Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Industry Point Source Category (40 CFR 432)

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Complete proposed document available at:
http://www.epa.gov/ost/guide/mpp/
The Final Development Document is available as well.

APPENDIX B

SURVEY DESIGN AND CALCULATION OF NATIONAL ESTIMATES

In 2001, EPA distributed two industry surveys. The first survey, entitled 2001 Meat Products Industry Screener Survey (short survey), was mailed to 1,650 meat products industry facilities. The second survey, entitled 2001 Meat Products Industry Survey (detailed survey), was mailed to 350 meat products industry facilities.

Section B.1 of this appendix describes the survey design (identification of facilities in the industry and sample design). Section B.2 of this appendix describes the selection of the sample. Section B.3 of this appendix describes response status of short survey facilities. Section B.4 of this appendix describes the calculation of sample weights. Section B.5 of this appendix describes the methodology for estimating national totals and their variance estimates. Section B.6 of this appendix summarizes EPA's plans for the analysis of the detailed survey.

B.1 SURVEY DESIGN

This section describes the development of the sampling plan, which includes identification of the meat products industry and stratification of facilities.

B.1.1 Sample Frame

To produce a mailing list of facilities for the detailed survey and short survey, EPA developed a sample frame of the meat products industry. A sample frame is a list of all members (sampling units) of a population, from which a random sample of members will be drawn for the survey. Therefore, a sample frame is the basis for the development of a sampling plan to select a random sample. EPA used several data sources to construct this sample frame. The March 2000 Hazard Analysis and Critical Control Points (HACCP) database was the main source of data. It was supplemented with information from the Urner-Barry Meat and Poultry Directory 2000 and an April 2000 list of 236 renderers provided by the National Renderers Association (NRA). The sample frame for the meat product survey contained 8,217 facilities.

EPA classified each facility into sampling strata by considering facility type, facility size, and type of animal used at the facility. Each facility was of one of the following 3 types: further processor, first processor, or renderer. Three size categories were used to determine the facility size. The size category was defined as large for facilities with 500 employees or more, small for

facilities with 10 to 499 employees, and very small for facilities with 9 employees or less. Each facility on the sample frame specialized in one or several types of animal. These types of animal corresponded to poultry, beef, pork, and other. Renderers were not identified by size or animal type.

B.1.2 Sample Design

The sample frame for the survey included an unknown number of out-of-scope facilities. In order to obtain reliable counts of eligible meat product facilities, i.e., the facilities that were in-scope, by type and facility size directly from the frame, the survey was designed as a two-phase sample.

A first-phase sample of 2,000 facilities was selected from a sample frame containing 8,217 facilities. Additionally, a second-phase sample of 350 facilities was selected from the first-phase sample. All 350 second-phase sample facilities were mailed the detailed questionnaire, while the remaining 1,650 first-phase sample facilities received the short questionnaire. While the abridged form collected basic data to determine eligibility status and types of meat processed, the long form collected data about the 350 second-phase sample facilities for technical and financial information. Because of time constraints, both surveys were sent out simultaneously. To improve the accuracy of estimates from the detailed survey, the final weights will be calibrated to the estimated counts of eligible facilities from the short survey.

EPA identified a list of 65 facilities that were to be selected for the second-phase detailed sample with certainty to obtain information necessary for evaluating facility operations and best technology options. The first-phase and second-phase facility samples were stratified samples. Stratification separated the eligible population into non-overlapping strata that were as homogeneous as possible. Stratification assured that the sample would contain the same proportions as found on the sample frame, for those variables used to define the strata. The first-phase sample (selecting 1,935 non-certainties from 8,152) was stratified by facility type and size. The stratification of the second-phase sample was based only on facility type, since just 285 facilities were to be selected from the 1,935 first-phase non-certainties.

Table B-1 shows the distribution of facilities on the sample frame by facility type (first processor, further processor, renderer, or missing), size, and certainty status. Most certainty facilities were large first processors. Only 5 certainty facilities were small and none of the very small facilities were included in the sample with certainty.

B.1.3 Imputing for Missing Facility Type

In order to estimate the number of eligible facilities by type, size, and meat product (the purpose of the short survey) it was necessary to include samples of sufficient size from each facility-type-by-size stratum. This required assigning each facility on the frame to one of these strata; however, this information was unknown for many facilities; thus, EPA imputed the missing stratification data.

Table B-1. Distribution of facilities in the sample frame by certainty, facility type, and size

Certainty status	Facility type	Size				Total
		Large	Small	Very small	Unknown	
Non-certainties	First Processor	149	234	0	0	383
	Further Processor	34	883	0	0	917
	Renderer	0	0	0	235	235
	Unknown	50	1,259	5,308	0	6,617
Non-certainty total		233	2,376	5,308	235	8,152
Certainties	First Processor	56	3	0	0	59
	Further Processor	1	0	0	0	1
	Renderer	0	0	0	1	1
	Unknown	2	2	0	0	4
Certainty total		59	5	0	1	65
Grand total		292	2,381	5,308	236	8,217

From Table B-1 it is seen that facility type had to be imputed for 6,617 non-certainty facilities.[1] The facilities to be imputed a specific type were chosen randomly from the set of facilities with missing type. The facilities with unknown facility type were distributed between "first processors" and "further processors" proportionally to the reported size of each type.

[1] It should be noted that no imputation was carried out on the 4 certainty facilities with missing facility type, as they were to be included in the sample by design.

Therefore, 9 (=50 x (34/(34+149))) of the 50 large facilities with missing facility type were assigned to the further processor category, while the remaining 41 large facilities were assigned to the "first processor" category. Similarly, 995 of the 1,259 small facilities with missing facility type were assigned the "further processor" type, and the remaining 264 small facilities were assigned the "first processor" type. All very small facilities were assumed to be further processors because very small facilities in this industry were typically further processors.

All imputed values were used only for allocating the sample. None of the values were used for estimation and any wrong assumption simply resulted in a less efficient sample (larger variance). In addition, this imputation process was not expected to introduce any bias in the statistical procedure. For example, all very small facilities were assumed to be further processors; however, if any very small facility reported as a first processor it was treated as such in all analyses.

B.1.4 Imputing for Missing Animal Type

Before selecting the samples, the frame was sorted by animal type within each stratum. This allowed for appropriate representation of the different animal types in random selection of the sample. Table B-2 shows the distribution by animal type of noncertainty facilities that were not renderers. It should be noted that the stratification did not require the specification of animal type for the renderers. All large facilities with missing animal type were randomly assigned to one of the 7 animal type categories described in Table B-2 proportionally to the large facilities with animal types reported in the frame. On the other hand, small and very small facilities were combined and randomly assigned to animal type groups proportionally to the number of small facilities reported with animal types.

Table B-2. Distribution of noncertainty and non-renderer facilities imputed for animal type

Facility size	Animal type	Number of facilities reported on frame	Number of facilities imputed
Large	Pork only	17	4
	Poultry only	127	30
	Poultry & Pork	2	0
	Beef only	10	2
	Beef & Pork	6	1
	Beef & Poultry	3	2
	Beef & Poultry & Pork	23	6
	Missing	45	N/A
Small and very small	Pork only	157	805
	Poultry only	152	779
	Poultry & Pork	32	164
	Beef only	196	1,005
	Beef & Pork	203	1,041
	Beef & Poultry	76	390
	Beef & Poultry & Pork	438	2,246
	Missing	6,430	N/A
Total		7,917	6,475

B.2 SAMPLE SELECTION OF FACILITIES

The design of the first-phase sample was based upon the assumption that large facilities were more likely to be eligible than small facilities, which in turn were expected to be eligible more frequently than very small facilities. Thus, EPA determined that oversampling of the large facilities would be appropriate, in order to include many eligible facilities. Too much oversampling would reduce the accuracy of estimates because some facilities would have much greater weights than other facilities. An examination of alternative oversampling schemes[2] suggested balancing these two constraints by selecting large facilities at six times the rate of very small facilities, and at twice the rate of small facilities.

[2] DCN-55,001 July 28, 2000 memorandum from David Marker to Helen Jacobs and Jade Lee-Freeman.

After sorting by animal type, the facilities were selected from each stratum using systematic sampling scheme. Systematic sampling involve selecting every k^{th} facility where k is determined by the selection rate. The allocation of the sample is described in Table B-3. The allocation in Table B-3 was based upon the 6-3-1 rule according to which, large facilities were selected at a rate that

was 6 times higher than that of very small facilities and twice higher than that of small facilities. Using this allocation scheme, EPA selected a total of 2,000 facilities from the frame of 8,217 facilities.

Table B-3. Allocation of the first-phase sample

Stratum *h*	**Sample frame size** (N_h)	**First phase sample size** (n_h)
Certainty	65	65
Large First Processor	190	152
Large FurtherProcessor	43	34
Small First Processor	498	199
Small Further Processor	1,878	750
Very Small Further Processor	5,308	706
Renderer	235	94
Total	8,217	2,000

The 350 sample facilities were allocated in the second-phase sample to provide similar precision for each of seven analytic domains of interest. These domains were: poultry, beef, and pork further processors; poultry, beef, and pork first processors; and renderers. The 285 noncertainty sample facilities were therefore allocated so that approximately 41 (=285/7) were in each of these seven domains. The entire second-phase sample, including the noncertainty sample, consisted of 122 further processors, 121 first processors, and 42 renderers, along with 65 facilities selected with certainty. The facilities were sorted within facility type by animal type (as listed in Table B-4) before selecting the samples. Table B-4 shows how the first-phase sample in the previous table was distributed across the short and detailed surveys.

Table B-4. Allocation of the sample to the short and detailed surveys

Facility size and type	Sample size		
	First phase	Short survey	Detailed Survey
Certainty	65	0	65
Large First processor	152	100	52
Large Further processor	34	31	3
Small First processor	199	130	69
Small Further processor	750	688	62
Very small Further processor	706	649	57
Renderer	94	52	42
Total	2,000	1,650	350

For the purpose of selecting the sample of facilities, the WESSAMP SAS macro developed at Westat was used. WESSAMP selects systematic samples within sampling strata defined through a set of parameters.

B.3 RESPONSE STATUS OF SHORT (SCREENER) SAMPLE FACILITIES

Of the 1,650 facilities to which a short form was mailed, 601 did not return the form and their eligibility status was unknown as of April 24, 2001[3]. A total of 193 facilities that were either out-of-scope or could not be located were classified as ineligible. EPA assumed that some of the 601 facilities that did not return the short form were eligible nonrespondents. Therefore, it was necessary to estimate the number of ineligible facilities for sample weight adjustments. (See Section B.4.) The remaining 856 facilities were eligible respondents. These were facilities that returned a complete form and indicated that they engaged in meat processing. Table B-5 shows the response status by stratum for the facilities that were mailed a short survey.

[3] Any surveys processed after that date will be included in the revised estimates for the final rule.

Table B-5. Response status for the short survey by first-phase stratum

Stratum	Sample size	Eligible Respondent (S_1)	Nonrespondent (S_4)	Ineligible	
				Out-of-Scope (S_3)	Non-deliverable
Large First Processor	100	81	18	1	0
Large Further Processor	31	25	5	1	0
Small First Processor	130	76	41	10	3
Small Further Processor	688	350	247	53	38
Very Small Further Processor	649	287	281	36	45
Renderer	52	37	9	4	2
Total	1,650	856	601	105	88

B.4 WEIGHTING OF THE SHORT SURVEY

This section describes the methodology used to calculate the base weights, non-response adjustments, and the final weights for the short survey. In its analysis, EPA applied sample weights to survey data. The short survey was weighted in order to account for variable probabilities of selection, differential response rates, and ineligible facilities. The base weights and non-response adjustments reflect the probability of selection for each facility and adjustments for facility level non-responses, respectively. Weighting the data allows inferences to be made about all eligible facilities, not just those included in the sample, but also those not included in the sample or those that did not respond to the survey. Also, the weighted estimates have a smaller variance than unweighted estimates (see Section B.5 of this appendix for variance estimation.)

B.4.1 Base Weight Calculation

The first step in weighting the short survey was to assign a base weight to each of the sample facilities. The base weight associated with a short survey facility was calculated by multiplying the reciprocal of the probability of including that facility in the first-phase sample of 2,000 facilities, by the reciprocal of the probability of not including that facility in the detailed survey sample in the second phase. Table B-6 shows the calculation of the base weight. The

short survey base weight for a given first-phase stratum *h* and second-phase stratum *l* can formally be written as follows:

$$Base\ weight_{hl} = \left(\frac{n_h}{N_h}\right)^{-1} \times \left(1 - \frac{m_l}{M_l}\right)^{-1}$$

where N_h is the number of facilities in the sample frame that belong to first-phase stratum *h*, n_h is the number of facilities selected in the first-phase sample that belong to first-phase stratum *h* (N_h and n_h are shown in Table B-5), M_l is the number of first-phase sample facilities that belonged to second-phase stratum *l*, and m_l is the number of facilities selected in the detailed survey sample from second-phase stratum *l*.

For example, in the first-phase sample, 34 of 43 large further processors were selected, so the first-phase inclusion probability was 0.7907. The second-phase sample only stratified by facility type, so the second-phase inclusion probability for further processors in the detailed survey was (3 + 62 + 57)/(34 + 750 + 706) = 0.0819 (see Table B-4). The overall inclusion probability for the short survey was (0.7907) x (1 - 0.0819) = 0.72596. The base weight was the reciprocal of this probability, 1.3775.

Table B-6. Base weight calculation for the short survey

Stratum	First-phase inclusion probability (n_h/N_h)	Second-phase detailed survey inclusion probabilities (m_l/M_l)	Short survey inclusion probabilities $\left(\frac{n_h}{N_h}\left(1-\frac{m_l}{M_l}\right)\right)$	Short survey base weights $\left(\left(\frac{n_h}{N_h}\right)^{-1} \times \left(1-\frac{m_l}{M_l}\right)^{-1}\right)$
Large First processor	0.8000	0.3447	0.52422	1.9076
Small First processor	0.3996	0.3447	0.26185	3.8191
Large Further processor	0.7907	0.0819	0.72596	1.3775
Small Further processor	0.3994	0.0819	0.36666	2.7273
Very Small Further processor	0.1330	0.0819	0.12212	8.1889
Renderer	0.4000	0.4468	0.22128	4.5192

B.4.2 Eligibility and Non-response Adjustment

The base weights associated with the short survey facilities were adjusted for non-response. Because the 601 nonresponding facilities had an unknown eligibility status, it was assumed that they were distributed among eligible and out-of-scope facilities in the same proportions as the respondents within each stratum. It was assumed that all nonrespondents did receive their surveys. The base weights of facilities were multiplied by the adjustment factor obtained by dividing the count of all sample facilities by the count of facilities with known eligibility status. The final weight, w_{hi} for a facility i in stratum h, can be written as follows:

$$\begin{aligned} w_{hi} &= \left(base\ weight\right)_{hi} \times \left(nonresponse\ adjustment\right)_h \\ &= \left(base\ weight\right)_{hi} \times \left(\frac{S_1 + S_3 + S_4}{S_1 + S_3}\right)_h \end{aligned}$$

where S_1, S_3, and S_4 represent counts for stratum h of eligible respondents, out-of-scope respondents who received their surveys, and facilities who did not respond, respectively (see Table B-6). This non-response adjustment was performed within strata in order to account for differential response rates in the short survey. For example, large further processors had 25 eligible respondents, 1 not involved in meat products, and 5 non-respondents. Its non-response adjustment factor was therefore 1.1923 (=31/26). Table B-7 shows the non-response adjustment factors and final weights for each stratum.

Table B-7. Non-response adjustment and final weight for the short survey

Stratum *h*	Short survey base weight	Non-response adjustment $\left(\frac{S_1 + S_3 + S_4}{S_1 + S_3}\right)$	Short survey final weight (W_{hi})
Large First Processor	1.9076	1.2195	2.3264
Small First Processor	3.8191	1.4767	5.6398
Large Further Processor	1.3775	1.1923	1.6400
Small Further Processor	2.7273	1.6129	4.3880
Very Small Further Processor	8.1889	1.8670	15.2658
Renderer	4.5192	1.2195	5.5113

EPA plans to revise the short survey weighting and estimation to include the facilities whose responses were processed after the initial deadline. The same procedures will be used as described above, but the number of completes, ineligibles, and nonrespondents will change, and so will the weights. These revised short survey weights also will be used to revise the detailed survey weights. (See Section B.6.)

B.5 ESTIMATION METHOD

This section presents the general methodology and equations for calculating estimates from the short survey.

B.5.1 National Estimates

National total estimates were obtained for each characteristic and domain of interest by multiplying the reported value by the non-response-adjusted weight and by summing all weighted values for the facilities that belong to the domain of interest *k*.

$$\hat{y}_k = \sum_i w_{ki} y_{ki}$$

Similarly, ratio estimates (for example, of the mean) in a given domain *k* were obtained as a ratio of two national total estimates. For example, the average cattle production by facilities doing first processoring was calculated by dividing the weighted production of cattle by the weighted count of first processors.

$$\overline{y}_k = \frac{\sum_i w_{ki} y_{ki}}{\sum_i w_{ki}}$$

where w_{hi} is the non-response adjusted weight for facility *i*, y_{ki} is the cattle production for facility *i*, both in domain *k*, and the summation is over all facilities reporting cattle production.

Note that many facilities were involved in more than one type of activity or production. Their classification into one activity type, either first processoring, processing, rendering, or some combination was determined by the relative concentration of their production in any

activity. Similar classification issues arose when reporting production by animal type (red meat, poultry, or mixed). If at least 85 percent of total production was of a given type of activity, it was classified accordingly (e.g., first processor). If no activity type accounted for 85 percent of production it was classified as mixed type. The same rule was used for animal type.

Further, note that the 65 certainty facilities were excluded from the short survey. The above estimation procedure will produce national estimates for all facilities except for those 65. To produce national estimates from the short survey that cover the entire meat products industry it will be necessary to combine these estimates with the reported data from the detailed questionnaires filled out for those 65 certainty facilities. Since these 65 facilities represent only themselves, they are each given a weight of one for such analyses. For the final rule, EPA will incorporate the values for the 65 facilities into its revised national estimates.

B.5.2 Variance Estimates

To compute the correct estimates of standard errors a set of jackknife replicate weights was constructed and attached to each facility. Under the jackknife replication method, a number of subsamples (called jackknife replicates) were generated from the full sample, and the entire weighting process as described in the previous sections was repeated for each replicate. In this way, a series of replicate weights were generated for each facility, which together with the full-sample weight were used to calculate sampling errors (see Wolters, 1985 for a description of the jackknife and other variance estimation methods)[4]. Given that there were almost 900 responding facilities for the short survey, it was decided to create 90 replicates for variance estimation. Each respondent was assigned a number between 1 and 90. The first replicate used the values from all facilities except those assigned to group 1. The other replicates were derived in a similar way by excluding the values for a different group each time.

In order to illustrate how the sampling errors have been calculated, let be the weighted national average estimate of a characteristic *y* (e.g., first processor meat production of cattle) for

[4] Wolters, K. M. (1985) Introduction to Variance Estimation, Springer-Verlag Publishers, New York.

the entire data set. If is the corresponding estimate for jackknife replicate *r*, then the estimated variance of *y* is given by the following formula:

$$\mathrm{var}(\bar{y}) = \sum_{r=1}^{90} \left(\bar{y}_{(r)} - \bar{y}\right)^2$$

where the summation extends over all 90 jackknife replicates that were formed for the short survey. This jackknife variance was often used to compute 95 percent confidence limits around the estimate. These limits are given by:

$$\bar{y} \pm 1.96\sqrt{\mathrm{var}(\bar{y})}$$

The WesVar program was used to compute estimates of standard errors.

B.6 ANALYSIS OF THE DETAILED SURVEY

The process of detailed surveys is more complex and time-consuming than the process of short surveys due to its length and the details of survey responses. In order to meet the court ordered deadline for the proposed rule, EPA only analyzed the short surveys. Detailed surveys will be analyzed for the final rule using similar methodology described in Sections B.4 and B.5. For the final rule, the base weight associated with a detailed sample facility was calculated by multiplying the reciprocal of the probability of including that facility in the first-phase sample of 2,000 facilities, by the reciprocal of the probability of including that facility in the detailed survey sample. Table B-8 shows the calculation of the base weight. The detailed survey base weight for a given first-phase stratum *h* and second-phase stratum *l* can formally be written as follows:

$$Base\ weight_{hl} = \left(\frac{n_h}{N_h}\right)^{-1}\left(\frac{m_l}{M_l}\right)^{-1}$$

where N_h is the number of facilities in the sample that belong to first-phase stratum *h* (N_h and n_h are shown in Table B-3), n_h is the number of facilities selected in the first-phase sample that belong to first-phase stratum *h*, M_l is the number of first-phase sample facilities that belong to second-phase stratum *l*, and m_l is the number of facilities selected in the detailed survey sample

from second-phase stratum *l* (second-phase stratum totals can be found in the column labeled "Detailed Survey" in Table B-4).

Table B-8. Base weight calculation for the detailed survey sample

Stratum	First-phase inclusion probability (n_h / N_h)	Second-phase inclusion probabilities (m_l / M_l)	Detailed survey inclusion probabilities $\left(\left(\frac{n_h}{N_h}\right)\left(\frac{m_l}{M_l}\right)\right)$	Detailed survey base weights $\left(\left(\frac{n_h}{N_h}\right)^{-1}\left(\frac{m_l}{M_l}\right)^{-1}\right)$
Large First Processor	0.8000	0.3447	0.2758	3.6260
Small First Processor	0.3996	0.3447	0.1378	7.2594
Large Further Processor	0.7907	0.0819	0.0647	15.4460
Small Further Processor	0.3994	0.0819	0.0327	30.5816
Very Small Further Processor	0.1330	0.0819	0.0109	91.8232
Renderer	0.4000	0.4468	0.1787	5.5952
Certainties	1.0000	1.0000	1.0000	1.0000

Due to duplication on the sample frame, a few facilities were sampled for both the short and detailed surveys. Such facilities were encouraged to complete both forms since estimates are made independently from both surveys.

The non-response adjustment for the detailed survey will be carried out with the same methodology used to adjust the base weights for the short survey (see Section B.4.2). However, the non-response-adjusted weights will further be adjusted to benchmark them to the weighted counts of eligible facilities calculated from the short survey. This is because the much larger sample size in the short survey provides better estimates of the number of eligible facilities in each stratum. This second adjustment will be done within the type and size categories and will yield the final weight. If *h* designates a first-phase stratum, then the detailed survey final weight w_i for a given facility *i* can be written as follows:

$$W_i = \left(NR - Adjusted\ Weight\right)_i \times \frac{\left(Estimated\ Number\ of\ Facilities\ from\ Short\ Survey\right)_h}{\left(Estimated\ Number\ of\ Facilities\ from\ Detailed\ Survey\right)_h}$$

National estimates and corresponding standard errors for the detailed survey will be calculated using the same methods described in Section B.5 for the short survey with the exception that for each jackknife replicate sample will be based on a different number of subsamples. In the documentation for the final rule, EPA will further describe the detailed questionnaire estimates.