with similar job duties and location before and after 1961) has a scaling factor applied to the assigned dose for each unmonitored quarter before 1960.

Table 4-8B: Job and 1961 Gamma Dose Information for Y-12 Workers Not Selected for Monitoring in 1960 and Having a Quarterly Dose above 300 mrem in 1961

Annual 1961 Dose	Highest 1961 Dose	Job Title	Department		Monitoring Quarters 1961-1965[a]
Previously monitored in late 1950s with same job tasks					
2493	2173	Craft Foreman	2703	Monitored in 1956 and 1957-Low Doses 1961 Doses Q1=8 Q2=220 Q3=2173 Q4=92 Highest 1962 Dose-98 Group 2 max Q3 Dose	19
1745	883	Mechanic-Devel.	2018	Monitored in 1958 and 1959-Low Doses 1961 Doses Q1=305 Q2=883 Q3=230 Q4=327 Highest 1962 Dose-429	19
1298	552	Mechanic-Devel.	2018	Monitored in 1958 and 1959-Low Doses 1961 Doses Q1=212 Q2=129 Q3=552 Q4=405 Highest 1962 dose 215	5
792	323	Receiving Clerk	2701	Monitored in 1958 and 1959-Three Low Doses and One Dose of 337 Changed from dept. 2128 on 10-03-60	20
756	337	Machine Operator	2776	Monitored in 1957-Dose 0	19
368	318	Metal Worker	2003	Monitored in 1958 and 1959-Low Doses	20
362	316	Cleaner	2659	Monitored in 1958 and 1959-Low Doses	20

Notes:

[a] Number of quarters of monitoring data from 1961-1965. Any worker with at least five monitored quarters in 1961-1965 (with similar job duties and location before and after 1961) has a scaling factor applied to the assigned dose for each unmonitored quarter before 1960.

Table 4-8C: Job and 1961 Gamma Dose Information for Y-12 Workers Not Selected for Monitoring in 1960 and Having a Quarterly Dose above 300 mrem in 1961

Change in department or job tasks between 1960 and 1961

Annual 1961 Dose	Highest 1961 Dose	Job Title	Department	Comments	Monitoring Quarters 1961-1965[a]
1686	1621	Engineer	2057	Changed from dept. 2058 on 08-01-60 1961 Doses Q1=1621 Q2=23 Q3=16 Q4=26 Highest 1962 Dose-6 Group 2 max Q1 Dose	5
1202	401	Mechanic-Devel.	2018	Switched from machinist on 09-19-60 1961 Doses Q1=337 Q2=309 Q3=157 Q4=401 Highest 1962 Dose-557	20
775	395	Chemical Operator	2638	Changed from dept. 2638 on 06-27-60	20
516	356	Production Operator	2722	Changed from dept. 2687 on 01-16-61	20

Notes:

[a] Number of quarters of monitoring data from 1961-1965. Any worker with at least five monitored quarters in 1961-1965 (with similar job duties and location before and after 1961) has a scaling factor applied to the assigned dose for each unmonitored quarter before 1960.

Table 4-8D: Job and 1961 Gamma Dose Information for Y-12 Workers Not Selected for Monitoring in 1960 and Having a Quarterly Dose above 300 mrem in 1961

Unclear why not monitored in 1960

Annual 1961 Dose	Highest 1961 Dose	Job Title	Department	Comments	Monitoring Quarters 1961-1965[a]
2443	1127	Mechanic-Devel.	2018	1961 Doses Q1=590 Q2=360 Q3=366 Q4=1127 Highest 1962 Dose-1,018	19
2210	1276	Mechanic-Devel.	2018	1961 Doses Q1=378 Q2=1276 Q3=316 Q4=240 Highest 1962 Dose-277 Group 2 max Q2 Dose	20

Table 4-8D: Job and 1961 Gamma Dose Information for Y-12 Workers Not Selected for Monitoring in 1960 and Having a Quarterly Dose above 300 mrem in 1961

Unclear why not monitored in 1960

Annual 1961 Dose	Highest 1961 Dose	Job Title	Department	Comments	Monitoring Quarters 1961-1965[a]
1582	617	Mechanic-Devel.	2018	1961 Doses - Q1=362 Q2=617 Q3=323 Q4=280 Highest 1962 Dose-956	19
1557	1413	Welder	2158	1961 Doses Q1=14 Q2=77 Q3=1413 Q4=53 Highest 1962 Dose-178	19
1106	624	Mechanic-Devel.	2820	Highest 1962 Dose-200	20
905	624	Mechanic-Devel.	2018	Highest 1962 Dose-71	20
798	381	Mechanic-Devel.	2018	Highest 1962 Dose-296	20
751	309	File Clerk	2617	Highest 1962 Dose-59	20
683	310	Process Operator	2619	Highest 1962 Dose-264	19
649	333	Chemical Operator	2617	Highest 1962 Dose-569	19
504	327	Mechanic-Devel.	2018	Highest 1962 Dose-861	19
370	318	Mechanic-Devel.	2158	Highest 1962 Dose-65	18
357	300	Record Clerk	2018	Highest 1962 Dose-19	20

Note:
[a] Number of quarters of monitoring data from 1961-1965. Any worker with at least five monitored quarters in 1961-1965 (with similar job duties and location before and after 1961) has a scaling factor applied to the assigned dose for each unmonitored quarter before 1960.

4.5 Comparison of Maximum Monitoring Data Results

Available monitoring data (CER databases) for members of the proposed class show that plumbers, pipefitters, and steamfitters were monitored at a frequency similar to that of the Y-12 work force as a whole. During the 1948 through 1957 period approximately 10% of the nearly 300 proposed class members were monitored at some time externally and approximately 30 % were monitored internally (urinalysis). Based on analyses presented in the preceding subsections, it is assumed that the proposed class members chosen for monitoring were those performing the highest exposure potential activities.

The following table presents a comparison between the maximum monitoring results of the proposed class members and of non-class members. This comparison indicates that as a class, even the most highly exposed plumbers, pipefitters, and steamfitters were not as highly exposed as other types of Y-

12 workers. The comparison further confirms that sufficient data are available to calculate conservative, maximum potential doses for the proposed class members.

Table 4-9: Comparison of Maximum Internal and External Annual Monitoring Results[a] Between Members of the Proposed Class[b] and Non-Class Members[c]

Year	Data Set	Gamma	Beta	Neutron	Urinalysis
50	Non Class	0	0	0	795
	P. Class[b]	-	-	-	4
51	Non Class	0	0	0	11,100
	P. Class[b]	0	0	0	18
52	Non Class	934	3,133	18	38,865
	P. Class[b]	600	0	0	48
53	Non Class	1,215	4,605	85	9,975
	P. Class[b]	0	300	0	8
54	Non Class	3,595	6,961	592	28,291
	P. Class[b]	0	287	0	321
55	Non Class	1,220	8,522	654	36,967
	P. Class[b]	751	751	0	470
56	Non Class	1,282	5,234	81	7,145
	P. Class[b]	0	90	0	771
57	Non Class	974	5,829	60	25,414
	P. Class[b]	83	826	0	199

Notes:
[a] Results for external measurements are mrem. Results for internal measurements are disintegration per minute (dpm).
[b] Proposed Class of Plumbers, Pipefitters, and Steamfitters.
[c] All Y-12 employees that are not members of the proposed class definition
- = No data available

5.0 Additional Analysis by Department

The following sections provide additional analysis by department.

5.1 Gamma Dose Analysis

The modified boxplots below for 1956 through 1965 are for departments with highest potential for external exposure. The corresponding table for each boxplot contains the summary statistics used to construct the boxplot. Comparing doses before and after 1961, it is apparent that there was dose levels after 1961 were not elevated above levels for earlier years when only selected individuals were monitored. In fact, when all workers were monitored, the dose distribution for several of these higher exposure potential departments dropped rather than rose. Only department 2619 showed some rising in dose distributions after 1961. However, levels were very similar to the mid-1950s, and nearly all quarterly doses were below 10% of the Radiation Protection Guidelines.

Figure 5. Modified Boxplot for Gamma Doses in Department 2233

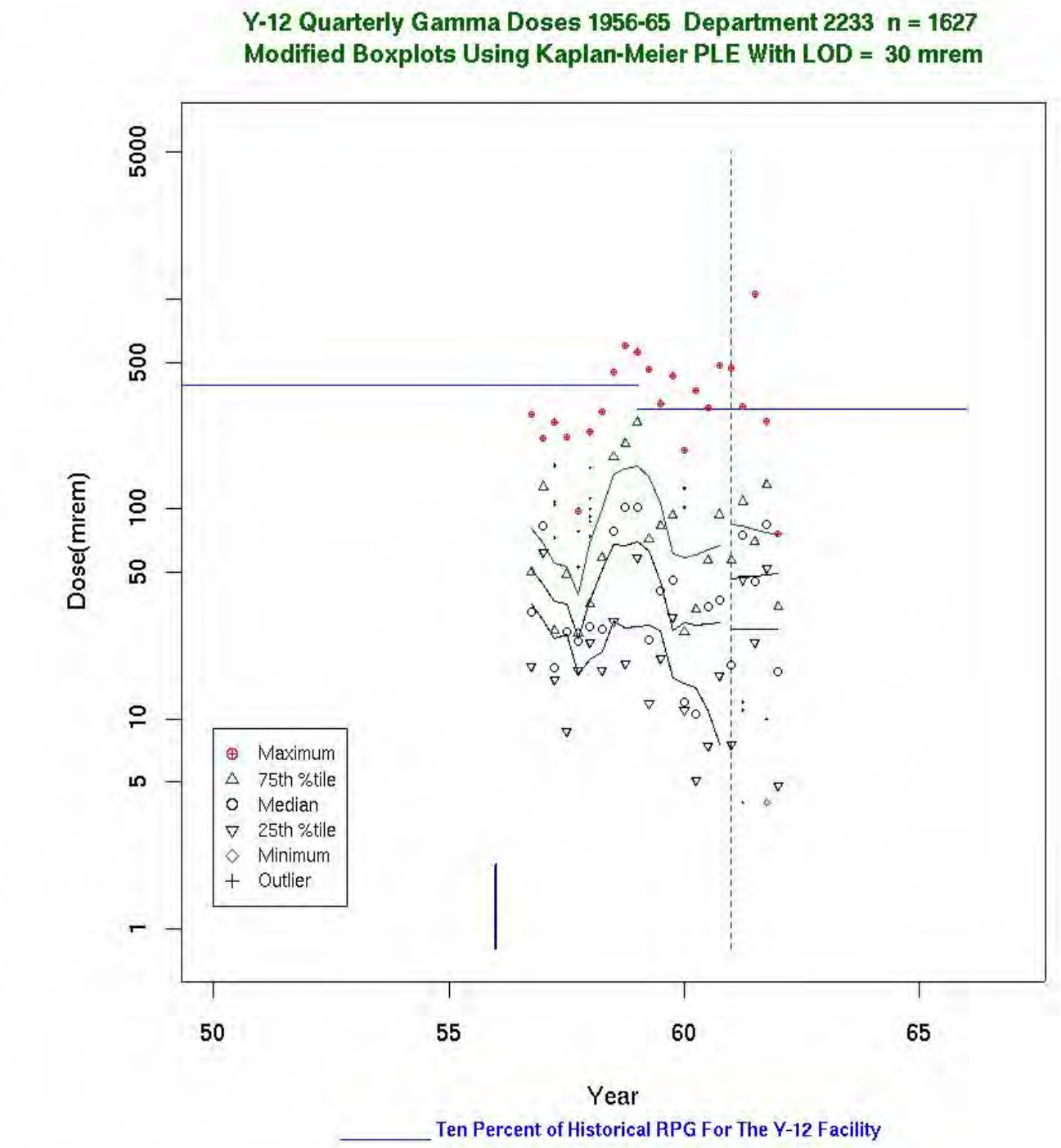


Table 5-1: Department 2233 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	100	NA	6
56 Q3	NA	NA	NA	NA	NA	NA	NA	NA	NA	93.8	NA	32
56 Q4	48.9	7.8	17.7	32.4	50	282	0.771	1,195	1,614	42.4	1	33
57 Q1	100.5	7.9	62.2	83.1	127.5	217	0.531	3,889	3,920	2.6	0	39
57 Q2	37.8	7.4	15.3	17.5	26.4	260	0.401	1,242	1,663	52.3	6	44
57 Q3	45.1	7.1	8.7	25.9	48.8	221	1.281	1,879	2,210	42.9	0	49
57 Q4	26.3	2.7	17.1	23.4	25.6	98	0.297	383	1,210	80.4	3	46
58 Q1	42.7	6	23.2	27.4	35	232	0.305	1,334	1,964	54.3	7	46
58 Q2	58.4	9.4	17	26.7	58.8	291	0.921	2,626	2,745	12.8	0	47
58 Q3	113.7	15.8	29	78	177	449	1.341	4,197	4,321	18.4	0	38
58 Q4	152.1	23.8	18.3	102	205	600	1.791	5,913	6,236	31.7	0	41
59 Q1	175.4	25	58.8	102.5	259.3	562	1.1	6,824	6,841	2.6	0	39
59 Q2	52.2	11.3	11.9	23.7	71.5	461	1.332	3,519	3,550	57.4	0	68
59 Q3	69.7	10.9	19.3	40.5	83	319	1.081	2,973	3,206	28.3	0	46
59 Q4	75.6	11.8	30.5	45.8	93	432	0.826	2,825	2,948	12.8	0	39
60 Q1	28.4	4.8	11	12	25.9	190	0.638	1,179	1,477	36.5	4	52
60 Q2	36.4	7.5	5.1	10.6	33.4	365	1.395	1,948	2,220	34.4	0	61
60 Q3	59.9	10.9	7.4	34	57	303	1.515	2,865	2,875	2.1	0	48
60 Q4	75.2	10.8	16.1	37	94	485	1.306	4,908	5,114	16.2	0	68
61 Q1	44.9	4.8	7.5	18	57.2	472	1.506	6,830	7,633	38.8	0	170
61 Q2	87.6	3.9	46.1	75	108.7	307	0.636	18,084	18,133	1.4	0	207
61 Q3	59.2	6.2	23.2	45	69.6	1054	0.816	10,840	10,834	0	1	183
61 Q4	97.7	3.7	52.1	84.6	131.1	261	0.684	20,605	20,615	0	0	211
62 Q1	28.8	8.7	4.8	16.8	34	76	1.451	218	230	12.5	0	8

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Table 5-2: Department 2618 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
57 Q4	32	4.3	16.6	21.2	37.5	70	0.603	325	448	42.9	0	14
58 Q1	38.2	5	16.4	27.9	43.8	125	0.726	897	1,108	34.5	0	29
58 Q2	192.8	24.6	87	174	275	450	0.853	4,598	4,627	4.2	0	24
58 Q3	152.7	25.1	69	113	200	495	0.789	3,908	3,970	11.5	0	26

Table 5-2: Department 2618 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
58 Q4	82.6	10.9	51.8	71	89.3	262	0.404	1,734	1,735	0	1	21
59 Q2	41.5	16.1	11.2	22.5	37	807	0.883	2,237	2,241	64.8	2	54
59 Q3	155.9	12.2	51.5	149.5	201.7	530	1.012	14,622	14,810	13.7	0	95
59 Q4	119.4	10.2	21.2	87	175.8	587	1.568	15,787	16,358	25.5	0	137
60 Q1	85.7	5.9	23.3	52.5	118.8	448	1.208	19,143	19,625	11.4	0	229
60 Q2	107.7	5.9	33.8	86	147.2	493	1.091	26,068	26,279	6.1	0	244
60 Q3	115.2	7.1	56	95.5	165.5	346	0.803	14,025	14,054	1.6	0	122
60 Q4	189.5	9.8	129	190.5	259	390	0.517	15,347	15,350	0	0	81
61 Q1	38.6	4.3	8.9	21.8	57	291	1.379	3,291	3,783	38.8	0	98
61 Q2	106.9	4.6	73.7	105.5	129.5	280	0.418	11,011	11,011	0	0	103
61 Q3	68.5	4.1	34.5	68	96.8	159	0.764	6,129	6,165	2.2	0	90
61 Q4	108.6	5.6	68.9	108.5	133.2	483	0.489	10,750	10,751	0	1	99
62 Q1	50.6	3.6	25	47.3	69.5	121	0.758	3,944	3,947	0	0	78
62 Q2	144.1	11.9	90	131	156	734	0.408	10,949	10,952	0	3	76
62 Q3	99.6	14.6	48.5	79.5	97.4	1025	0.517	7,270	7,271	0	2	73
62 Q4	71	3.7	45.8	72.9	88.6	175	0.49	5,252	5,254	0	0	74
63 Q1	39.6	6	6.2	32	41.4	536	1.405	3,485	3,643	14.1	0	92
63 Q2	34.7	4	13.3	17.5	43.6	215	0.88	2,781	3,297	33.7	0	95
63 Q3	37.8	4.9	2.6	25.7	54.9	273	2.269	3,189	3,440	27.5	0	91
63 Q4	22	1.6	12.2	16.7	24.8	83	0.524	1,424	2,090	41.1	1	95
64 Q1	42.3	1.6	16.9	34.4	43.5	156	0.699	4,063	5,922	44.3	0	140
64 Q2	40.4	2.5	26.1	28	33.6	191	0.188	3,646	5,656	52.1	27	140
64 Q3	88.5	3.9	56.3	74.3	110.5	235	0.5	12,364	12,390	0.7	0	140
64 Q4	54.5	3.4	25	44.3	70.9	233	0.773	7,261	7,466	8.8	0	137
65 Q1	20	2	8.3	14.3	23.1	152	0.761	1,444	2,120	45.3	1	106
65 Q2	26	2.6	10.2	19.5	29	130	0.777	1,637	1,768	11.8	0	68
65 Q3	33.2	3.3	17.2	26.8	38.3	171	0.59	2,192	2,191	0	1	66
65 Q4	37.1	3	20.6	29.3	45.5	108	0.586	1,890	1,892	0	0	51

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)

[8] Cumulative dose

[9] n*kmm—"adjusted" cumulative dose

[10] Percent non-detects

[11] Number of positive outliers

[12] Total number of quarterly doses

Figure 6. Modified Boxplot for Gamma Doses in Department 2618

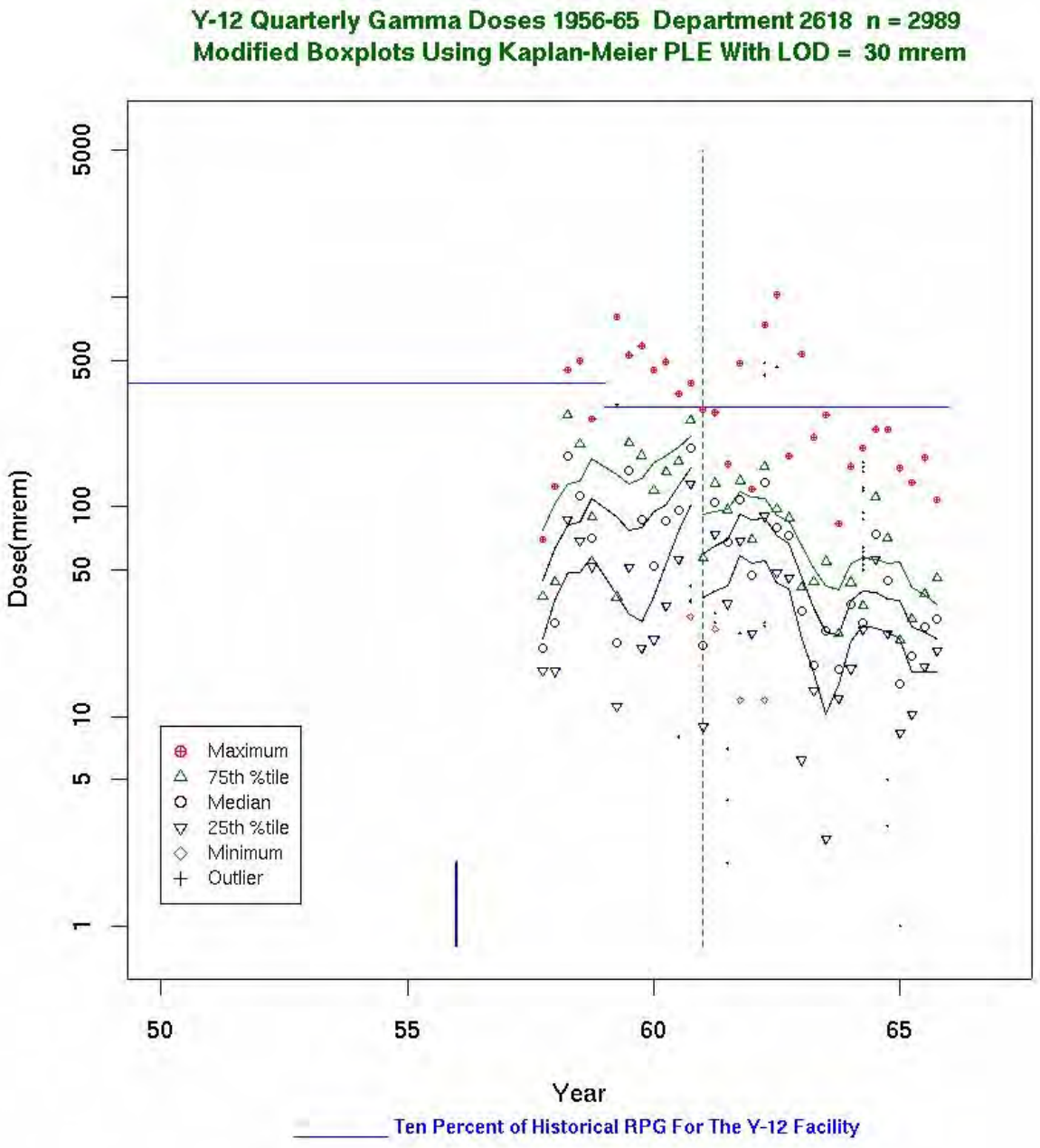


Figure 7. Modified Boxplot for Gamma Doses in Department 2619

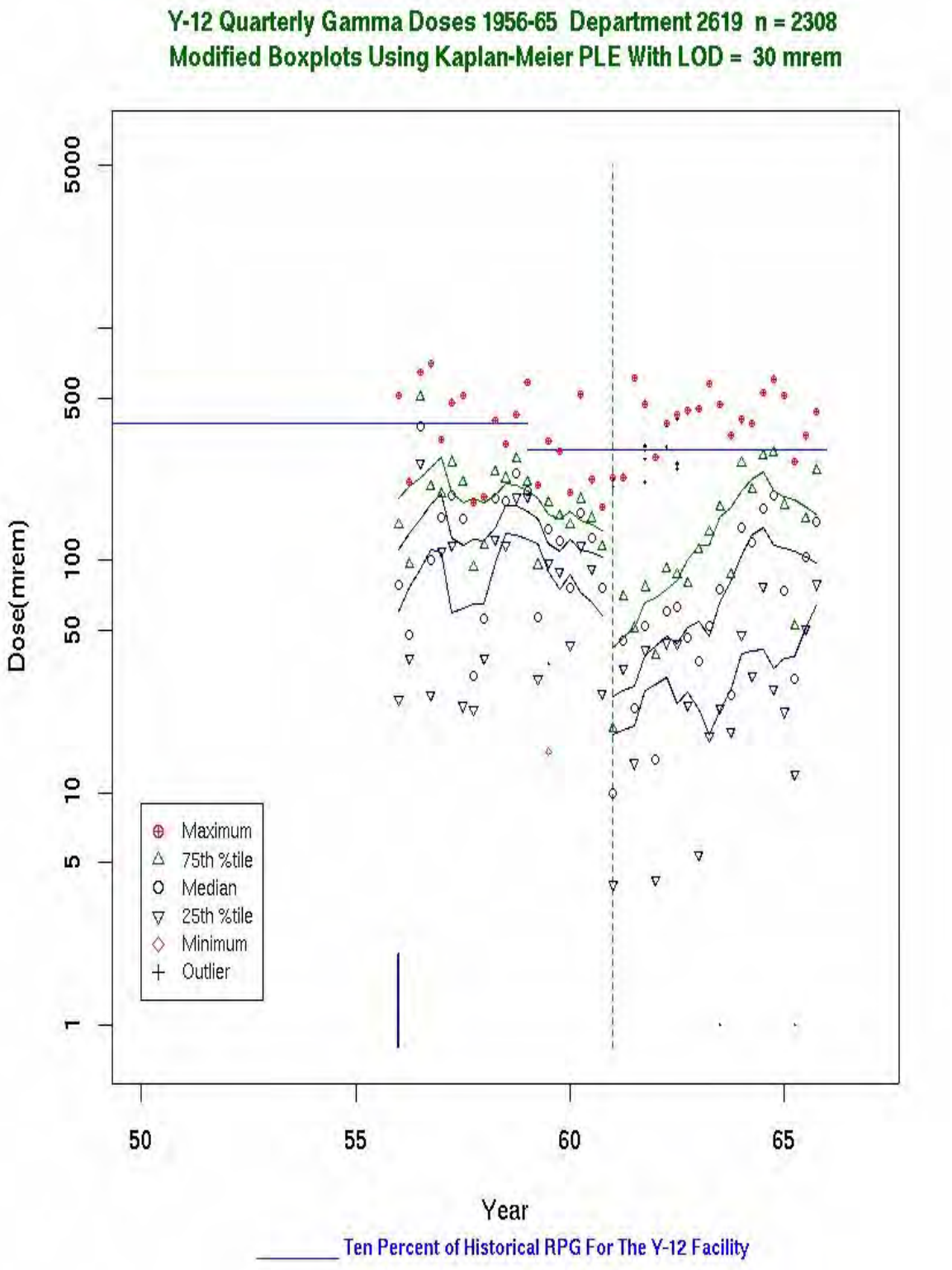


Table 5-3: Department 2619 Summary Statistics for Gamma Doses

Date (by year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	115	22.1	25.3	78.5	142	513	1.278	3,105	3,105	14.8	0	27
56 Q2	77.5	12.7	38	48	96	218	0.687	1,535	1,550	10	0	20
56 Q3	378.8	35.8	261.5	378	502.3	649	0.484	7,197	7,197	0	0	19
56 Q4	168.9	39.3	26.3	100	208.8	701	1.537	3,367	3,547	28.6	0	21
57 Q1	160.6	18.8	110	154	192.5	332	0.415	2,830	2,891	11.1	0	18
57 Q2	209.1	26.6	116	190	264	479	0.61	3,346	3,346	0	0	16
57 Q3	157.4	25.2	23.6	150	216	513	1.642	3,253	3,463	31.8	0	22
57 Q4	61.2	9.9	22.9	32	93	178	1.039	1,132	1,224	20	0	20
58 Q1	83.2	15.5	38	56	115.5	188	0.824	1,165	1,165	0	0	14
58 Q2	195.8	24.9	123.5	186	239.5	399	0.491	2,741	2,741	0	0	14
58 Q3	182.2	19.4	116	180	225	316	0.491	2,186	2,186	0	0	12
58 Q4	246.4	18.2	186.5	237.5	274.6	425	0.287	3,696	3,696	0	0	15
59 Q1	222.3	26.1	188.2	199.5	218.2	585	0.11	3,335	3,334	0	1	15
59 Q2	79.5	13.3	30.8	57	95.5	211	0.84	1,231	1,352	23.5	0	17
59 Q3	147.5	19.4	97	136	176	326	0.442	2,360	2,360	0	0	16
59 Q4	127.8	15.3	89.2	121.5	155.5	294	0.412	2,211	2,300	16.7	0	18
60 Q1	93.4	11.4	43	76	143	196	0.891	2,226	2,242	4.2	0	24
60 Q2	169.8	18.2	115.4	159	183.3	517	0.343	3,905	3,905	0	1	23
60 Q3	125.7	8.6	92	125	151.8	222	0.371	2,891	2,891	0	0	23
60 Q4	86.7	14	26.6	76	114.5	169	1.082	896	954	18.2	0	11
61 Q1	18.6	2.6	4	10	18.9	228	1.153	1,826	3,013	64.8	3	162
61 Q2	61.2	3.2	34.1	45.2	69.8	228	0.531	9,664	9,670	0	1	158
61 Q3	46	5	13.4	23	51	612	0.99	7,267	7,268	0	1	158
61 Q4	72	4.8	41	52.4	76.6	472	0.464	11,155	11,160	0	6	155
62 Q1	29.3	2.8	4.2	13.8	39	278	1.654	4,343	4,336	0	0	148
62 Q2	77.5	4.7	44.1	60.4	92.2	388	0.547	11,546	11,548	0	3	149
62 Q3	76	5	43.8	63	86.4	422	0.504	11,092	11,096	0	5	146
62 Q4	65.1	5	23.9	46.2	79.8	440	0.894	9,426	9,440	0.7	0	145
63 Q1	74.1	8.4	5.4	37	111	448	2.239	8,090	8,447	29.8	0	114
63 Q2	92.9	9.8	17.6	52	132	576	1.494	10,123	10,405	15.2	0	112
63 Q3	113.6	10.6	23.1	75.5	169.9	469	1.478	12,115	12,382	17.4	0	109
63 Q4	68.4	7	18.4	26.4	87	344	1.152	6,927	7,387	22.2	0	108
64 Q1	159.4	16.4	48	137.5	262.8	403	1.26	7,509	7,811	20.4	0	49
64 Q2	141.3	15.7	32	119.5	201.2	390	1.363	6,171	6,500	23.9	0	46
64 Q3	187.2	19.2	77	166	280.8	525	0.959	8,800	8,798	0	0	47
64 Q4	195.9	23.8	28	190	289	604	1.73	7,705	7,836	17.5	0	40
65 Q1	142.5	28.6	22.3	74.5	173	511	1.519	3,983	4,132	24.1	0	29
65 Q2	56.4	13.7	12	31	52	267	1.087	1,269	1,354	25	0	24
65 Q3	128.3	19	50.5	104	150	344	0.807	2,823	2,823	0	0	22
65 Q4	181.2	26.3	79	146	243.5	435	0.834	3,987	3,986	0	0	22

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] **[log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)**
[8] **Cumulative dose**
[9] **n*kmm—"adjusted" cumulative dose**
[10] **Percent non-detects**
[11] **Number of positive outliers**
[12] **Total number of quarterly doses**

Figure 8. Modified Boxplot for Gamma Doses in Department 2701

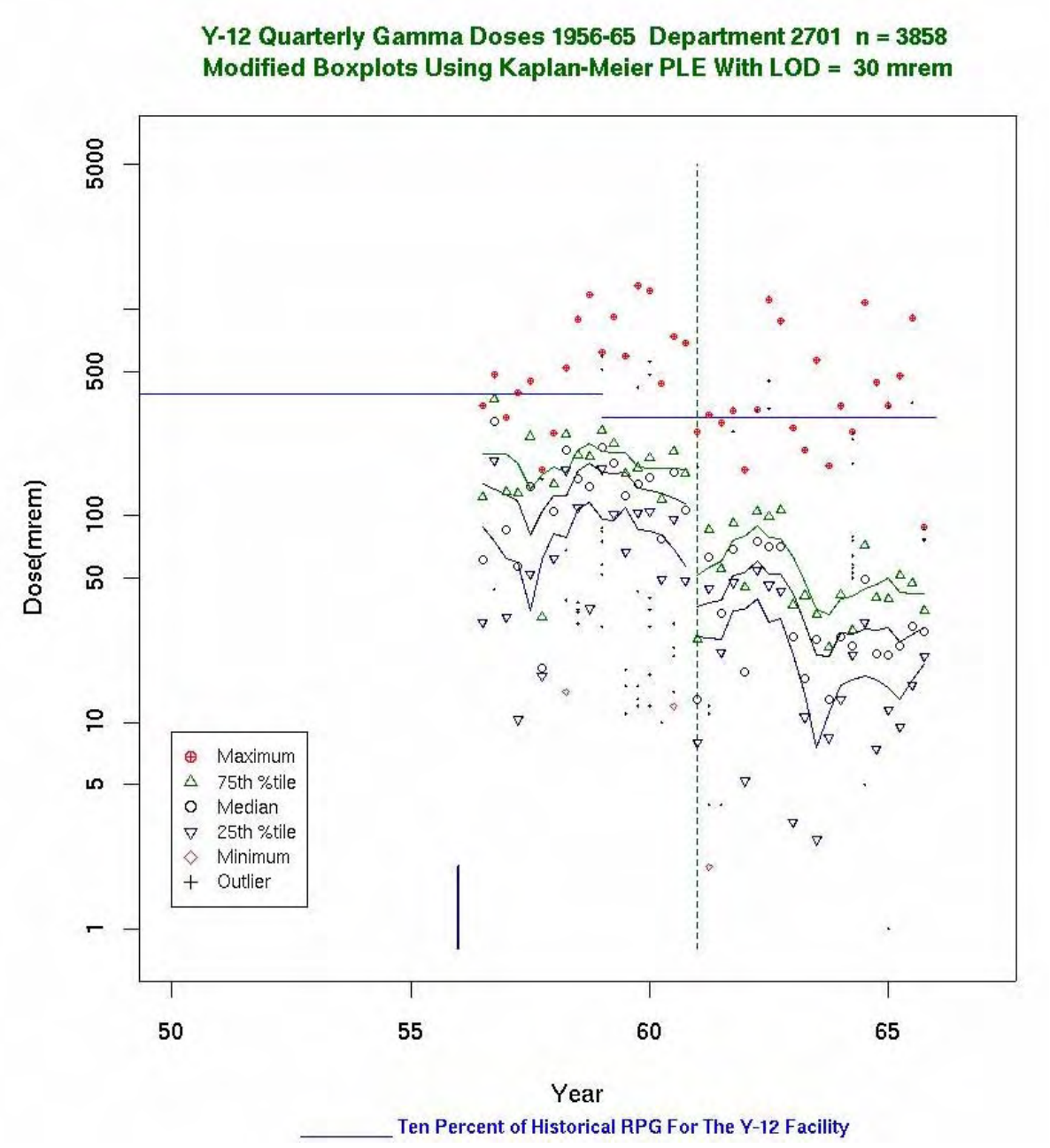


Table 5-4: Department 2701 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q3	94.3	11.2	30.4	61.2	123.5	342	1.04	4,100	4,432	23.4	0	47
56 Q4	280	17.8	185	288	365	481	0.504	14,439	14,560	7.7	0	52
57 Q1	99.1	9.5	32.2	86	130.3	300	1.035	4,994	5,351	22.2	0	54
57 Q2	82.2	10.4	10.3	57	128.8	395	1.871	4,576	4,685	15.8	0	57
57 Q3	157.2	14.5	52	138	242	447	1.14	9,280	9,432	15	0	60
57 Q4	30.2	3.6	16.7	18.2	32.2	167	0.487	1,359	1,721	33.3	2	57
58 Q1	106.3	7.3	62.5	105	141.5	251	0.606	6,518	6,591	4.8	0	62
58 Q2	218.5	11	166	209	247	516	0.295	13,108	13,110	0	1	60
58 Q3	163.7	15.3	110	151.8	196	895	0.428	9,955	9,986	4.9	1	61
58 Q4	147.8	16.4	35.5	139	193.5	1,170	1.257	10,985	11,528	23.1	0	78
59 Q1	216.7	8.7	168.4	213.5	258.2	615	0.317	25,700	25,787	2.5	3	119
59 Q2	175.4	11.7	102.5	180	223	915	0.576	16,252	16,488	8.5	1	94
59 Q3	122	8.6	67	125.6	160.2	594	0.646	11,468	11,590	6.3	1	95
59 Q4	148.4	13.2	103	143	170.5	1,290	0.374	15,289	15,434	10.6	2	104
60 Q1	171.2	15.9	105	153	191	1,227	0.444	14,359	14,381	1.2	3	84
60 Q2	96.8	8.1	49.2	77	120.5	435	0.663	8,284	8,325	3.5	0	86
60 Q3	163.4	7.8	95.9	161.5	205.8	737	0.566	24,023	24,020	0	1	147
60 Q4	119.9	8.1	48.5	106	159.5	685	0.882	16,886	17,026	4.9	0	142
61 Q1	22.8	2.3	8	12.9	25.1	255	0.852	2,985	4,150	50	2	182
61 Q2	70.2	2.7	44.3	62.7	85.5	309	0.487	13,909	13,900	0	1	198
61 Q3	44.2	2.4	21.7	33.9	55.3	280	0.694	8,781	8,796	0.5	1	199
61 Q4	78.6	3.1	47.5	69	92.4	323	0.493	15,569	15,563	0	2	198
62 Q1	34.6	3.8	5.2	17.4	45	166	1.6	3,596	3,598	0	0	104
62 Q2	91.6	5.4	54.8	75	105	326	0.483	8,980	8,977	0	2	98
62 Q3	94.3	11.8	46.1	71.2	99.1	1,114	0.567	9,615	9,619	0	3	102
62 Q4	89.5	9.7	43.4	70.8	106	873	0.662	8,859	8,860	0	1	99
63 Q1	31.4	3.9	3.3	25.9	37	266	1.782	3,112	3,485	27	0	111
63 Q2	32.1	3.6	10.6	16.2	41	208	1.002	2,882	3,595	42.9	0	112
63 Q3	38.9	6.3	2.7	25.2	33.1	564	1.847	4,008	4,746	41.8	0	122
63 Q4	19.4	2	8.4	13	23.2	174	0.75	1,407	2,464	59.1	1	127
64 Q1	42.6	3.3	12.9	25.8	41.5	339	0.866	2,642	4,473	58.1	1	105
64 Q2	36.6	4.1	21.1	23.4	27.9	255	0.207	1,961	3,733	70.6	13	102
64 Q3	65.9	10.8	30.5	49	71.8	1,077	0.635	6,578	6,590	1	1	100
64 Q4	36.3	5.4	7.4	21.6	40	440	1.255	3,078	3,630	40	0	100
65 Q1	35.9	5.3	11.5	21.1	39.6	343	0.919	2,828	3,410	37.9	2	95
65 Q2	42.3	6.6	9.5	23.5	51.5	473	1.254	3,457	3,638	17.4	0	86
65 Q3	51.9	12	15.2	29.1	47	907	0.834	4,150	4,152	0	2	80
65 Q4	31.9	1.7	20.9	27.7	34.6	88	0.375	2,517	2,520	0	4	79

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)

[8] Cumulative dose

[9] n*kmm—"adjusted" cumulative dose

[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Figure 9. Modified Boxplot for Gamma Doses in Department 2702

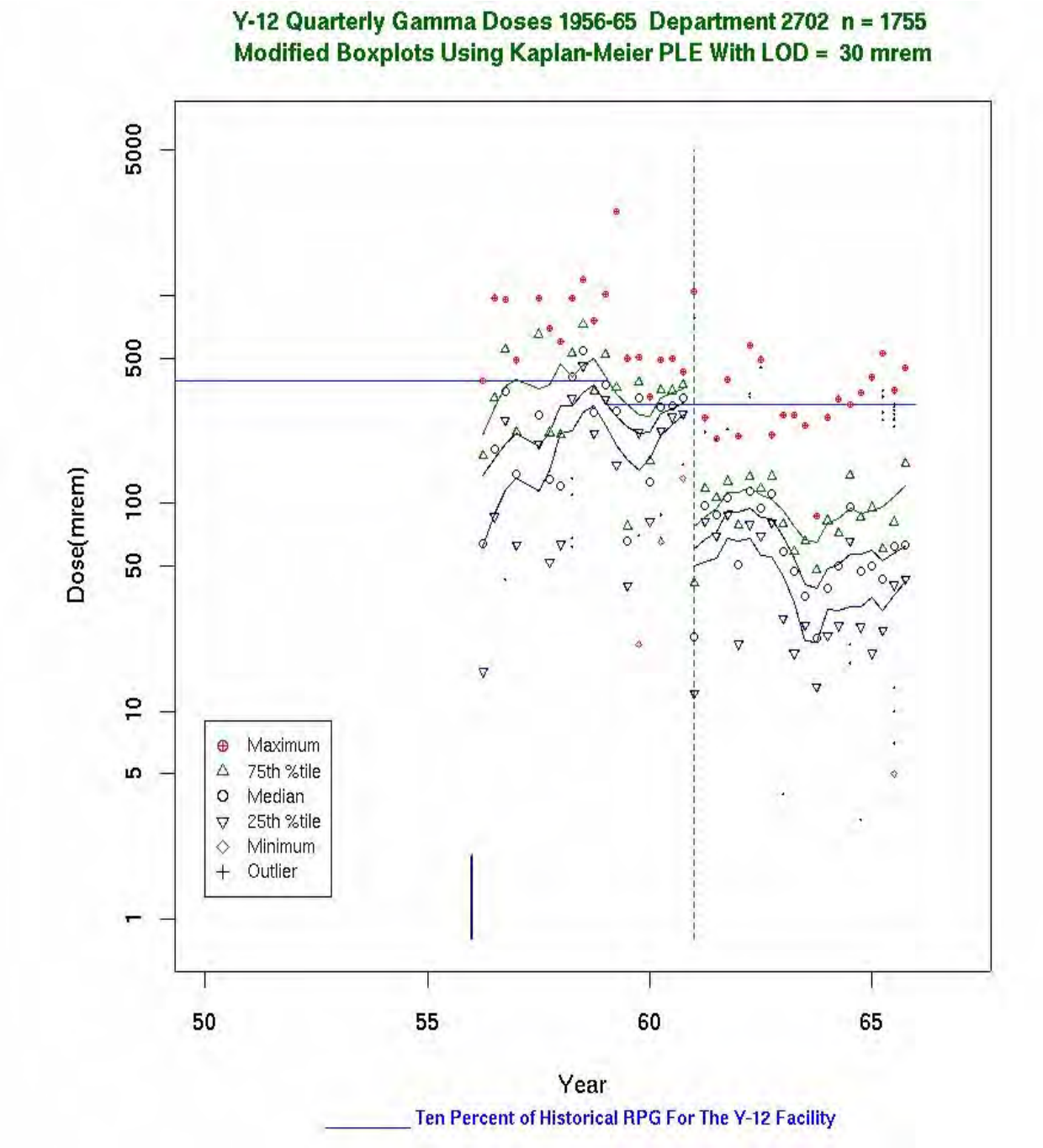


Table 5-5: Department 2702 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	3
56 Q2	115.7	15.6	15.5	64	168.8	388	1.772	5,815	6,132	28.3	0	53
56 Q3	231.2	25.8	86.2	183.5	322.8	977	0.978	11,669	11,791	7.8	0	51
56 Q4	403	30	252.3	345	552.3	955	0.581	18,880	18,941	4.3	0	47
57 Q1	161.4	15.8	63	137.5	219	487	0.924	7,366	7,424	4.3	0	46
57 Q3	399.2	43.6	193	266	651.5	974	0.902	15,109	15,170	5.3	0	38
57 Q4	172	27.2	52.5	131	218.5	695	1.057	6,516	6,536	2.6	0	38
58 Q1	170.3	21.3	63.5	121.5	214.3	599	0.901	7,280	7,323	4.7	0	43
58 Q2	421.3	33.1	319.3	407.5	524.3	971	0.368	16,402	16,431	2.6	0	39
58 Q3	613.9	36.4	459.8	539	723	1,196	0.336	21,485	21,486	0	0	35
58 Q4	314.5	26.2	217.5	275	344.8	754	0.341	11,008	11,008	0	1	35
59 Q1	423.6	34.9	318.7	370	520.2	1,015	0.363	12,283	12,284	0	0	29
59 Q2	361	84.8	154	277	363	2,540	0.636	10,109	10,108	0	1	28
59 Q3	91.6	14.3	40	66.2	77.8	500	0.493	2,932	2,931	0	1	32
59 Q4	300.9	16.6	219	320	383.8	505	0.416	12,637	12,638	0	0	42
60 Q1	129.9	10.3	82	126	160	324	0.496	4,647	4,676	2.8	0	36
60 Q2	288.5	16.3	224.2	292	349.3	489	0.328	12,405	12,406	0	0	43
60 Q3	302.1	11.3	260.4	294.5	348.2	499	0.216	12,992	12,990	0	0	43
60 Q4	313.3	12.7	270.2	322	372.5	427	0.238	10,964	10,966	0	0	35
61 Q1	69.5	26.6	12.2	22.7	41.4	1,052	0.903	3,123	3,266	21.3	2	47
61 Q2	108.1	6.3	82.2	97.7	117.5	257	0.264	4,973	4,973	0	2	46
61 Q3	93.9	5.5	69.8	88.2	106.1	205	0.311	4,415	4,413	0	2	47
61 Q4	119.3	7.6	88.5	107	127.5	393	0.271	5,490	5,488	0	2	46
62 Q1	60.6	7.7	21	51	78.5	211	0.977	2,364	2,363	0	0	39
62 Q2	133.3	16.2	79	114	135	574	0.397	4,800	4,799	0	3	36
62 Q3	115.6	15.5	69.9	94.4	118.1	493	0.389	4,279	4,277	0	2	37
62 Q4	121.7	7.1	80.6	110.5	135.4	213	0.385	4,747	4,746	0	0	39
63 Q1	65.8	8.8	28	58.3	79.5	266	0.774	2,605	2,632	7.5	0	40
63 Q2	55.5	8.2	19	47	58.7	265	0.836	2,111	2,220	15	0	40
63 Q3	56.6	7.1	26	36	66	237	0.691	2,131	2,264	15	0	40
63 Q4	32.2	3.8	13.1	22.4	47.8	87	0.958	1,024	1,191	29.7	0	37
64 Q1	60.3	5.2	23.1	39.2	82.5	260	0.943	3,739	4,462	32.4	0	74
64 Q2	59.2	5.3	25.8	50	71.5	319	0.756	4,050	4,381	17.6	0	74
64 Q3	109.2	7.2	65.5	96.5	137	298	0.547	8,036	8,081	2.7	0	74
64 Q4	73.9	8.6	25.4	47	85.5	341	0.9	5,162	5,321	12.5	0	72
65 Q1	77.7	10.6	19	50	95.5	403	1.195	4,975	5,128	13.6	0	66
65 Q2	74.2	11.8	24.5	43	60.5	526	0.67	4,493	4,600	8.1	5	62
65 Q3	84.8	10.3	40.5	62	81.3	349	0.516	5,260	5,258	0	8	62
65 Q4	114.4	13.3	43	63	155	448	0.951	6,862	6,864	0	0	60

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose

[9] **n*kmm—"adjusted" cumulative dose**
[10] **Percent non-detects**
[11] **Number of positive outliers**
[12] **Total number of quarterly doses**

Figure 10. Modified Boxplot for Gamma Doses in Department 2703

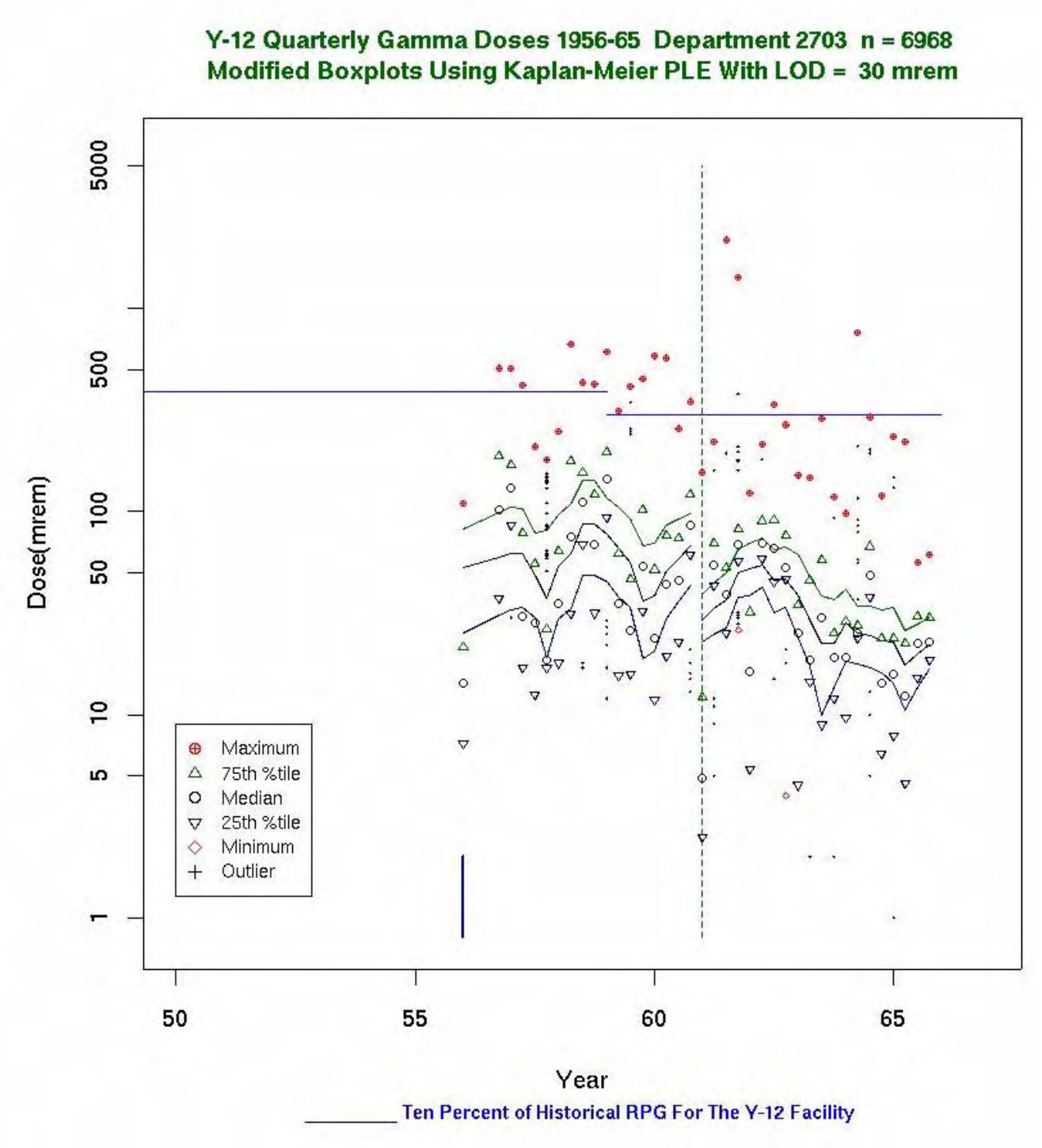


Table 5-6: Department 2703 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	29	0.6	7.2	14.3	21.5	110	0.814	350	5,046	96.6	0	174
56 Q4	125.9	6.3	37.2	102	188	507	1.2	30,796	31,223	11.7	0	248
57 Q1	136.2	5.2	85.3	131	169.9	504	0.511	25,865	25,878	2.6	1	190
57 Q2	60.5	4.8	17.1	30.5	78.8	418	1.134	11,447	12,402	26.8	0	205
57 Q3	40.9	2.7	12.6	28.3	55.5	209	1.101	7,255	7,935	21.6	0	194
57 Q4	32.6	2.3	17	18.7	26.3	180	0.324	4,219	6,487	56.3	25	199
58 Q1	52.9	3.3	17.9	35.1	64	247	0.945	10,296	11,215	22.2	0	212
58 Q2	114.9	7.2	31.4	75.3	177.8	665	1.286	23,076	23,554	10.7	0	205
58 Q3	120.2	5	69	111.7	155.4	433	0.602	27,913	28,247	7.2	0	235
58 Q4	89.7	4.3	31.6	69	121	422	0.995	24,552	25,834	18.1	0	288
59 Q1	151.2	5.1	93.2	143.5	195.9	610	0.55	46,938	47,326	5.8	1	313
59 Q2	43.2	3.2	15.6	35	62.3	311	1.029	12,059	12,182	44	0	282
59 Q3	43.5	2.7	15.8	26	46.3	410	0.799	12,221	14,094	31.5	5	324
59 Q4	73.1	3.1	32.2	54	102.2	450	0.856	24,107	25,585	18.6	0	350
60 Q1	44.3	3.2	11.8	23.8	51.7	581	1.094	13,585	15,062	26.2	1	340
60 Q2	60.9	3.5	19.5	43.8	76.5	571	1.014	19,984	20,402	8.1	0	335
60 Q3	57.3	2.7	22.8	45.5	74.2	256	0.874	16,052	16,216	3.2	0	283
60 Q4	97.6	3.7	61	85.5	121.6	348	0.511	24,938	25,083	2.7	1	257
61 Q1	11	1.8	2.5	4.9	12.2	156	1.182	671	1,276	64.7	1	116
61 Q2	58.8	2.2	43.3	54.7	69.5	220	0.35	8,026	8,056	1.5	2	137
61 Q3	55.2	11.8	25.3	39.1	52.8	2,173	0.545	10,102	10,102	0	2	183
61 Q4	81.6	7.5	57	69.2	82.2	1,413	0.272	15,427	15,422	0	8	189
62 Q1	23.4	1.9	5.4	16.4	32	123	1.313	3,071	3,089	0.8	0	132
62 Q2	79.8	2.8	58.4	69.8	90	214	0.321	10,213	10,214	0	2	128
62 Q3	71.5	3.6	45	66.1	90.2	336	0.516	8,914	8,938	0.8	1	125
62 Q4	64.6	2.7	46.4	52.8	76	268	0.365	8,207	8,204	0	1	127
63 Q1	24.3	2.3	4.5	25.1	34.5	150	1.509	2,385	2,916	40	0	120
63 Q2	30.5	2	14.5	18.5	45.7	147	0.85	3,328	3,934	28.7	0	129
63 Q3	38.1	3.3	8.9	29.9	57.8	287	1.389	4,540	4,839	20.5	0	127
63 Q4	24.3	1.7	12	19	25.1	118	0.546	2,391	3,038	29.6	3	125
64 Q1	34.7	1.1	9.6	19.2	28.7	98	0.814	1,296	3,991	78.3	0	115
64 Q2	37.7	6.7	23.7	25.3	27.4	756	0.107	2,010	4,298	76.3	10	114
64 Q3	61.1	3.9	37.8	48.4	67.2	292	0.427	6,950	6,965	0.9	3	114
64 Q4	18.1	1.7	6.4	14.3	23.7	119	0.968	1,635	2,082	31.3	0	115
65 Q1	21.5	2.8	7.9	15.9	23.9	233	0.823	1,651	2,386	47.7	3	111
65 Q2	22.6	5.4	4.6	12.4	22.4	220	1.173	891	972	16.3	0	43
65 Q3	24.9	1.9	15.2	22.5	30.5	56	0.514	945	946	0	0	38
65 Q4	26.9	1.5	18.6	22.7	30	61	0.354	1,184	1,184	0	0	44

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)

[8] Cumulative dose

[9] **n*kmm—"adjusted" cumulative dose**
[10] **Percent non-detects**
[11] **Number of positive outliers**
[12] **Total number of quarterly doses**

Figure 11. Modified Boxplot for Gamma Doses in Department 2793

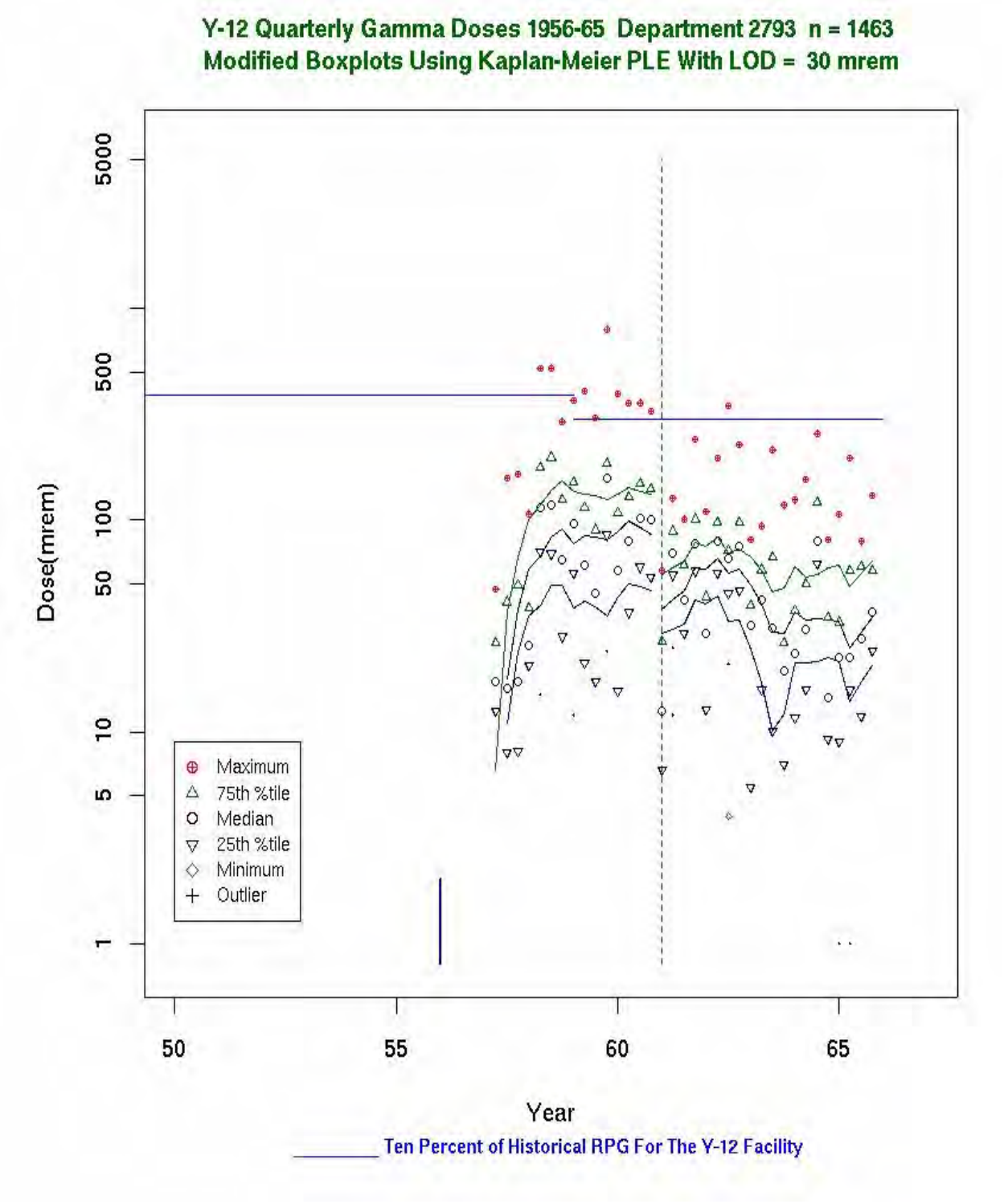


Table 5-7: Department 2793 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
57 Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	71.4	NA	7
57 Q2	23.6	3.8	12.5	17.2	26.3	47	0.55	192	260	36.4	0	11
57 Q3	48.4	9.3	8	16.1	41	157	1.209	923	1,258	61.5	0	26
57 Q4	42.7	7.2	8.1	17.2	49.3	165	1.334	1,022	1,281	50	0	30
58 Q1	36.3	4	20.5	25.5	38.5	107	0.469	1,025	1,343	37.8	1	37
58 Q2	135	12.7	70.5	114.5	177.3	521	0.683	6,829	6,885	5.9	0	51
58 Q3	138.4	11.4	69.3	118	197.6	522	0.777	8,946	8,996	4.6	0	65
58 Q4	86.2	8.2	28.1	64.5	124.5	292	1.104	5,483	5,775	17.9	0	67
59 Q1	110.6	8.1	56	96	150	366	0.73	7,876	7,963	5.6	0	72
59 Q2	78.3	9.6	21.3	61	115	405	1.252	5,315	5,324	27.9	0	68
59 Q3	61	6.5	17.3	45	90	303	1.224	3,770	3,904	14.1	0	64
59 Q4	157.3	14.8	85	157	184.5	796	0.574	9,364	9,438	5	1	60
60 Q1	75.1	9.4	15.6	58	108.5	394	1.44	3,984	4,055	9.3	0	54
60 Q2	92.6	9.1	36.5	80	129	357	0.936	4,970	5,000	3.7	0	54
60 Q3	113.1	9.2	60	101.5	148	358	0.669	6,763	6,786	1.7	0	60
60 Q4	108.5	8.7	54	101	140	325	0.706	6,050	6,076	1.8	0	56
61 Q1	18.3	2.5	6.6	12.6	26.6	58	1.032	513	750	41.5	0	41
61 Q2	73.8	4.1	54.9	70	88.8	126	0.356	3,080	3,100	2.4	0	42
61 Q3	48	3.2	29	42	61.5	101	0.557	2,206	2,208	0	0	46
61 Q4	84.4	5.6	57.3	77.5	101	240	0.42	3,797	3,798	0	1	45
62 Q1	33.6	3.7	12.7	29.3	43.5	110	0.91	1,277	1,277	0	0	38
62 Q2	85.1	5.8	56	79	98	196	0.415	3,063	3,064	0	0	36
62 Q3	69.4	8.7	45.2	66.1	72.2	347	0.347	2,569	2,568	0	1	37
62 Q4	80.7	8	46.5	75	98	226	0.553	2,905	2,905	0	0	36
63 Q1	32.4	4.1	5.5	32	39.7	81	1.462	1,079	1,102	8.8	0	34
63 Q2	41.5	4.3	15.9	42	58.1	94	0.96	1,329	1,452	20	0	35
63 Q3	47	8.3	10.1	31	67	215	1.401	1,515	1,598	17.6	0	34
63 Q4	24.6	4	7	19.4	26.4	117	0.983	597	886	47.2	0	36
64 Q1	39	4.2	11.7	23.4	37.2	124	0.856	496	975	64	0	25
64 Q2	47.5	6.6	15.8	30.5	50	155	0.853	936	1,140	29.2	0	24
64 Q3	98.3	11.1	62	80	121	256	0.496	2,262	2,261	0	0	23
64 Q4	27	4.7	9.2	14.4	34.8	81	0.986	536	621	26.1	0	23
65 Q1	31.3	5.4	9	22.5	33	106	0.963	834	1,002	34.4	0	32
65 Q2	37.5	6.8	15.7	22.4	57.5	196	0.962	1,083	1,162	16.1	0	31
65 Q3	37	4.9	11.9	27.5	60.5	79	1.207	1,072	1,073	0	0	29
65 Q4	49.2	5.6	24	37	58	130	0.654	1,477	1,476	0	0	30

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)

[8] Cumulative dose

[9] n*kmm—"adjusted" cumulative dose

[10] Percent non-detects

[11] Number of positive outliers

[12] **Total number of quarterly doses**

The following two modified boxplots for 1956-1965 are for the departments with low potential for external exposure that had a large number of working quarters before and after 1961. Because of the low exposure potential, most of the quarters before 1961 were not monitored in these departments. The corresponding tables contain the summary statistics used to obtain the boxplots. It is evident that gamma doses for nearly all of these workers were so low that they did not even reach the level of 10% of the Radiation Protection Guidelines. In fact, approximately 75% of the doses were below 1% of the Radiation Protection Guidelines each quarter.

Figure 12. Modified Boxplot for Gamma Doses in Department 2014

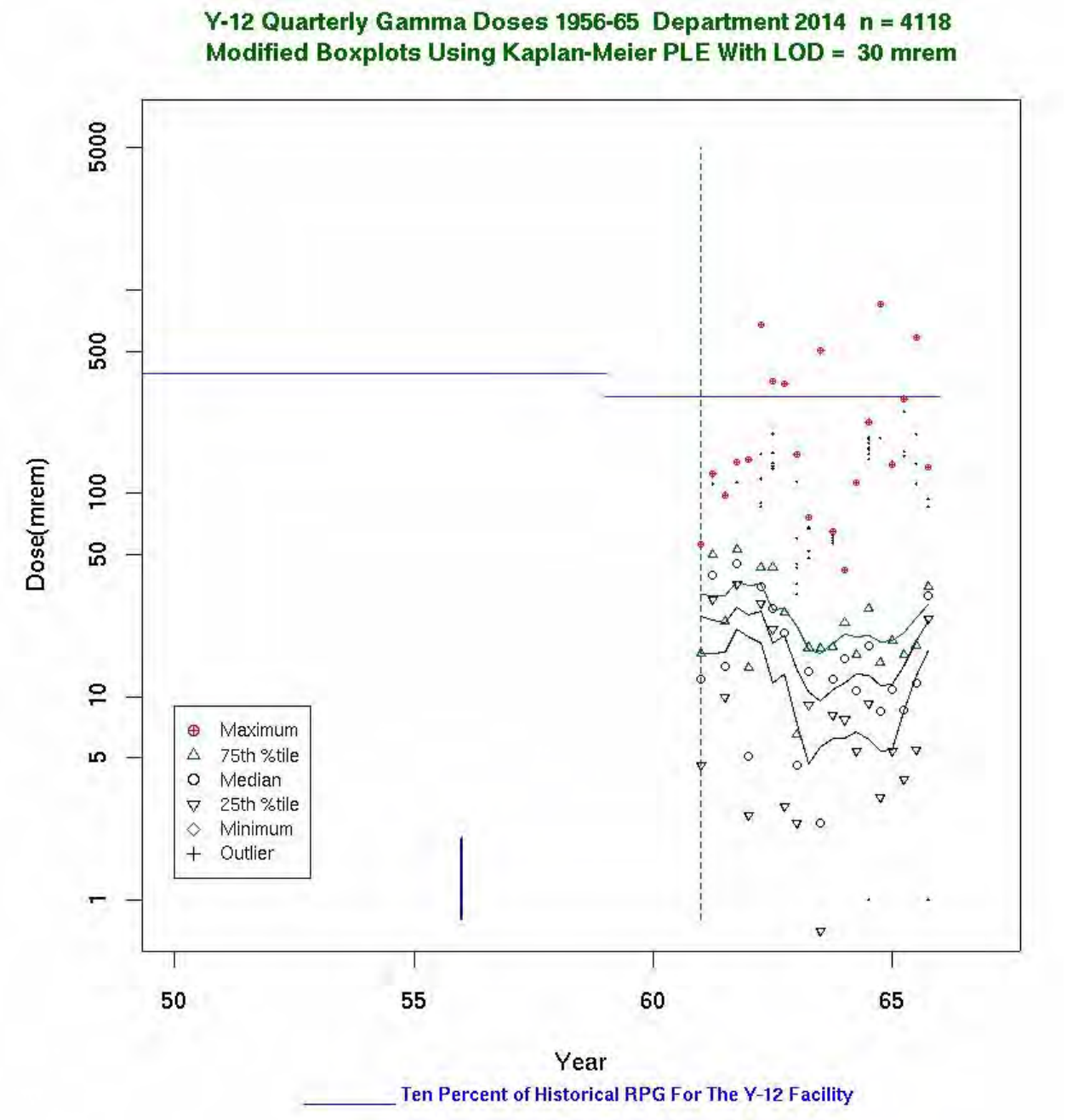


Table 5-8: Department 2014 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
59 Q4	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	3
60 Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	33.3	NA	3
61 Q1	12.9	2.1	4.6	12.1	16.3	56	0.946	255	1,883	91.1	0	146
61 Q2	42.4	1.4	29.9	39.3	50.1	124	0.383	6,019	6,021	0	2	142
61 Q3	19.2	1.2	9.9	14	23.5	98	0.643	2,686	2,688	0	1	140
61 Q4	47.5	1.4	35.8	45.1	52.8	142	0.288	6,314	6,318	0	2	133
62 Q1	13.4	1.1	2.6	5.1	13.8	147	1.248	3,131	3,122	0	0	233
62 Q2	40.7	3	28.9	34.7	43.4	675	0.302	9,032	9,035	0	5	222
62 Q3	38.9	2.2	21.4	27	43.2	355	0.518	8,640	8,636	0	6	222
62 Q4	24.9	2.1	2.9	20.5	26	346	1.616	5,582	5,602	0.4	0	225
63 Q1	11	1.4	2.4	4.6	6.5	155	0.741	1,132	2,398	71.1	14	218
63 Q2	15.3	1	9.1	13.2	17.4	76	0.482	710	3,458	85.4	5	226
63 Q3	14.3	3	0.7	2.4	17.3	502	2.383	2,030	3,418	75.3	0	239
63 Q4	16.2	2	8.1	12.2	17.6	65	0.571	510	3,823	93.6	5	236
64 Q1	30.2	0.1	7.7	15.4	23.1	42	0.814	220	6,704	97.3	0	222
64 Q2	21.7	0.5	5.4	10.7	16.1	113	0.814	298	4,514	96.6	1	208
64 Q3	28.6	2.6	9.2	17.8	27.2	225	0.807	5,516	6,063	17.5	10	212
64 Q4	17	4.4	3.2	8.5	14.7	853	1.117	1,875	3,519	84.5	2	207
65 Q1	15.8	1.1	5.4	10.9	18.8	139	0.926	2,722	3,602	32	1	228
65 Q2	16.3	2.2	3.9	8.6	16.1	292	1.058	2,635	3,586	42.7	4	220
65 Q3	20.8	3	5.5	11.7	17.9	582	0.881	4,492	4,493	0	4	216
65 Q4	32.6	0.9	24.2	31.2	34.6	134	0.266	6,982	7,009	0.5	4	215

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Table 5-9: Department 2018 Summary Statistics for Gamma Doses

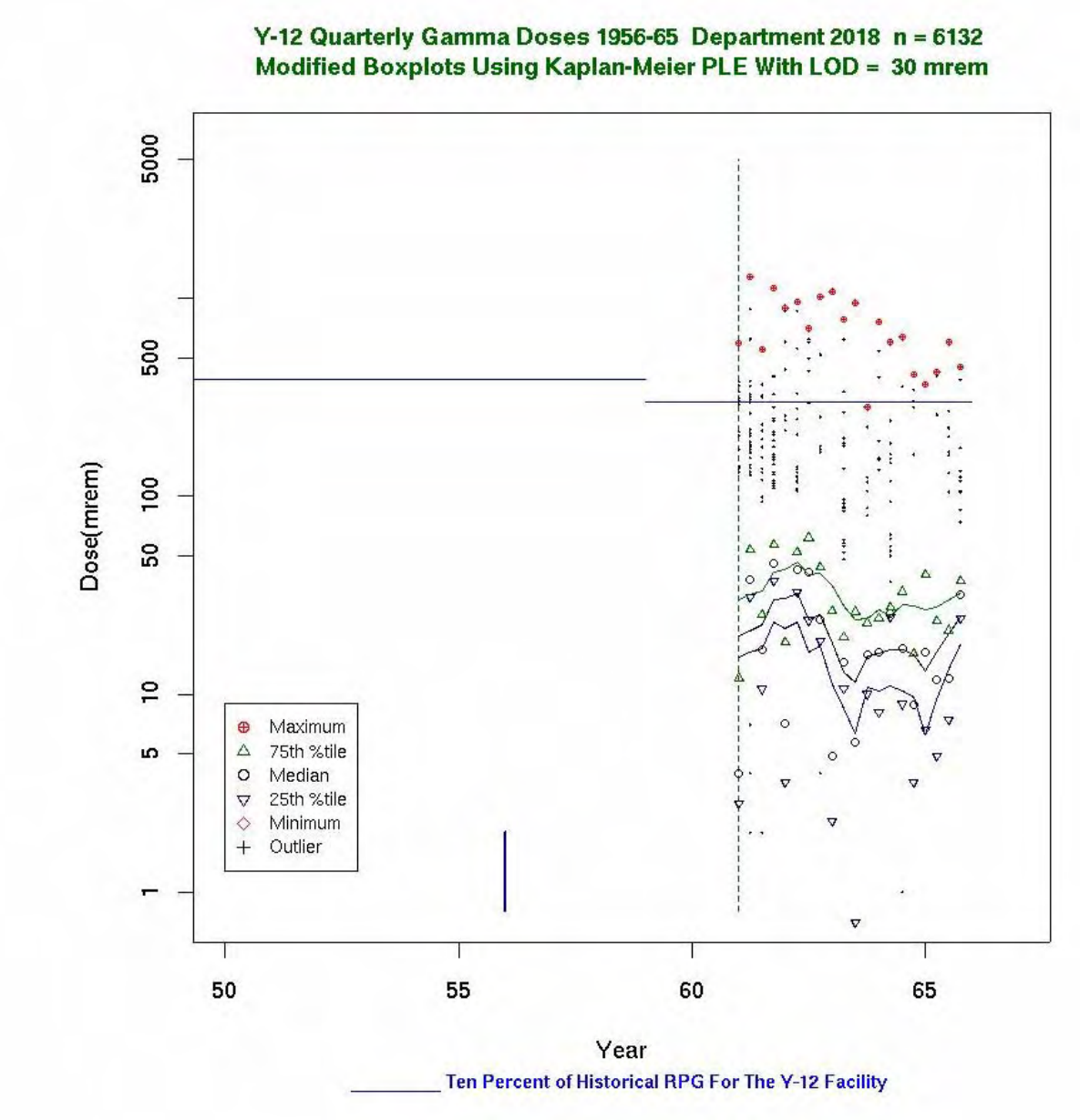
Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
60 Q4	NA	NA	NA	NA	NA	NA	NA	NA	NA	100	NA	3
61 Q1	20	3.3	2.8	4	12.1	590	1.085	4,655	6,980	85.4	14	349
61 Q2	67.3	5.9	31	38.1	53.7	1,276	0.407	23,606	23,622	0.3	35	351
61 Q3	29	2.7	10.6	16.7	25.2	552	0.641	9,987	10,034	0.9	15	346

Table 5-9: Department 2018 Summary Statistics for Gamma Doses

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
61 Q4	60.8	3.9	37.3	45.9	57	1,127	0.313	20,966	20,976	0	23	345
62 Q1	28.1	4.4	3.6	7.1	18.3	896	1.213	10,083	10,088	0.3	8	359
62 Q2	56.7	4.4	32.8	42.4	52.1	956	0.344	19,008	18,994	0	21	335
62 Q3	57.8	4	23.6	41.2	61.7	702	0.711	19,938	19,941	0	6	345
62 Q4	38.5	3.8	18.6	23.8	43.8	1,018	0.635	13,275	13,321	0.9	8	346
63 Q1	30.8	5.1	2.3	4.9	26.3	1,082	1.81	8,807	10,657	56.4	1	346
63 Q2	27.3	3.2	10.7	14.6	19.5	779	0.445	6,390	9,473	56.8	34	347
63 Q3	26.7	4	0.7	5.7	26.1	949	2.643	6,407	9,185	70.1	0	344
63 Q4	21.3	1.7	10	15.8	22.9	280	0.616	2,387	7,348	85.5	9	345
64 Q1	39.3	3.7	8.1	16.2	24.2	757	0.814	3,041	10,454	92.9	7	266
64 Q2	33.6	2.8	24.4	25.7	27.6	598	0.093	2,413	8,602	90.2	19	256
64 Q3	30.4	3.2	8.9	16.9	33	633	0.974	7,373	8,026	18.9	2	264
64 Q4	19.4	3.1	3.6	8.9	16	411	1.098	2,735	4,908	82.2	5	253
65 Q1	28.9	2.3	6.6	16.2	40.3	367	1.337	6,288	6,965	24.5	0	241
65 Q2	29.2	3.7	4.9	11.8	23.3	421	1.159	5,676	6,512	31.8	4	223
65 Q3	27.7	3.7	7.4	12	21	597	0.775	6,212	6,205	0	12	224
65 Q4	38.9	2.8	24.1	32	37.5	449	0.327	8,553	8,558	0	12	220

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Figure 13. Modified Boxplot for Gamma Doses in Department 2018



5.2 Beta Dose Analysis

The modified boxplots below for 1956-65 are for departments with highest potential for external exposure. The corresponding table for each boxplot contains the summary statistics used to construct the boxplot. In no instance did the dose distribution rise when complete monitoring began in 1961. For most of the departments with high exposure potential, monitoring was fairly complete even before 1961.

Figure 14. Modified Boxplot for Beta Doses in Department 2233, 1956-1965

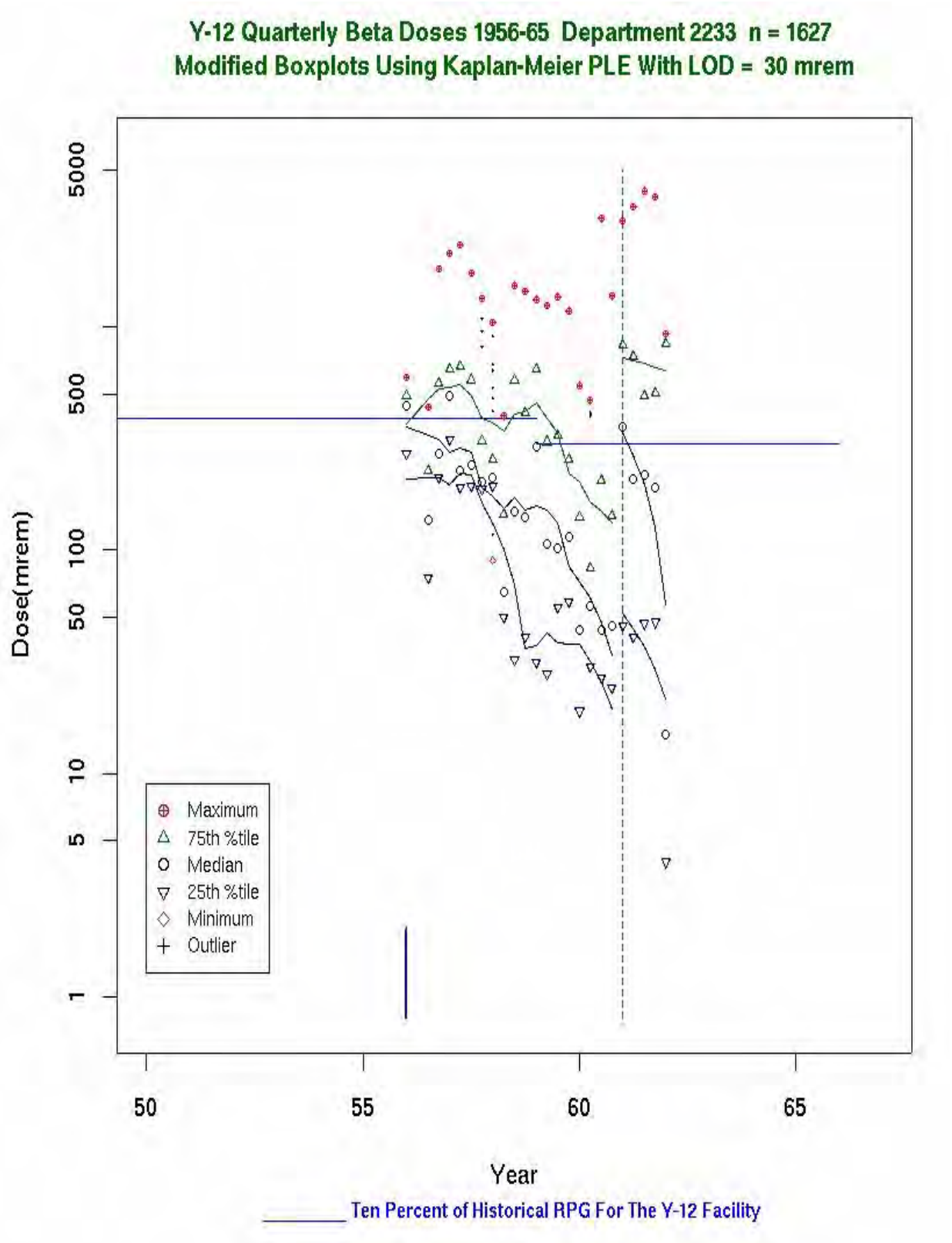


Table 5-10: Department 2233 Summary Statistics

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	425.2	58.2	269	444	487.5	594	0.441	2,551	2,551	0	0	6
56 Q3	170.5	18.5	75	135.7	227	435	0.821	5,455	5,456	0	0	32
56 Q4	457.7	66.9	211.2	271.5	559.5	1,814	0.722	15,104	15,104	0	0	33
57 Q1	545.5	54.4	314.2	489.5	644.5	2,139	0.532	21,276	21,274	0	1	39
57 Q2	541.9	84.3	190.7	227	665	2,329	0.926	23,845	23,844	0	0	44
57 Q3	449.5	57.5	194.2	240.3	580	1,733	0.811	22,026	22,026	0	0	49
57 Q4	316.8	37	187.5	202.7	308.5	1,333	0.369	14,572	14,573	0	4	46
58 Q1	281.4	27.9	193.6	211	256	1,042	0.207	12,946	12,944	0	7	46
58 Q2	112.1	13.8	50.2	65	143.8	398	0.779	5,269	5,269	0	0	47
58 Q3	367.1	68	32.2	149	573.5	1,533	2.134	13,886	13,950	10.5	0	38
58 Q4	314.6	58.6	40.6	140.5	412.5	1,435	1.718	12,849	12,899	7.3	0	41
59 Q1	408.1	61.4	31.5	291.8	646	1,325	2.239	15,897	15,916	2.6	0	39
59 Q2	272.4	41.9	27.9	107	305	1,242	1.774	18,511	18,523	1.5	0	68
59 Q3	256.4	46.6	55	102	326.5	1,365	1.32	11,796	11,794	0	0	46
59 Q4	206.7	41.1	58.5	114.8	253.3	1,180	1.086	8,061	8,061	0	0	39
60 Q1	103	17.5	19	43.5	140	546	1.482	5,259	5,356	11.5	0	52
60 Q2	87.6	13	29.9	56.5	83	466	0.757	5,345	5,344	0	4	61
60 Q3	260.7	80.7	26.6	44	205	3,051	1.513	12,482	12,514	4.2	0	48
60 Q4	168.7	34.7	24	46	142	1,368	1.318	11,471	11,472	0	0	68
61 Q1	532.8	44.1	46	356	827	2,963	2.142	90,242	90,576	11.2	0	170
61 Q2	497.7	45.5	40.8	206.5	738.8	3,450	2.148	102,783	103,024	8.7	0	207
61 Q3	409.9	42.7	46.8	216.5	490.8	,069	1.743	74,919	75,012	2.7	0	183
61 Q4	442.9	44.7	47.5	189.2	505.3	3,816	1.753	93,318	93,452	4.3	0	211
62 Q1	355.6	146.8	4	15	841	930	3.965	2,845	2,845	0	0	8

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Table 5-11: Department 2618 Summary Statistics

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
57 Q4	662.8	119.7	309.5	524	762	1,644	0.668	9,279	9,279	0	0	14
58 Q1	601.8	77.4	182.8	536	903.5	1,711	1.185	17,453	17,452	0	0	29
58 Q2	1151	206.4	243	595	1548	3,674	1.373	27,625	27624	0	0	24
58 Q3	911.3	170.5	188	504	1,341.5	3,084	1.457	23,695	23,694	0	0	26
58 Q4	212.1	66	15.8	54.5	178.3	987	1.799	4,239	4,454	38.1	0	21

Table 5-11: Department 2618 Summary Statistics

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
59 Q2	235	54	11.9	83.5	328.5	2,532	2.459	12,645	12,690	5.6	0	54
59 Q3	516.5	67.9	26	211	826.5	3,440	2.565	48,522	49,068	24.2	0	95
59 Q4	555.8	59.1	46.1	290.5	843.7	3,890	2.155	75,836	76,145	14.6	0	137
60 Q1	449.6	42	28.6	166	594.5	3,300	2.25	102,504	102,958	10	0	229
60 Q2	663.8	46.5	92	429	985	4,751	1.757	161,727	161,967	5.7	0	244
60 Q3	770.7	71.8	78	479	1,148.5	3,457	1.994	93,958	94,025	3.3	0	122
60 Q4	615.6	69.8	45.8	430	1,047.2	2,900	2.321	49,818	49,864	3.7	0	81
61 Q1	727.4	55.8	275	564	1176	2,124	1.077	71,209	71,285	9.2	0	98
61 Q2	970.2	69.1	442.5	929.5	1,296.2	3,071	0.797	99,891	99,931	4.9	0	103
61 Q3	775.5	65.5	202	665	1,101.5	2,539	1.257	69,787	69,795	1.1	0	90
61 Q4	740.5	56.9	269.5	620.5	1,040.2	2,508	1.001	73,274	73,310	4	0	99
62 Q1	645.3	61.8	170.5	526	1,039.5	2,218	1.34	50,272	50,333	3.8	0	78
62 Q2	1340	108.3	422	1248	2,087	4,266	1.185	101,796	101,840	2.6	0	76
62 Q3	795.1	65	293	745.5	1,118.2	2,196	0.993	57,968	58,042	4.1	0	73
62 Q4	707.5	71.3	214.2	553	982	2,728	1.129	52,349	52,355	4.1	0	74
63 Q1	594.4	84.3	92	372	651	4,415	1.45	54,481	54,685	8.7	0	92
63 Q2	610.9	66.7	85.8	386	899	2,519	1.742	57,991	58,036	9.5	0	95
63 Q3	802.2	100	151.5	597	931.7	5,825	1.347	72960	73,000	3.3	0	91
63 Q4	610.5	68.1	138	449	686.5	3,047	1.189	57,935	57,998	4.2	0	95
64 Q1	421.7	38.3	70	331	570	2,366	1.555	58,888	59,038	7.9	0	140
64 Q2	552.7	40.1	241	442	706	2,789	0.797	77,373	77,378	0	0	140
64 Q3	837.5	56.2	410	653	1,005	3,034	0.665	117,227	117,250	0.7	0	140
64 Q4	959	66.7	381.7	722	1,325	3,810	0.922	130,994	131,383	9.5	0	137
65 Q1	362.2	36.6	67.5	222	5,81.5	2,035	1.596	38,201	38,393	12.3	0	106
65 Q2	577.1	76.9	128	374	633	2,924	1.185	39,203	39,243	2.9	0	68
65 Q3	345.9	37.8	98	242	540	1,312	1.265	22,799	22,829	3	0	66
65 Q4	424.1	54.6	107.5	332.5	633.5	1,572	1.315	21,587	21,629	7.8	0	51

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Figure 15. Modified Boxplot for Beta Doses in Department 2618, 1956-1965

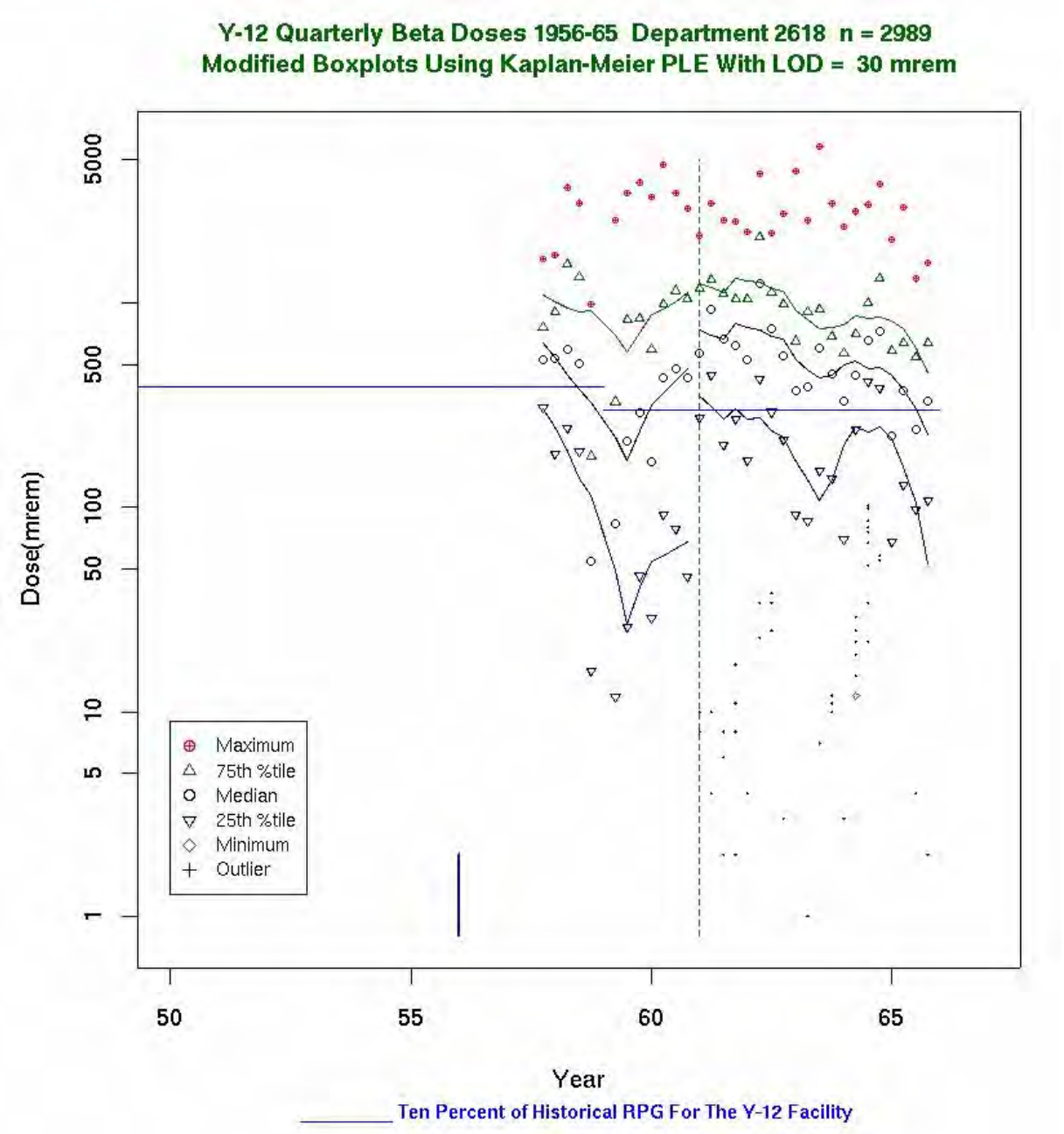


Figure 16. Modified Boxplot for Beta Doses in Department 2619, 1956-1965

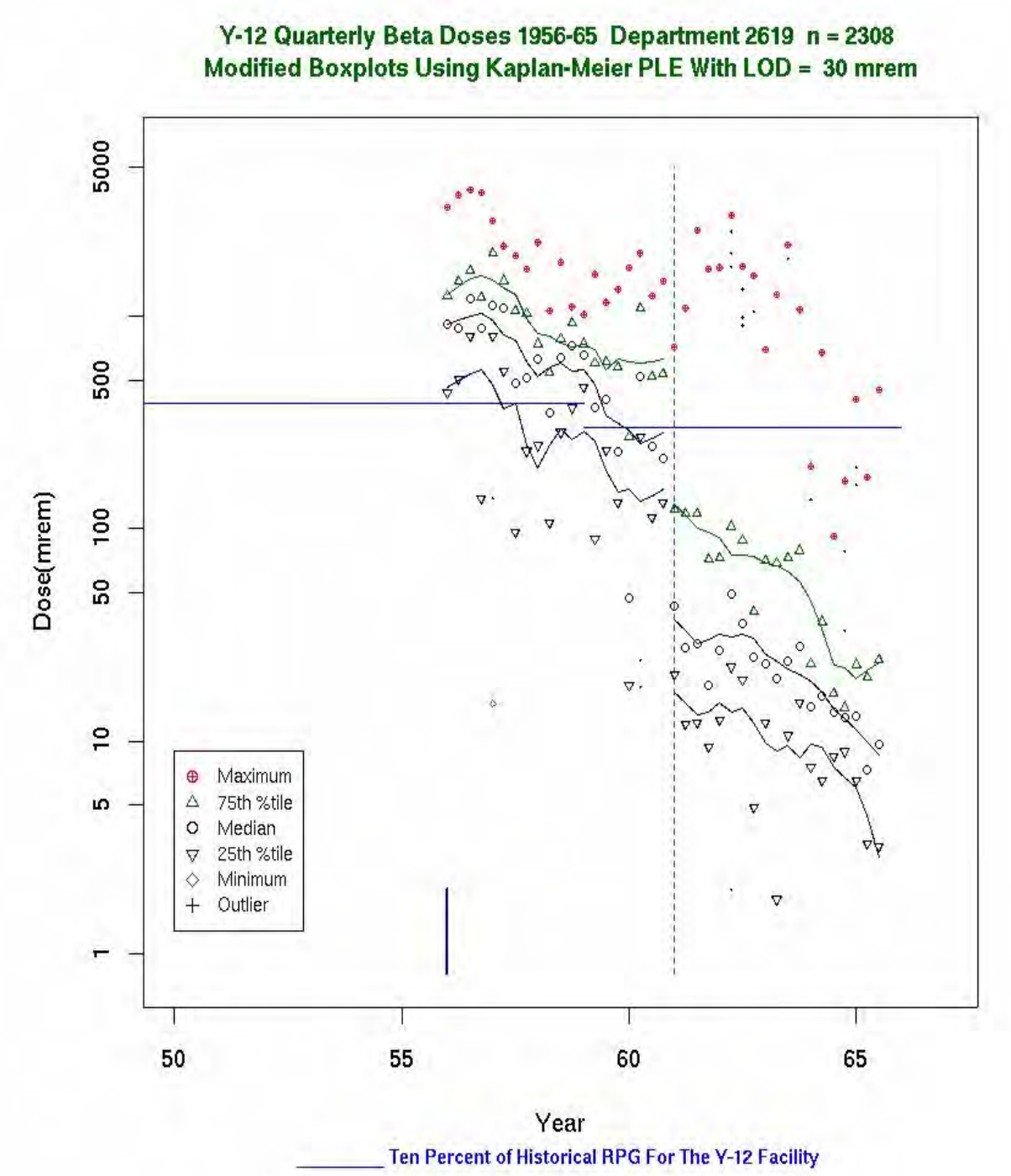


Table 5-12: Department 2619 Summary Statistics

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	1,066	155	437.2	915	1,244	3,250	0.775	28,783	28,782	0	0	27
56 Q2	1,221.1	193.3	505	879	1,460	3,727	0.787	24,422	24,422	0	0	20
56 Q3	1,408.2	199.9	802.5	1,203	1,629.8	3,933	0.525	26,756	26,756	0	0	19
56 Q4	996	193.7	138.8	883.5	1231	3,803	1.618	20,916	20,916	0	0	21
57 Q1	1,354.2	189.9	804	1127	1,983.5	2,805	0.669	24,376	24,376	0	0	18
57 Q2	1,109.6	142.9	553	1,091	1,471	2,140	0.725	17,753	17,754	0	0	16
57 Q3	653.7	118.7	96.5	482	1,057	1,923	1.774	14,382	14,381	0	0	22
57 Q4	682.3	105.2	232	513	1031	1,665	1.106	13,646	13,646	0	0	20
58 Q1	711	147.6	246	627	742.5	2,216	0.819	9,954	9,954	0	0	14
58 Q2	410.6	76.7	106.5	351	541.5	1,062	1.205	5,719	5,748	7.1	0	14
58 Q3	692.9	123.4	284	640	777	1,800	0.746	8,315	8,315	0	0	12
58 Q4	706.9	73.2	369.8	727.5	933.9	1,102	0.687	10,603	10,604	0	0	15
59 Q1	638.4	50.4	461.5	652.5	742	1,020	0.352	9,576	9,576	0	0	15
59 Q2	481.1	104.4	89	371.5	597.5	1,580	1.412	8,059	8,179	23.5	0	17
59 Q3	476	69.9	233	406	611	1,162	0.715	7,616	7,616	0	0	16
59 Q4	369.8	78.3	133	230	578	1,330	1.089	6,566	6,656	16.7	0	18
60 Q1	217.7	75.1	18.4	47	270	1,690	1.991	5,061	5,225	33.3	0	24
60 Q2	748.9	121.3	271.3	516.5	1,088.8	1,968	1.03	17,203	17,225	4.3	0	23
60 Q3	383.7	70.6	113.5	243.5	518.2	1,249	1.126	8,796	8,825	4.3	0	23
60 Q4	379.8	116.7	132	213	532.9	1,455	1.034	4,118	4,178	18.2	0	11
61 Q1	114.3	12.2	20.6	43.3	123.3	717	1.325	17,716	18,517	26.5	0	162
61 Q2	95.8	12	12	27.5	118.3	1,085	1.698	14,737	15,136	18.4	0	158
61 Q3	127	21.9	12.2	28.8	117.5	2,534	1.681	19,842	20,066	9.5	0	158
61 Q4	75	15.3	9.4	18.3	72.2	1,657	1.512	11,051	11,625	29	1	155
62 Q1	81	15	12.6	26.7	73	1,699	1.303	11,539	11,988	19.6	1	148
62 Q2	151.5	31.7	22.3	49	102.5	2,965	1.132	22,169	22,574	15.4	4	149
62 Q3	116.1	18.8	19.5	36	88.3	1,707	1.118	16,356	16,951	21.9	4	146
62 Q4	94.2	18.1	4.9	24.8	40.8	1,552	1.564	12,425	13,659	56.6	3	145
63 Q1	60.7	9.3	12.2	23.2	70.5	697	1.299	6,131	6,920	46.5	0	114
63 Q2	77.2	17.2	1.8	19.8	69	1,261	2.702	8,085	8,646	44.6	0	112
63 Q3	110.1	27.8	10.6	23.8	73.2	2,156	1.431	11,203	12,001	46.8	2	109
63 Q4	76.2	12.4	15.2	28.1	79	1,069	1.223	7,594	8,230	35.2	1	108
64 Q1	28	5.5	7.5	14.4	23	197	0.827	811	1,372	71.4	2	49
64 Q2	54.3	17.4	6.5	16.3	36.5	671	1.274	2,130	2,498	58.7	1	46
64 Q3	19	2.9	8.5	13.6	16.8	92	0.504	214	893	85.1	1	47
64 Q4	19.3	4.2	8.9	12.9	14.4	168	0.357	319	772	85	3	40
65 Q1	44	15	6.5	13.1	22.9	405	0.932	851	1,276	75.9	3	29
65 Q2	20.7	7.5	3.3	7.3	19.9	174	1.334	365	497	54.2	0	24
65 Q3	46.6	21.6	3.2	9.6	24	449	1.485	886	1,025	54.5	0	22
65 Q4	NA	NA	NA	NA	NA	NA	NA	NA	NA	90.9	NA	22

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] **Maximum dose in quarter**
[7] **[log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)**
[8] **Cumulative dose**
[9] **n*kmm—"adjusted" cumulative dose**
[10] **Percent non-detects**
[11] **Number of positive outliers**
[12] **Total number of quarterly doses**

Figure 17. Modified Boxplot for Beta Doses in Department 2701, 1956-1965

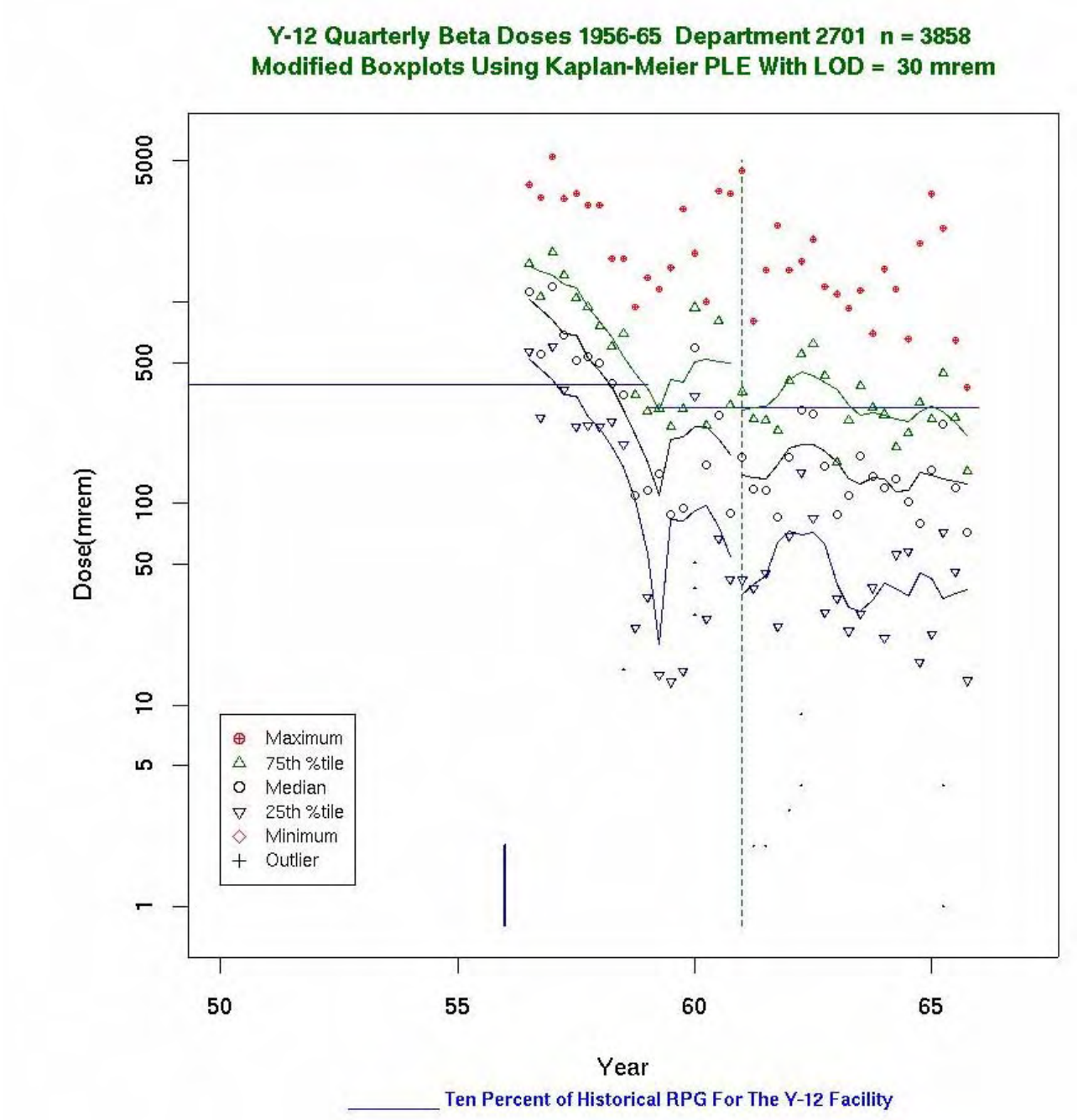


Table 5-13: Department 2701 Summary Statistics												
Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q3	1,228.4	115.7	569	1117.5	1547.5	3,833	0.742	57,734	57,735	0	0	47
56 Q4	800.3	95.1	265	550	1,060	3,290	1.028	41,613	41,616	0	0	52
57 Q1	1,430.2	145.3	604.5	1194	1,769.5	5,255	0.796	77,233	77,231	0	0	54
57 Q2	950	97	366.8	682	1,357.8	3,268	0.97	54,148	54,150	0	0	57
57 Q3	780.2	94.9	241	513	1,042	3,465	1.085	46,810	46,812	0	0	60
57 Q4	764.1	92.1	243.2	538.5	939.8	3,028	1.002	43,556	43,554	0	0	57
58 Q1	668.3	75.6	241.5	495	757	3,017	0.847	41,433	41,435	0	0	62
58 Q2	503	47.6	255	393	602	1,634	0.637	30,149	30,180	1.7	0	60
58 Q3	484.9	51.3	195.2	347	691.8	1,633	0.938	29,561	29,579	1.6	0	61
58 Q4	237.2	29.1	24	109	344	947	1.974	18,284	18,502	16.7	0	78
59 Q1	211.7	22.2	34.1	116	285.2	1,322	1.575	24,783	25,192	16.8	0	119
59 Q2	210.1	24.8	14.1	140	295.5	1,153	2.255	19,648	19,749	7.4	0	94
59 Q3	173.7	24.1	13	87.7	241.2	1,472	2.168	16,097	16,502	27.4	0	95
59 Q4	248.3	42.5	14.8	95	295	2,880	2.22	25,512	25,823	17.3	0	104
60 Q1	646.7	41.5	339	595	935	1,750	0.752	54,295	54,323	1.2	0	84
60 Q2	193.7	23.3	26.8	156	244	1,007	1.636	16,629	16,658	2.3	0	86
60 Q3	632.6	68.2	66.5	272	807.8	3,544	1.851	92,898	92,992	4.1	0	147
60 Q4	301.4	43.6	42.2	90	308.5	3,435	1.475	42,692	42,799	4.9	0	142
61 Q1	254.8	29	41.7	170	358.5	4,475	1.595	46,024	46,374	13.2	0	182
61 Q2	182	13.1	37.7	118.5	261.5	799	1.436	35,795	36,036	12.1	0	198
61 Q3	184.8	14.2	45.3	115.5	259.8	1,441	1.294	36,683	36,775	3	0	199
61 Q4	184.5	20.4	24.6	85	230.5	2,403	1.657	36,124	36,531	13.1	0	198
62 Q1	276.9	27.5	68.7	169	407	1,438	1.319	28,702	28,798	4.8	0	104
62 Q2	392	35.7	143	291	549	1,582	0.997	38,365	38,416	3.1	0	98
62 Q3	402.6	37.1	84.5	276	615	2,051	1.471	41,022	41,065	2	0	102
62 Q4	281.6	31.6	28.9	154	431	1,195	2.004	27,644	27,878	11.1	0	99
63 Q1	150.8	17.7	33.8	88	159.2	1,097	1.15	16,310	16,739	18.9	0	111
63 Q2	180.1	18.8	23.3	109	257	926	1.78	19,889	20,171	21.4	0	112
63 Q3	256.2	22.9	28.4	172.3	383.5	1,143	1.93	30,909	31,256	13.1	0	122
63 Q4	183.7	14.6	38.2	135.5	300.2	699	1.527	23,215	23,330	6.3	0	127
64 Q1	203.2	24.2	21.6	120	275.7	1,451	1.888	21,131	21,336	12.4	0	105
64 Q2	181.8	20.4	55.8	133	190.5	1,161	0.91	18,487	18,544	2.9	0	102
64 Q3	166.8	15.5	58	102	224	652	1.002	16,637	16,680	2	0	100
64 Q4	225.6	32.9	16.3	80	318	1,947	2.202	21,177	22,560	46	0	100
65 Q1	230.3	39.2	22.4	145.5	263.5	3,424	1.826	21,564	21,878	17.9	0	95
65 Q2	357.6	43.9	71.5	248	442.5	2,314	1.351	30,709	30,754	4.7	0	86
65 Q3	179.7	18.2	46	119	267	642	1.304	14,276	14,376	7.5	0	80
65 Q4	97.7	10.1	13.2	71.8	144.1	375	1.771	7,546	7,718	19	0	79

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Figure 18. Modified Boxplot for Beta Doses in Department 2702, 1956-1965

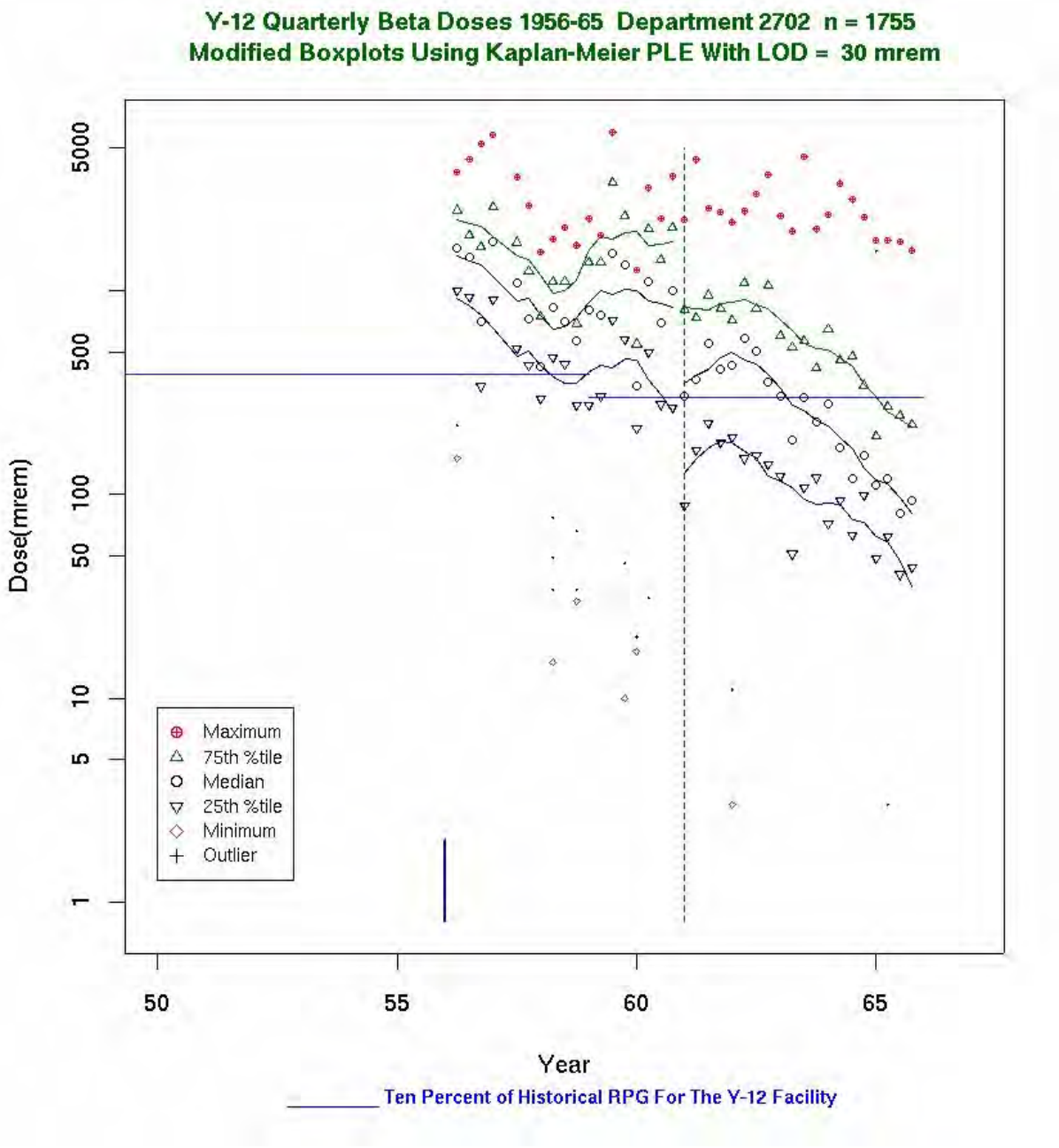


Table 5-14: Department 2702 Summary Statistics

Date year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	3
56 Q2	1,744.9	126.7	1,005.7	1,625.5	2,478.7	3,828	0.669	92,479	92,480	0	0	53
56 Q3	1,643.2	128.6	934.2	1,455	1,864.5	4,419	0.512	83,802	83,803	0	0	51
56 Q4	1,234.7	181.1	338.5	707.5	1,631	5,234	1.166	58,029	58,031	0	0	47
57 Q1	1,911.1	187.7	905.5	1,728	2,574	5,829	0.774	87,912	87,911	0	0	46
57 Q3	1,290.9	142.4	522	1,098	1,725	3,621	0.886	49,053	49,054	0	0	38
57 Q4	906.2	89.3	432	725	1,236	2,606	0.779	34,434	34,436	0	0	38
58 Q1	565.2	57.5	293.5	422	745.3	1,550	0.691	24,302	24,304	0	0	43
58 Q2	833.8	76	468	823	1107	1,789	0.638	32,518	32,518	0	0	39
58 Q3	779.6	73	434	705.5	1,110.5	2,032	0.696	27,287	27,286	0	0	35
58 Q4	591.3	70.2	272.5	565	690.5	1,671	0.689	20,696	20,696	0	0	35
59 Q1	904.4	117.8	275.7	800.8	1,368.5	2,245	1.188	26,199	26,228	3.4	0	29
59 Q2	871.7	105.8	305	763	1,370	1,875	1.114	24,407	24,408	0	0	28
59 Q3	2,070.8	284.5	715	1,530	3,400	5,956	1.156	66,266	66,266	0	0	32
59 Q4	1,799.9	268.7	578	1,343	2,316.5	10,407	1.029	75,596	75,596	0	0	42
60 Q1	434.1	48.6	210	340	547	1,265	0.71	15,627	15,628	0	0	36
60 Q2	1,285	132	496.8	1,100.5	2,019.3	3,186	1.04	55,227	55,255	2.3	0	43
60 Q3	903	99.9	276	699	1,424.3	2,255	1.216	38,831	38,829	0	0	43
60 Q4	1,226.8	170.7	265.8	999	2,030.3	3,628	1.507	42,937	42,938	0	0	35
61 Q1	496.3	74.1	88	305.5	805.8	2,221	1.642	23,306	23,326	2.1	0	47
61 Q2	696.3	126.2	165.5	364	735	4,379	1.105	31,998	32,030	2.2	0	46
61 Q3	697.2	84.7	224.5	551.5	949	2,547	1.069	32,768	32,768	0	0	47
61 Q4	577.5	75.7	180.2	412	813	2,431	1.117	26,563	26,565	0	0	46
62 Q1	559.1	82.8	189.8	430.5	718	2,177	0.986	21,805	21,805	0	0	39
62 Q2	761	113.9	150	587	1,086	2,450	1.467	27,397	27,396	0	0	36
62 Q3	667.8	108.5	155	503.5	817	2,986	1.232	24,710	24,709	0	0	37
62 Q4	781.3	142.6	140.1	358	1,063.5	3,700	1.502	30,469	30,471	0	0	39
63 Q1	461.1	73.4	123	304.5	603	2,328	1.178	18,380	18,444	10	0	40
63 Q2	399.9	78.7	51	184	525	1,966	1.728	15,944	15,996	12.5	0	40
63 Q3	560.2	135.6	108	297	566	4,539	1.228	22,388	22,408	2.5	0	40
63 Q4	343.6	59.9	120.5	226	416	1,998	0.918	12,655	12,713	5.4	0	37
64 Q1	417.9	54.4	72.2	279	645	2,352	1.623	30,834	30,925	8.1	0	74
64 Q2	429.2	71.7	93	170	458	3,368	1.182	31,703	31,761	4.1	0	74
64 Q3	362.9	61	62.7	119	477	2,792	1.504	26,840	26,855	1.4	0	74
64 Q4	304.1	48	99	156	343.5	2,283	0.922	21,565	21,895	15.3	1	72
65 Q1	212.4	40.8	48.5	111	192.5	1,758	1.022	13,888	14,018	10.6	2	66
65 Q2	262.7	43.8	62	120	268.5	1,761	1.087	16,263	16,287	3.2	0	62
65 Q3	236.1	47	40.5	80.5	243.5	1,739	1.33	14,604	14,638	4.8	0	62
65 Q4	214.6	40.8	44	93	219	1,579	1.19	12,774	12,876	11.7	0	60

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)

[8] **Cumulative dose**
[9] **n*kmm—"adjusted" cumulative dose**
[10] **Percent non-detects**
[11] **Number of positive outliers**
[12] **Total number of quarterly doses**

Figure 19. Modified Boxplot for Beta Doses in Department 2703, 1956-1965

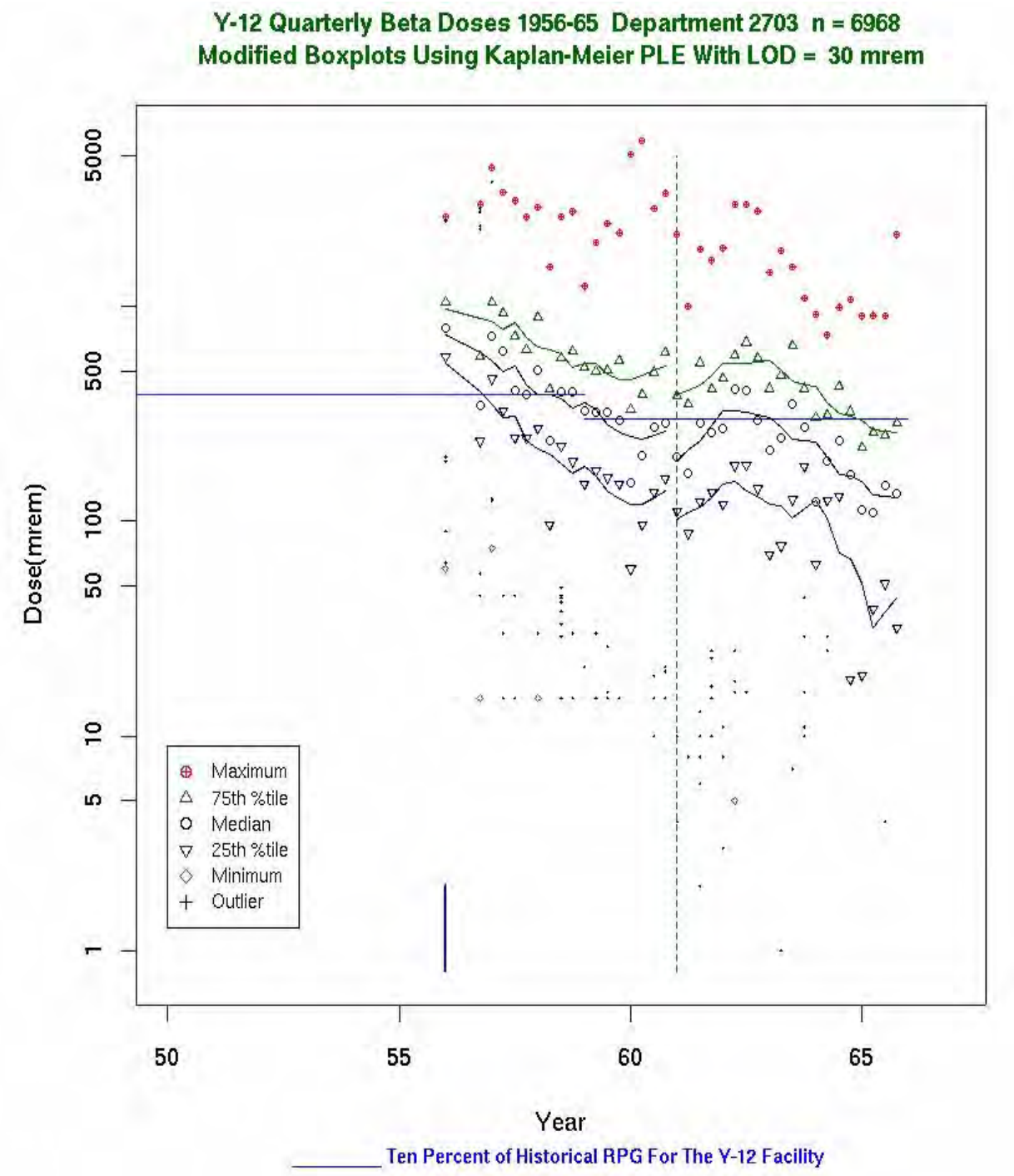


Table 5-15: Department 2703 Summary Statistics

Date year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
56 Q1	890	35.7	587	798	1,043	2,619	0.426	154,852	154,860	0	2	174
56 Q4	533.7	33.3	235	346	582	2,998	0.672	132,352	132,358	0	7	248
57 Q1	948.1	56	459	729	1,038.5	4,439	0.605	180,144	180,139	0	2	190
57 Q2	751.8	41.7	324.5	614.5	932.5	3,393	0.782	154,099	154,119	0.5	0	205
57 Q3	557	33.3	243.7	406	728.5	3,096	0.812	108,048	108,058	0.5	0	194
57 Q4	531.4	29.7	244.5	390	628.8	2,599	0.7	105,743	105,749	0	1	199
58 Q1	638.9	32.8	270	507	889	2,898	0.883	135,451	135,447	0	0	212
58 Q2	289	16.8	96.3	237.8	411.8	1,520	1.077	59,129	59,245	2.4	0	205
58 Q3	440.1	21.5	224.8	402.5	572.5	2,620	0.693	103,289	103,424	3	1	235
58 Q4	441.6	20.7	189	397	618	2,755	0.878	126,909	127,181	5.9	0	288
59 Q1	372.4	15.8	148.5	326	519	1,235	0.928	116,224	116,561	4.5	0	313
59 Q2	368.6	16.9	171.3	321	495.5	1,989	0.788	103,709	103,945	5.7	0	282
59 Q3	367.5	17.6	159	321	505	2,430	0.857	118,699	119,070	6.5	0	324
59 Q4	384.4	18.3	149	293	560.5	2,209	0.982	134,216	134,540	5.4	0	350
60 Q1	266.6	21.5	60	151	332	5,109	1.268	90,379	90,644	3.8	1	340
60 Q2	337	25	95.9	202	388	5,910	1.036	112,788	112,895	1.8	1	335
60 Q3	398.9	24.4	135.8	274	493	2,848	0.956	112,806	112,889	1.4	0	283
60 Q4	453.8	28.6	158.6	284.5	606.7	3,360	0.994	116,605	116,627	0.4	0	257
61 Q1	286.4	26	111	200	383	2,148	0.918	33,093	33,222	6	0	116
61 Q2	250.9	18.4	87.5	166	348.7	999	1.025	34,279	34,373	5.1	0	137
61 Q3	380.8	24.1	122.5	285	545.8	1,835	1.108	69,651	69,686	1.6	0	183
61 Q4	315.6	18.6	136.5	257.5	413.3	1,630	0.821	59,543	59,648	2.6	0	189
62 Q1	351.1	27.9	119	271	463	1,860	1.007	46,321	46,345	1.5	0	132
62 Q2	530.9	44.9	181	413	595	2,985	0.882	67,957	67,955	0	0	128
62 Q3	499.6	38.8	182.8	405.5	680.3	2,986	0.974	62,409	62,450	1.6	0	125
62 Q4	407.5	35.1	141.2	295.5	573	2,787	1.038	51,633	517,52	3.9	0	127
63 Q1	276.6	24.3	70	214	414	1,433	1.318	32,794	33,192	15	0	120
63 Q2	304.9	25.3	76.8	244.5	478.5	1,809	1.357	39,168	39,332	14	0	129
63 Q3	447.1	32.6	125.7	350	652.5	1,523	1.221	56,632	56,782	6.3	0	127
63 Q4	301.2	16.9	179.3	274	414.3	1,093	0.621	37,616	37,650	1.6	0	125
64 Q1	214.8	20	63.2	123.9	302.7	916	1.161	24,576	24,702	7	0	115
64 Q2	226.3	13.6	125	189.8	311.1	733	0.676	25,583	25,798	7	0	114
64 Q3	285.2	17.6	130.5	236	424	990	0.874	32,509	32,513	0	0	114
64 Q4	198.9	17.5	18.4	164	324	1,071	2.128	21,462	22,874	40.9	0	115
65 Q1	148.4	15.4	19.2	113	220.5	898	1.808	16,279	16,472	14.4	0	111
65 Q2	221.9	38.9	39	109.5	257.3	909	1.398	9,523	9,542	2.3	0	43
65 Q3	207.8	32.8	51	145.5	251	901	1.181	7,888	7,896	2.6	0	38
65 Q4	250	55.3	32	134	285	2,151	1.621	10,921	11,000	13.6	0	44

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)

[8] Cumulative dose

[9] n*kmm—"adjusted" cumulative dose

[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Figure 20. Modified Boxplot for Beta Doses in Department 2793, 1956-1965

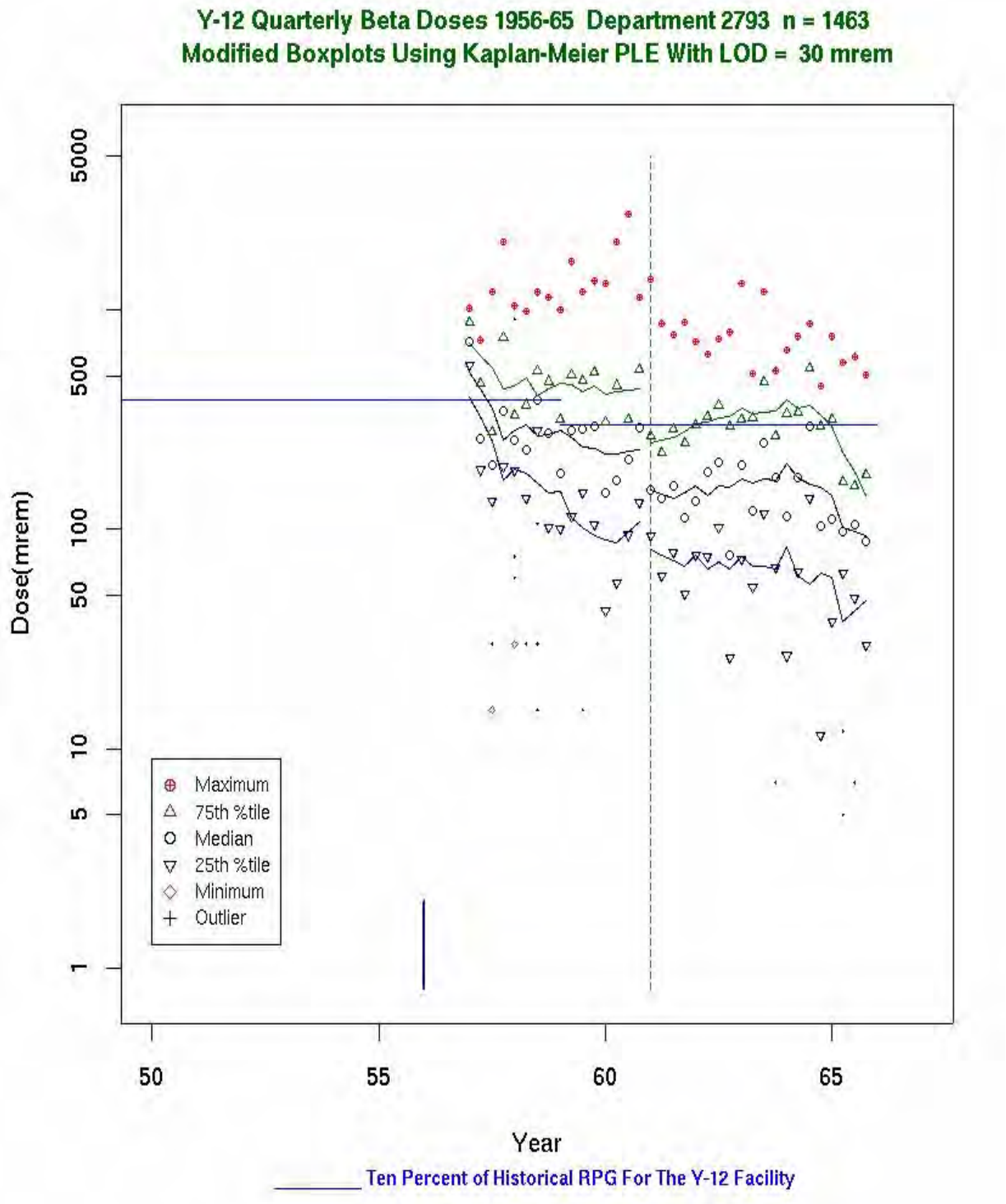


Table 5-16: Department 2793 Summary Statistics

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
57 Q1	766.7	72	560	719	882	1,021	0.337	5,367	5,367	0	0	7
57 Q2	348	62.8	186.5	259	460	731	0.669	3,828	3,828	0	0	11
57 Q3	288.4	52.1	134.8	195	279	1,209	0.54	7,498	7,498	0	1	26
57 Q4	567.9	88.9	193.5	344	746	2,033	1	17,036	17,037	0	0	30
58 Q1	293.4	33.4	185.7	253.5	330.5	1,039	0.427	10,855	10,856	0	2	37
58 Q2	285	28.8	137.8	229.5	369	982	0.73	14,537	14,535	2	0	51
58 Q3	427.4	28.6	281.3	391	528	1,200	0.467	27,765	27,781	1.5	0	65
58 Q4	334.8	33.1	101.8	273.5	472	1,142	1.137	22,355	22,432	6	0	67
59 Q1	241.1	25.2	100	180	318	1,002	0.858	17,273	17,359	5.6	0	72
59 Q2	373.5	41.9	115	283	504	1,655	1.095	25,398	25,398	1.5	0	68
59 Q3	334.8	31.4	146	285	478	1,210	0.879	21,405	21,427	1.6	0	64
59 Q4	387.7	43.3	105	293	517	1,350	1.182	23,234	23,262	1.7	0	60
60 Q1	245.8	39.6	42.5	146	308	1,315	1.468	13,230	13,273	3.7	0	54
60 Q2	356.2	57.8	57	167	452.5	2,045	1.536	19,155	19,235	9.3	0	54
60 Q3	341.5	59.6	94	208	318	2,720	0.903	20,466	20,490	1.7	1	60
60 Q4	370	37.9	133	289	533	1,137	1.029	20,722	20,720	0	0	56
61 Q1	238.7	41	93.8	150.3	264.5	1,375	0.769	9,746	9,787	4.9	1	41
61 Q2	196	28.9	61	138	222.5	869	0.959	8,163	8,232	7.1	0	42
61 Q3	214.7	27.7	78	158	287.7	768	0.968	9,874	9,876	0	0	46
61 Q4	202	32.4	50.5	113.5	248	876	1.18	9,049	9,090	6.7	0	45
62 Q1	191.5	24.7	76.5	135	297.5	713	1.007	7,265	7,277	2.6	0	38
62 Q2	227.9	29.1	75	183	326	626	1.089	8,186	8,204	2.8	0	36
62 Q3	254.5	30.4	102.5	202.5	366.2	736	0.944	9,358	9,416	5.4	0	37
62 Q4	178.8	33.8	26.1	76	293	788	1.793	6,275	6,437	19.4	0	36
63 Q1	250.5	44.9	73	195	316.5	1,323	1.087	8,466	8,517	5.9	0	34
63 Q2	187.6	27.3	54.8	122	320.8	511	1.311	6,553	6,566	5.7	0	35
63 Q3	345.7	48.7	117.5	248	470.5	1,204	1.028	11,732	11,754	2.9	0	34
63 Q4	198.6	23.6	67	173	267	530	1.025	7,136	7,150	5.6	0	36
64 Q1	207.8	40.6	26.5	114.5	335	657	1.881	5,147	5,195	12	0	25
64 Q2	246.2	43.8	64	172	340	754	1.238	5,890	5,909	4.2	0	24
64 Q3	371.7	55.2	138.8	294	543.5	864	1.012	8,548	8,549	4.3	0	23
64 Q4	164	30.8	11.5	104	292.8	451	2.4	3,661	3,772	30.4	0	23
65 Q1	186	33.5	38	111.5	318	754	1.575	5,887	5,952	18.8	0	32
65 Q2	161.5	28.9	62.8	98	164.8	574	0.716	4,988	5,006	6.5	0	31
65 Q3	143.4	25.3	48.5	105.5	157.5	614	0.873	4,141	4,159	3.4	0	29
65 Q4	130.8	22.2	29.5	88	176.5	504	1.326	3,868	3,924	10	0	30

Notes:

[1] K-M estimate of the mean for the quarter

[2] K-M estimate of the standard error of the K-M mean

[3] 25th quantile

[4] 50th quantile; estimate of the GM

[5] 75th quantile

[6] Maximum dose in quarter

[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)

[8] Cumulative dose

[9] n*kmm—"adjusted" cumulative dose

[10] Percent non-detects

[11] Number of positive outliers

[12] **Total number of quarterly doses**

The following two modified boxplots for 1956-1965 are for the departments with low potential for external exposure that had a large number of working quarters before and after 1961. The corresponding tables contain the summary statistics used to obtain the boxplots. Because of the low exposure potential, most of the quarters before 1961 were not monitored. However, when complete monitoring was initiated, nearly all doses were below 10% of the Radiation Protection Guidelines.

Figure 21. Modified Boxplot for Beta Doses in Department 2014, 1956-1965

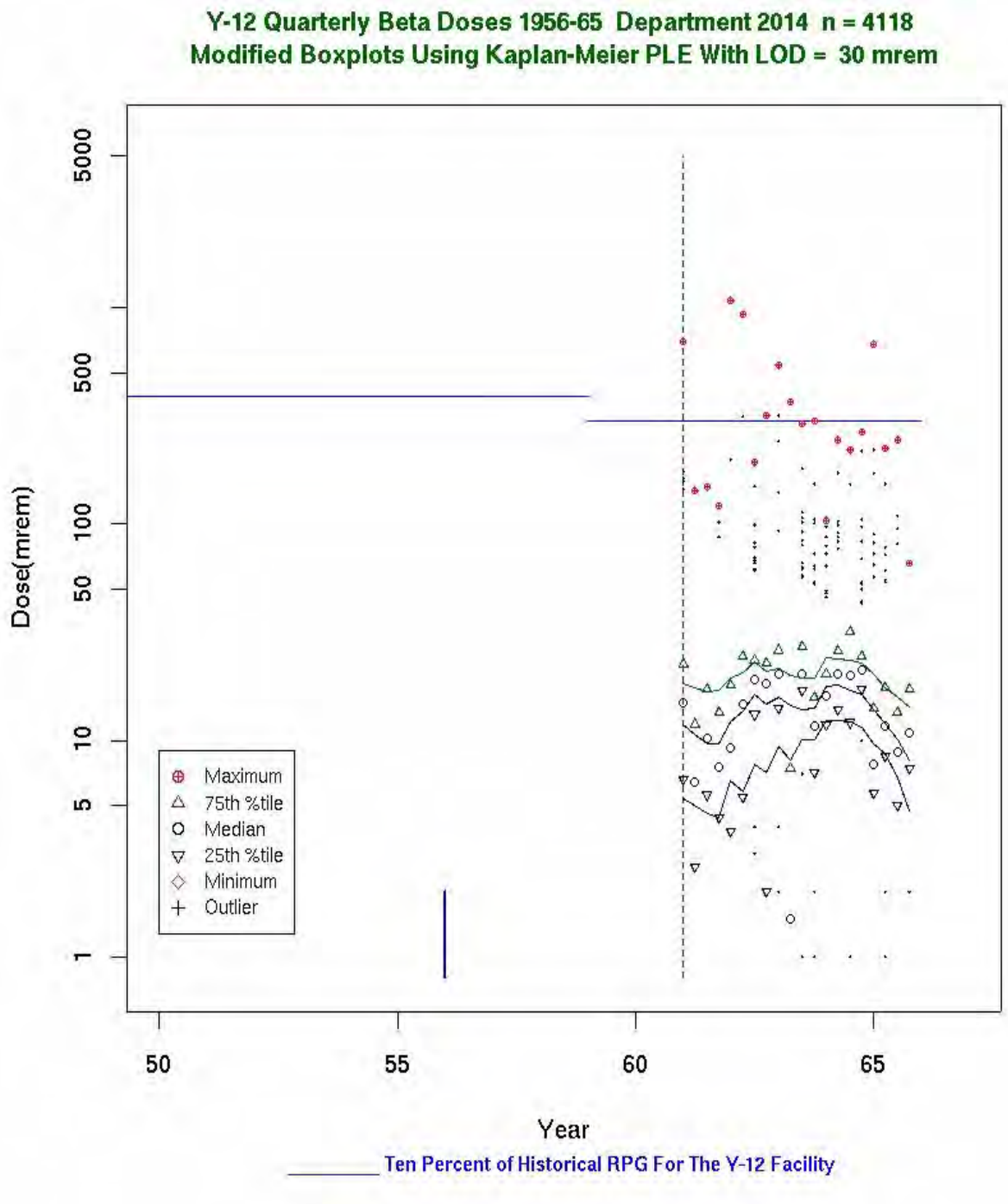


Table 5-17: Department 2014 Summary Statistics

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
59 Q4	NA	NA	NA	NA	NA	NA	NA	NA	NA	33.3	NA	3
60 Q1	NA	NA	NA	NA	NA	NA	NA	NA	NA	66.7	NA	3
61 Q1	29.9	5.4	6.6	15	22.6	698	0.918	3,181	4,365	59.6	5	146
61 Q2	10.4	1.3	2.6	6.4	11.9	143	1.141	719	1,477	59.9	1	142
61 Q3	14.7	1.4	5.6	10.3	17.3	148	0.842	1,818	2,058	15	1	140
61 Q4	12.7	1.6	4.4	7.5	13.5	121	0.822	722	1,689	68.4	3	133
62 Q1	21.6	4.9	3.8	9.3	18	1,082	1.157	4,099	5,033	38.6	2	233
62 Q2	27.1	4.6	5.5	14.8	24.4	931	1.11	5,251	6,016	26.1	2	222
62 Q3	22	1.6	13.2	19.1	23.5	192	0.426	1,812	4,884	77	10	222
62 Q4	18	2.7	2	18.2	22.7	317	1.789	1,413	4,050	82.7	0	225
63 Q1	27.6	3.6	14.1	20.3	26.1	540	0.456	2,747	6,017	79.4	6	218
63 Q2	9.3	2	0.5	1.5	7.4	368	1.97	1,036	2,102	74.8	0	226
63 Q3	27	1.7	17.1	20.3	27.1	291	0.343	4,340	6,453	44.8	15	239
63 Q4	16.9	1.7	7.1	11.7	15.9	300	0.594	1,896	3,988	71.2	10	236
64 Q1	19.8	1.1	11.8	16.1	20.3	104	0.404	1,574	4,396	76.6	12	222
64 Q2	29.3	2	13.9	20.4	26	245	0.464	3,507	6,094	62.5	14	208
64 Q3	24.7	1.6	12.1	20.1	31.7	219	0.712	4,727	5,236	15.6	2	212
64 Q4	25.2	2.4	17.2	21.3	24.6	267	0.266	1,391	5,216	88.9	11	207
65 Q1	19.3	3.3	5.7	7.8	14	678	0.672	2,224	4,400	78.5	10	228
65 Q2	16.4	1.4	8.5	11.7	17.6	224	0.541	2,755	3,608	30.9	7	220
65 Q3	13.9	1.4	5	8.8	13.5	245	0.736	2,030	3,002	39.8	4	216
65 Q4	13.6	1.6	7.4	10.8	17.3	66	0.633	514	2,924	87.9	1	215

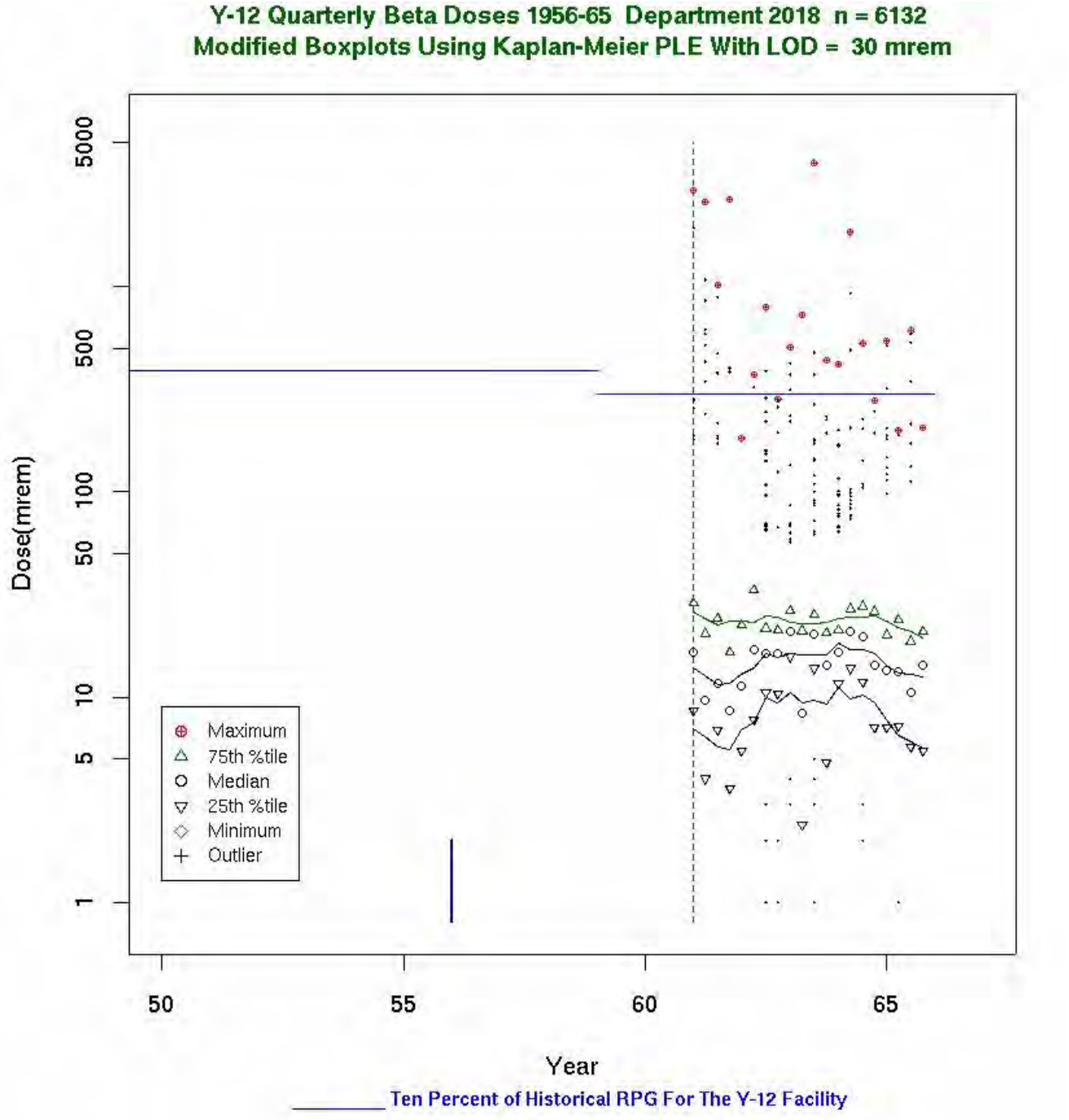
Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Table 5-18: Department 2018 Summary Statistics

Date (year, quarter)	Kmm[1]	Kmse[2]	xq25[3]	xq50[4]	xq75[5]	Xmax[6]	Rsdy[7]	Cdose[8]	Cdosea[9]	Pnd[10]	Nout[11]	N[12]
60 Q4	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	3
61 Q1	45.7	10.2	8.6	16.5	28.8	2,935	0.897	13,213	15,949	51	10	349
61 Q2	40.5	8.9	4	9.6	20.4	2,583	1.202	12,468	14,216	49.6	9	351
61 Q3	32.2	4.7	6.9	11.6	24.2	1,014	0.933	10,618	11,141	12.4	11	346
61 Q4	25.5	7.8	3.6	8.6	16.5	2,641	1.126	6,671	8,798	60.9	3	345
62 Q1	19.4	1.3	5.5	11.3	22.3	181	1.034	5,817	6,965	28.7	1	359
62 Q2	30	2.2	7.8	16.9	33.3	372	1.08	9,018	10,050	23.3	2	335
62 Q3	25.4	3	10.5	16.3	21.6	788	0.533	5,410	8,763	64.3	20	345
62 Q4	20.1	2.1	10.4	16.2	21.1	283	0.525	2,059	6,955	90.2	7	346
63 Q1	29.6	2.7	15.7	20.8	26.3	503	0.382	5,108	10,242	75.1	17	346
63 Q2	22.9	3.7	2.4	8.3	21	726	1.622	5,147	7,946	75.2	1	347
63 Q3	42	11.8	13.8	20.3	25.1	4,000	0.445	10,946	14,448	56.4	24	344
63 Q4	20.9	2	4.8	14.2	20.6	437	1.072	4,496	7,210	61.7	4	345
64 Q1	25.2	2.3	11.6	16.5	21.2	417	0.45	3,309	6,703	77.4	16	266
64 Q2	40.1	8.2	13.8	20.9	26.9	1,832	0.495	7,176	10,266	61.7	15	256
64 Q3	26.4	2.4	11.9	19.6	27.7	530	0.629	6,331	6,970	14.4	6	264
64 Q4	26.4	3.6	7.1	14.2	26.1	277	0.963	2,828	6,679	85.8	3	253
65 Q1	28.3	3.8	7.1	13.5	20.1	539	0.771	4,396	6,820	71.4	12	241
65 Q2	22.6	1.9	7.2	13.2	23.9	198	0.884	4,374	5,040	24.2	2	223
65 Q3	27.8	4.8	5.7	10.5	18.7	614	0.882	5,308	6,227	34.8	9	224
65 Q4	17	1.7	5.5	14.3	20.8	205	0.981	1,295	3,740	78.6	1	220

Notes:
[1] K-M estimate of the mean for the quarter
[2] K-M estimate of the standard error of the K-M mean
[3] 25th quantile
[4] 50th quantile; estimate of the GM
[5] 75th quantile
[6] Maximum dose in quarter
[7] [log(xq75) – log (xq25)] / 1.35— estimate of log (GSD)
[8] Cumulative dose
[9] n*kmm—"adjusted" cumulative dose
[10] Percent non-detects
[11] Number of positive outliers
[12] Total number of quarterly doses

Figure 22. Modified Boxplot for Beta Doses in Department 2018, 1956-1965



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