CHAPTER 10
POLLUTANT LOADING METHODOLOGY

10.1 INTRODUCTION

EPA identified several potential regulatory options for the concentrated aquatic animal production (CAAP) industry. To develop and evaluate these options, EPA used a computer spreadsheet model that estimates compliance costs and pollutant loadings for different combinations of the technologies and practices included in the regulatory options considered. Chapter 9 presents the costing methodology. This chapter describes the methodology used to estimate the pollutant loading reductions associated with installing and operating the pollutant control technologies and best management practices (BMPs) considered for the regulatory options.

10.1.1 Approach for Estimating Loadings

Consistent with EPA's intentions described in the preamble to the proposed rule, EPA based its analyses for the final rule on data collected from the detailed questionnaire. The preamble described the detailed questionnaire (Hochheimer, 2003) and EPA's plans to recalculate estimates for costs and benefits associated with the proposed regulatory options. EPA reviewed the responses from the detailed questionnaire, performed follow-up activities on the detailed questionnaires resulting from inconsistencies or questions from an initial review of responses, and completed analyses of the data contained in these responses.

For the analyses that support the final regulation, EPA used a facility-specific approach for estimating pollutant load reductions. EPA obtained detailed, facility-level information for a randomly-drawn, stratified sample of potentially in-scope facilities through the detailed AAP survey (USEPA, 2002a). The sample was taken from a group of screener surveys. EPA analyzed the detailed survey information and determined the level of treatment currently in place at each facility (i.e., baseline). For each facility, EPA evaluated the specifications of technologies and BMPs for each option that were used to determine regulatory compliance in comparison to the technologies in place at the facility. EPA used data from the facility to estimate the pollutant load reductions that would be expected from any components that were not in place.

Feed inputs to aquatic animal culture systems are the drivers of effluent quality discharged from CAAP facilities. Feed offered to the cultured species contributes to pollutant discharges in two ways. First, metabolic wastes and unmetabolized feed consumed by the cultured species are contained in the feces and urine. Pollutants contributed include organic solids (in the form of TSS and contribute to BOD), nutrients (i.e., nitrogen and phosphorus), and small amounts of metals and other compounds that are present in the feed. Second, uneaten feed settles, breaks down, and increases the pollutant load in the culture water. Depending on the culture and effluent treatment systems, some or all of the feed by-products can be discharged from a CAAP facility. For each in-scope facility that responded to the detailed survey, EPA estimated raw waste loads, baseline loads, and effluent loads for different regulatory option scenarios. All of the estimates are based on feed inputs to the systems.

EPA developed a series of Microsoft Excel spreadsheets to serve as a computing platform for the analysis. The spreadsheets linked feed inputs, unit pollutant load reductions of the technologies or practices representing each regulatory option, and facility attributes to derive a facility-specific load reduction estimate for compliance. For example, a pollutant load module was developed for feed management BMPs. Inputs, in the form of estimated pollutant loads, were customized for each individual facility using feed data supplied in the detailed survey. For each facility, EPA evaluated feed management strategies to enable the facility to meet narrative limits. EPA adjusted the total load reductions according to the layout of the individual facility, the technologies or practices currently in place. To check these estimates, EPA compared predicted loads and concentrations with discharge monitoring data that were available for some of the facilities. Finally, EPA multiplied the load reduction estimates for each facility by its sample weight and then summed the weighted load reductions to determine national estimates.

10.1.2 Organization of the Chapter

The following pollutant load reduction information is discussed in detail in this chapter:

- *Section 10.2* presents the structure of the load reduction model. EPA's load reduction model for the CAAP industry uses a facility specific approach to develop pollutant load reductions (from baseline loads) associated with each regulatory option.
- *Section 10.3* provides detailed background information on the contribution of feeds to pollutant loads (including constituents of feeds, feeding practices, and feed conversion ratios (FCRs)), the fate of feed in CAAP systems, and the method used to estimate raw pollutant loads.
- *Section 10.4* discusses unit load reduction modules, which are components of the treatment technologies that compose the regulatory options. Each treatment technology unit load reduction module contains formulas by which to calculate the pollutant load reductions associated with each regulatory option based on the facility characteristics.
- *Section 10.5* discusses a summary of the facility groupings, based on analysis of the detailed surveys. This section also provides estimates of raw and baseline pollutant loads from facilities.
- *Section 10.6* describes the estimates of pollutant loads from facilities when the regulatory options were applied.
- *Section 10.7* provides a summary of estimates for loads of other materials (i.e., metals, PCBs, drugs) that would be removed with solids.

10.2 LOADING MODEL STRUCTURE

EPA estimated the loading reduction associated with each of the regulatory options under consideration. EPA estimated loading reductions based on the implementation of control technologies that have known pollutant removal efficiencies and can achieve discharge limits for total suspended solids, as demonstrated by facilities in the CAAP industry.

To generate industry loading removals associated with each regulatory option for CAAP facilities, EPA developed a computer-based model made up of several individual treatment technology modules. Figure 10.2–1 illustrates the loading model and shows that it consists of several components, which can be grouped into five major categories:

- Feed input
- Baseline facility configuration
- Unit load reduction modules
- Output data—facility-specific pollutant load estimates and national pollutant load estimates
- Weighting factors

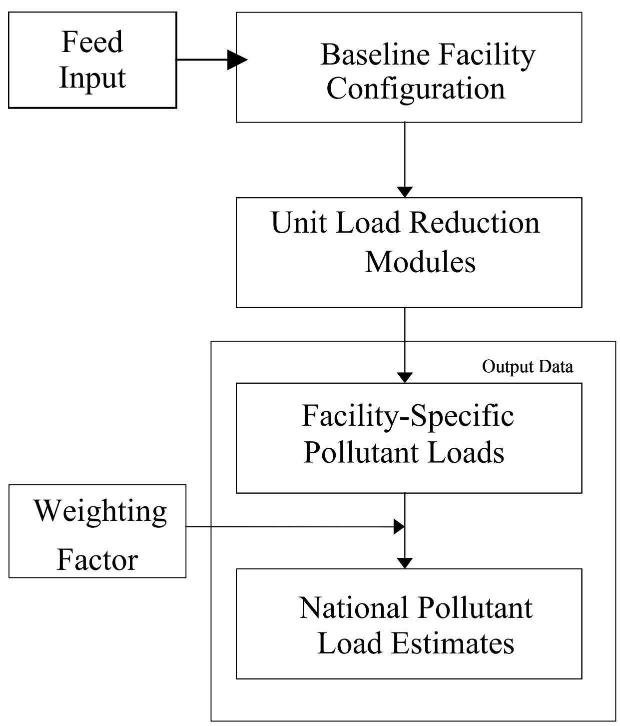

Figure 10.2–1. Schematic of Loading Model Structure

Since feed inputs are directly proportional to pollutant loads, annual feed use was first evaluated for each facility. Once a validated feed estimate was obtained, raw pollutant loads were calculated using known relationships between feed inputs and pollutant outputs. The configuration of each specific facility was analyzed and the characteristics matched to the pollutant reduction components of the specified options. Each unit load reduction module calculates loading reductions for a specific wastewater treatment technology (e.g., a primary settling basin or feed management) based on loading reductions for the specific facility characteristics. When sufficient information from the detailed survey were provided that enabled EPA to match facility-specific configurations to the desired regulatory outcome, a unit load reduction module was not evaluated (i.e., no costs or pollutant load reductions were assigned). For example, EPA assumed that facilities with quiescent zones and settling basins listed on the detailed survey had these technologies properly designed, installed, and operated. Thus, the facility would not bear a regulatory cost or contribute to national reductions in pollutants from primary settling. When possible, the facility's monitoring data were checked to confirm consistency with the regulatory limits. All of the unit load reductions were summed for a facility to estimate the farm-level pollutant load reductions. Weighting factors were then applied to the loading reductions to weight the reductions by the estimated percentage of operations that are similar to the specific facility. EPA summed these weighted facility reductions to estimate national load reductions resulting from the regulation.

10.2.1 Facility Configuration

The facility configuration part of the loading model sets up the characteristics of each unique facility, based primarily on system type, species, the combination of existing and final management practices and technologies, annual production, and feed inputs.

Input data to the model include the following:

- Data associated with feeding practices, including feeding in pounds/day and pollutant concentrations conversion factors associated with feed to estimate raw waste loads.
- Estimates of annual production.
- Average daily flow rates to each production unit and treatment component.
- Technologies and BMPs in place.
- Pollutant removals of technology options and BMPs.

10.2.2 Unit Load Reduction Modules

The unit load reduction modules contain the pollutant removal information for each component, BMP, or treatment technology contained in the regulatory options. The load reduction modules calculate the pollutant removals for the specific facilities, based on culture species and production system, using pollutant-specific removals for each of the regulatory options. The various load reduction factors are discussed in Section 10.5.

10.2.3 Output Data

Output data from the loading model provide estimates of baseline pollutant loadings discharged and incremental pollutant removals associated with each regulatory option for individual facilities and at a national level. Section 10.6 discusses the output data in more detail.

10.2.4 Weighting Factors

EPA's detailed industry survey was sent to a representative sample of the CAAP industry. Each sampled facility represents one or more facilities in the national population of CAAP facilities. The relationship between the sampled facility (which responded to the detailed survey) and the facilities it represents in the national population is characterized by a sample weighting factor. This weighting factor is used by EPA to scale its estimates from the sample population to the national population by multiplying an individual facility's sample weight and load estimates for pollutants. The sample weights are initially calculated when the stratified sample is drawn and then adjusted for non response in the surveys.

In August 2001, EPA mailed approximately 6,000 screener surveys to aquatic animal production facilities. EPA received responses from 4,900 facilities, of which about 2,300 facilities reported that they produce aquatic animals. EPA used the screener responses to select a stratified random sample to receive the detailed questionnaire. Sample criteria were designed to primarily capture facilities that produce aquatic animals and are likely to be covered by the proposed rule. EPA also developed sample criteria to capture facilities that are out of scope (based on information in the screener survey) to validate its assumptions about the applicability of the proposed regulation. For example, the sample criteria includes facilities with ponds, which are out of scope in the proposed regulation, to confirm that additional regulations for ponds are unnecessary. The Technical Development Document (TDD) for the proposed rule (USEPA, 2002b), page A11, describes in detail the criteria and includes facilities that are in-scope and out of scope. The facilities selected met one of these criteria:

- Aquariums.
- Production includes alligators and total biomass exceeds 100,000 pounds.
- Production includes trout or salmon and total biomass exceeds 20,000 pounds.
- Predominant production method is ponds; predominant species is catfish; and total biomass exceeds 2,200,000 pounds.
- Predominant production method is ponds; predominant species is shrimp, tilapia, other finfish, or hybrid striped bass; and total biomass exceeds 360,000 pounds.
- Predominant production method is any method except ponds, and total biomass exceeds 100,000 pounds.

Applying these criteria resulted in 539 facilities from the screener questionnaire responses with these characteristics. EPA then classified the 539 facilities into 44 groups defined by facility type (commercial, government, research, or tribal), the predominant species, and predominant production system type. A sample was drawn from the 539 facilities ensuring sufficient representation of facilities in each of the 44 groups. The sample drawn consisted of 263 facilities. From these 263 facilities EPA excluded 11 facilities that were duplicates on the mailing list or, after revising production estimates, did not meet the production thresholds described in the selection criteria for a CAAP facility. Detailed questionnaires were finally sent to 252 facilities.

EPA received responses on 215 of the 252 questionnaires. A few responses contained information on more than one facility. Subsequently, EPA separated that information into several questionnaires so that a single questionnaire represented an individual facility. EPA also excluded data from 12 facilities that returned incomplete responses. Because these facilities would not have been subject to the proposed limitations, EPA did not ask for more information. After separating multiple responses and excluding incomplete responses, information is available from 205 facilities.

Because EPA selected the 205 facilities using a statistical design (see Appendix A of the TDD, USEPA, 2002b, for more information), the responses allowed EPA to build a database to be used for estimating population characteristics reflecting the above criteria. For national (i.e., population) estimates, EPA applied survey weights to the facility responses that incorporate the statistical probability of a particular facility being selected to receive the detailed questionnaire and adjusted for non-responses. (The response rate was about 80% for the detailed questionnaire. Appendix A of the proposed Technical Development Document addresses the nonresponse adjustments for the screener questionnaire.) In this case, a survey weight of 3 means that the facility represents itself and two others in the population.

10.3 FEED INPUTS

10.3.1 Introduction

Food represents the fuel for a living organism, allowing it to live, grow, and reproduce. Food represents the input of energy to the aquatic animals; its main forms of energy are fats, carbohydrates, and proteins. All energy acquired through the ingestion of food is ultimately converted to wastes (in feces or by excretion), used in metabolic processes, or deposited as new body tissues (Jobling, 1994).

Jobling (1994) estimates that 20% to 35% of the ingested energy in aquatic animals is deposited as growth (i.e., new body tissue). Goddard (1996) states that up to one third (33%) of the content of feed used in intensive aquatic animal production may be indigestible and thus is excreted as feces, which may contain up to 30% of the dietary carbon and 10% of the consumed nitrogen. Chen (2000) estimates that up to 80% of feed input (on a dry weight basis) will not be used for growth and will eventually support metabolic processes or be wasted.

In most in-scope CAAP facilities, the aquatic animals being grown are carnivores (e.g., trout, salmon, striped bass) and omnivores (catfish and tilapia). Practical diets for these species are common and generally available to the facilities. However, there are many factors that contribute to the balance of growth, meeting metabolic needs, and producing wastes when feeding aquatic animals. These factors include many individual characteristics, as well as the interaction among the different factors. Some of the individual characteristics include:

- Species-specific factors—genetics, trophic level
- Diet—energy levels, form, feeding program, ingredients

- Environment—temperature, water quality, stressors

The combination of these factors can contribute to overall success at a CAAP facility in meeting its production goals and to the amount of waste produced. This combination of factors also results in variation among (and often within) facilities in terms of waste output. EPA attempted to account for some of this variation by using annual averages to describe feed inputs and pollutant outputs. EPA also grouped similar types of facilities (such as ownership-system type-species combination) when performing analyses. The following provides more detailed information about some of the sources of variation associated with feeds (and feeding) and the efficiency in which the aquatic animal uses the feed.

The aquatic animal producer has an economic incentive to observe that the feed introduced is fully utilized by the fish with little or no waste. Nevertheless, even under the most careful feeding conditions it is, from a practical point of view, difficult to eliminate feed waste completely (Cho et al., 1991). However, significant improvements in the utilization of feed have been realized during the last decade. Although feed waste cannot be determined accurately, it can be minimized by aiming at optimum rather than maximum production, along with other techniques available to the producer. This requires an awareness of important principles that can impact feed utilization by the fish.

Feeding of high energy diets is now a common practice for trout and salmon, which are carnivorous species. Omnivores (like catfish and some tilapia species), on the other hand, are fed lower-energy diets than carnivores. Diets of herbivores (such as tilapia and carp species) are even lower in energy. These herbivore fish require more bulk in their diet (which means they must be fed a higher percentage of their body weight on a daily basis to meet their energy and growth requirements) and a more-or-less continuous feed intake as they lack a stomach, but have a long gut.

Carnivores may use 44% of the feed calories for metabolism, 29% for growth, and 27% excreted, while herbivores use 37% for metabolism, 20% for growth, and a high 43% excretion. These are rule-of-thumb values; they depend on diets (especially low versus high energy), percent digestibility, and species. The capacity of different species of fish to utilize the energy contained in different nutrients varies greatly (DeSilva and Anderson, 1995). Also, the best performance occurs at a species optimum temperature.

Diets should provide required energy by means of fats and carbohydrates and spare the protein for metabolic needs, especially growth. This has two important facets; protein is the most expensive component of the diet and should not be used for energy, but rather for growing muscle (meat) and secondly this reduces the nitrogen waste.

Protein sparing is a good idea, but if the protein-to-energy ratio is tilted too much toward energy, feeding rate and efficiency are impaired. The goal, therefore, is to achieve the optimum protein-to-energy ratio, which is species dependent (Forster and Hardy, 2000).

The less protein is used as an energy source (i.e., as an aerobic substrate), the less nitrogen is excreted. For example, Johnsen and Wandsvik (1991) reported that using high energy diets have resulted in reduced nitrogen excretion by species up to 35%. Well balanced, high-energy diets have accomplished much in reducing nutrient wastes, as well as reductions in solid wastes. This fact is also reflected in major improvements in the efficiency of feeding, which is measured by feed conversion ratio (FCR) values. For instance, in Nordic countries, FCRs for species were over 2.0 in 1976, but only 1.0-1.1 in 1995 (Pearson and Black, 2000).

As an example, for optimum growth and efficiency of a feeding program, feeding levels should be adjusted when energy levels of the feed vary significantly. For low-energy diets, feeding levels should be increased and vice versa (Barrows and Hardy, 2001). Successful utilization of feed has physical and physiological aspects. Many factors play a role in the effectiveness of these two major functions and it is important for the aquatic animal producer to be aware of these.

The physical component, the capture and ingestion of the feed, depends on the fish's sensory capacities to locate food and their ability to capture, handle, and ingest food items. Once ingested, they depend on their physiological and biochemical capacities to digest, transfer, and utilize the ingested nutrients (Kestemont and Baras, 2001).

Because of the many factors controlling feed intake (appetite), the management of feeding and feed distribution is a very complex one (Guillaume et al., 2001). It is also important to properly distribute and time the availability of food for the fish. The activation of the feeding behavior (appetite) can be influenced by many factors such as:

- Aquatic animal health and stress
- Water quality, especially temperature and dissolved oxygen
- Whether the stomach is full or empty
- Time of day; diurnal responses
- Time of year; seasonal responses
- Rearing density
- Rearing unit characteristics, such as shape, depth, and flow pattern

With respect to the physiological/biochemical component affecting the utilization of the ingested feed, the following should be considered:

- Diet composition; the energy content, nutritional balance in particular with respect to the energy to protein ratio, digestibility of the ingredients, plant versus animal source ingredients, vitamins, minerals and additives.
- Carnivorous versus omnivorous/herbivorous species.
- Water quality, especially temperature, dissolved oxygen, as well as the buildup of ammonia and carbon dioxide in the rearing water.
- Overall fish health and stress.

Estimation of feed requirements may be relatively easy in theory, but estimates will seldom match the needs of the aquatic animals at a specific time, because of large variations in feed intake, both between days and over long periods of time (Alanärä et al., 2001; Guillaume et al., 2001). Often the most difficult part is accurately estimating the biomass to be fed. Feeding tables, formulae, etc. are guidelines, but in practice, daily observations are needed so any necessary adjustments can be made. Models that allow estimation of feed requirements are important for production plans, i.e., long-term planning of feed use. However, ultimately the best approach for producers is to develop their own feed budgets based on accurate records over the years. Ideally, feeding should be tuned to the aquatic animal's demand or appetite.

The act of feeding fish, according to DeSilva and Anderson (1995), is often considered to be the single most important element in aquatic animal production. One aspect of feeding, determining the optimum ration size, is one of the most difficult tasks in any aquatic animal production operation.

The facility operator may have to adjust the amount of feed based on specific requirements by the aquatic animals and, accordingly, select appropriate feed application and distribution relative to feeding schedules and methods.

10.3.2 Feed Conversion Ratio (FCR)

Feed conversion ratio (FCR) represents the ratio of feed fed to fish gain.

It is commonly used as a measure of the efficiency of a feeding program. Overall, the tendency among producers is to aim for fast and maximum growth, while showing less concern for FCRs and feed wastage. This approach is not necessarily the most economic one (Doupé and Lymbery, 2003).

In trout that grow normally, an FCR of 1.2 or less indicates that dietary energy requirements are met. For example, Barrows and Hardy (2001) state that the production of one kilogram trout requires between 3,740 and 3,960 kilocalories/kilogram of digestible diet. In practical terms, this corresponds to a feed containing about 4,000 kilocalories/kilogram diet, with a protein level of 42% and a dietary fat level of about 20%. The dietary requirements for trout, salmon, and catfish have been well studied and optimal diets (in terms of energy requirements) can be formulated. Other species have not been studied as extensively and optimal diets may not be available.

With higher energy feeds, FCRs of 1.0 or less are now routinely observed in salmon and trout farming. Anytime FCRs are significantly greater, then less of the feed input goes to growth and more is used to support metabolic processes and there is increased waste generation, intrinsically as well as extrinsically (wasted feed).

As stated earlier, many factors contribute to feeding efficiency. For example, the feeding method and feed availability can be shown to have significant effects on feeding efficiency, effluent quality, and growth.

Alanärä and Cripps (1991) report that demand feeding with unrestricted amounts of feed available resulted in an FCR of 1.49, while a restricted feeding strategy produced an FCR of 1.07. Interestingly, there was no significant difference in growth between these two groups. This seems to indicate either feed loss (feed not ingested) or over-indulgence with poor digestion (internal "loss"). Whether the waste was external (physical) or internal (physiological), the impact on effluent quality was significant. Total phosphorus output was reduced 45% from 10.2 to 5.6 grams/kilogram of fish. Total nitrogen was reduced 44% from 75.9 to 42.7 grams/kilogram of fish. But then, Äsgärd and Hillestad (1999) write that restricting feed below voluntary intake (satiation) can be a waste of resources. It is their opinion that the faster the growth the greater the amount of feed is converted to flesh, i.e., the lower the FCR. Aquatic animals, first of all, must meet their metabolic energy requirements. If feed intake only provides for this, no energy is left available for growth. As feed intake increases beyond metabolic energy requirements growth occurs until it reaches the maximum the animal is willing to consume. The preponderance of data show that optimum FCR and maximum growth do not coincide.

Eriksson and Alanärä (1990) report that fish (rainbow trout), when offered food in excess, grew larger than those on restricted feed. However, those on restricted feed converted their food much more efficiently than those feeding to excess, and as a result, the release of phosphorus and nitrogen was reduced by more than 50%.

Other studies showed that when rainbow trout were fed 75% of the maximum ration for feed intake and growth rate, the lowest FCRs were realized. Under this feeding program fish utilized feed more efficiently and released less nutrients into the effluent, but the overall weight gain was lower than in fish fed to satiation.

When feeding approaches satiation, fish slow down in their feeding activity, and unless the volume of introduced feed is reduced, the fish may not keep up with its capture, and feed may potentially be lost. Frequently fed fish (for example fingerlings) utilize their feed more efficiently than those fed less frequently. The benefit is lower FCR. As a rule of thumb, Barrows and Hardy (2001) recommend 1.0% body weight per feeding to ensure that, first of all, enough feed is offered that all fish have an opportunity to obtain feed, and secondly not too much feed is presented so their feeding action will remain high and the stomach is not over full. If fish gorge themselves, the feed may pass through the digestive system faster resulting in reduced nutrient absorption (higher FCR). This means the feed loss (nutrient loss) is indirect or internal, but it still contributes significantly to the various waste components, such as solids, BOD, nitrogen, and phosphorus.

Cho et al. (1991) mentions that under the most careful feeding conditions, it is still difficult to eliminate feed waste completely, but it can be minimized, i.e., to less than 5%, by aiming at optimum rather than maximum production. This requires the application of scientific feeding standards and sensible feeding practices and by using well-manufactured feeds of high water stability.

In 1991, Gowen et al., reported that food waste may account for as much as 20% of the total food fed and may account for 70% of organic carbon input in net pen culture of salmon. Pearson and Black (2000) report that current estimates of feed waste for salmonid net pen culture vary between 1% and 5%. This agrees with the statement by Riley (2001) that FCRs of 1.1 are now achievable in net pen operations by applying computer-operated pneumatic feeding systems, which allow precise control of the feeding operation and, subsequently, greatly reduces feed going to waste.

Hinshaw and Fornshell (2002) mention that feed waste varies from 1% to as high as 15% for trout raceway culture. Yet, intensive raceway culture offers greater opportunity for more accurate feeding programs than net pen culture. As a whole, today's trout industry in Idaho and North Carolina accomplish FCRs of 1.0 to 1.2 and keep feed wastes below 3.0% (Fornshell and Sloan, personal communication).

Immediate improvements in FCR and feed waste can be realized by simply offering the fish feed when they will use it most effectively and efficiently (Bergheim et al., 1991). As mentioned earlier, frequently fed fingerlings utilize their feed more efficiently, thus lowering the FCR and feed waste. Appetite returns in some carnivorous species, such as rainbow trout and eel, on the basis of stomach emptying time (Goddard, 1996).

It is important to understand that obtaining the highest weight gain and lowest FCR are separate goals; however, compromises can be made based on the goals of the hatchery program (Barrows and Hardy 2001). Optimizing both growth rate and FCR appears to be mutually exclusive. However, optimizing FCR benefits the environment, as it reflects low volumes of feed waste. It can also have an economic benefit.

10.3.3 FCR Analysis

EPA analyzed FCR data from many of the flow-through and recirculating system facilities that completed the detailed survey of the CAAP industry. The purpose of the FCR analysis was two fold:

1. FCRs were used to estimate and check the amount of feed used at each facility.
2. FCRs were used as a surrogate for estimating potential load reductions resulting from feed management activities.[1]

For those facilities that provided annual production and feed use data, EPA calculated an FCR estimate:

FCR = Feed Input/Facility Production

Where:

FCR = the annual feed conversion ration for the production system (pounds of feed per pound of aquatic animals produced)

Feed Input = annual feed use at the facility (pounds)

Facility Production = annual production of aquatic animals at the facility (pounds)

EPA was able to calculate FCRs for 69 flow-through and recirculating system facilities that responded to the detailed survey. EPA validated the feeding, production, and estimated FCRs by contacting each facility. For those facilities that were not able to supply accurate feed and/or production information, EPA randomly assigned an FCR. EPA attempted to capture and account for as much of the variation as possible when

[1] Note: EPA used FCR values as a means to estimate potential load reductions, not as a target to set absolute FCR limits for a facility or industry segment.

analyzing FCRs and in the random assignment process. For example, the production system, species, and system ownership (which are all known from the detailed surveys) were expected to influence feeding practices, so facilities were grouped according to these parameters. EPA included ownership as a grouping variable to account for some of the variation in production goals. Most commercial facilities that were evaluated are producing food-sized fish and generally are trying to maintain constant production levels at the facility; commercial facilities would tend to weigh maximum weight gain against FCR in determining their feeding strategy. Non-commercial facilities are generally government facilities that are producing for stock enhancement purposes. Production goals are driven by the desire to produce a target size (length and weight) at a certain time of year for release. Non-commercial facility feeding goals may not weigh as heavily on maximum growth. Some of the sources of variation, such as water temperature and age of the fish, were accounted for by evaluating distributions of the similar facility FCRs and using Monte Carlo simulations.

The process for the random assignment included:

- EPA grouped facilities by ownership, species, and production.
- FCRs were estimated for each facility with sufficient data and grouped.
- The distributions of grouped data were examined for possible outliers, which were defined as FCRs less than 0.75 or greater than 3.0. When extreme values were found and validated, they were removed from the grouping.[2] Some extreme values were updated based on validating information from the facility, and the updates were found to be within the range used for analysis.
- After removing outliers, the first and third quartiles were calculated for each grouping.[3]
- For each grouping, the target FCR was assumed to be the first quartile value.
- For the facilities with no FCR information, a random FCR between the first and third quartiles was assigned with a uniform distribution between the first and third quartile.[4]

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[2] Although these extremes may be possible and a function of production goals, water temperature, etc., EPA was not able to validate and model all of the factors contributing to the extreme FCR rates. Facilities excluded because of extreme values were not assigned a random FCR, but were found to have a documented reason for the extreme value. For example, one facility produced broodstock for stock enhancement purposes.

[3] The first quartile of a group of values is the value such that 25% of the values fall at or below this value. The third quartile of a group of values is the value such that 75% of the values fall at or below this value.

[4] The uniform distribution leads to the most conservative estimate of uncertainty; i.e., it gives the largest standard deviation. The calculation of the standard deviation is based on the assumption that the end-points of the distribution are known. It also embodies the assumption that all effects on the reported value, between a and b, are equally likely for the particular source of uncertainty. Detailed calculations are contained in the analysis spreadsheets located in the CBI record for this rulemaking (Tetra Tech, 2003a).

- For some categories there were not sufficient data to do the quartile analysis. In these cases, data from a similar category were used. Table 10.3−1 below summarizes the results of the quartile analysis.

Table 10.3–1. Quartile Analysis

Category	*Number of Facilities*	*First Quartile—Third Quartile*
Commercial – Catfish – FT	<5	
Commercial – Trout – FT	36	1.12–1.48
Government – Trout – FT	57	1.19–1.60
Research – Trout – FT	<5	
Tribe – Trout – FT	<5	1.19–1.60
Government – Salmon – FT	24	1.00–1.31
Commercial – Salmon – FT	6	1.00–1.31
Tribe – Salmon – FT	<5	1.00–1.31
Commercial – Tilapia – FT	<5	2.10–2.21
Commercial – Striped Bass – FT	<5	1.22–1.87
Government – Other finfish – FT	<5	
Government – Trout – Recirculating	<5	1.12–1.48
Government – Salmon – Recirculating	<5	1.00–1.31
Commercial – Striped Bass – Recirculating	<5	1.22–1.87
Commercial – Tilapia – Recirculating	<5	2.10–2.21
Commercial – Other finfish – Recirculating	<5	
Commercial – Baitfish – Recirculating	<5	

10.3.4 Feed Inputs

EPA assumed the sources of pollutant loadings in CAAP facility production systems are the feed input and resulting metabolic wastes generated by the aquatic animals. The pollutant loadings calculated in the loading model were based on the feed input to the system and the feed-to-pollutant calculation, as described in 10.3.5.

Feed inputs to the model were typically obtained from the facility’s response to the detailed survey. In these cases, the response from the detailed survey was checked and validated with the facility. In some cases, the facility was not able to provide accurate feed data and estimates were made by multiplying the specific facility production, which was determined by analysis of the detailed survey, by the facility-specific FCR:

Feed input = facility production * FCR

Where:

Facility production = the average yearly production at the facility (pounds)

FCR = the annual feed conversion ratio for the production system (pounds of feed per pound of fish produced) estimated using the procedure described in 10.3.3

If feed inputs were estimated using FCR values, EPA attempted to validate the estimates by contacting each facility. Table 10.3−2 provides a summary of the feed information, grouped by ownership, species, and system type.

Table 10.3–2. Range of Feed Loads by System-Species-Ownership Grouping

System	*Species*	*Ownership*	*Number*	*Range (lb)*
Flow-through	Salmon	Commercial & Non-commercial	13	112,200–1,178,480
Flow-through	Striped Bass-Tilapia-Catfish-Other	Commercial & Non-commercial	10	62,400–259,360
Flow-through	Trout	Commercial	13	42,700–750,000
Flow-through	Trout	Non-commercial	28	24,000–744,200
Recirculating	Striped Bass-Salmon-Shrimp-Tilapia-Other	Commercial & Non-commercial	7	132,000–7,206,700

10.3.5 Feed-to-Pollutant Conversion Factors

EPA only modeled pollutant generation at each facility as a function of feed inputs, which are the feed and associated metabolic wastes. EPA used values for the feed-to-pollutant conversion factors (Table 10.3−3) in the loading model to represent the range of values found in literature reviews (Hochheimer and Meehan, 2004).

Table 10.3–3. Feed-to-Pollutant Conversion Factors

Polluant	*Conversion Factor*
BOD	0.35
TN	0.0275
TP	0.005
TSS	0.25

Source: Hochheimer and Meehan, 2004.

EPA found studies that determine the pollutants associated with feeding fish are often done in controlled laboratory situations using tanks with static water. The feed-to-pollutant conversion factors vary somewhat by species and the constituents in the feed, so EPA used typical values found in the literature to represent some of this variability. For the purpose of estimating pollutant loadings, EPA assumed that all feed added to a production system is consumed and undergoes some metabolic conversion by the aquatic animals. Although feed conversion ratios greater than 1 indicate potentially uneaten feed, the amount of uneaten feed could vary considerably on a daily basis in a given production unit. Some of the factors that contribute to this variation are stress to the animals (e.g., changes in dissolved oxygen, spikes in production unit ammonia, unusual activity at the production facility, or a recent storm), water temperature, age of the aquatic animal, and the presence of disease. The mass of pollutants associated with unmetabolized feed are greater than those that are consumed and undergo the metabolic processes of the aquatic animals, so EPA used the more conservative value in the loading models.

EPA used the feed-to-pollutant conversion factors to estimate an untreated or "raw loading," which was used as the input to pollutant control technologies and BMPs. EPA calculated raw pollutant loadings by using the following equations:

Raw pollutant loading = annual feed input * feed-to-pollutant conversion factor

Where:

Raw pollutant loading = the pollutant load for each pollutant (i.e., TSS, BOD, TN, TP) in pounds/year

Annual feed input = the amount of feed distributed to the production system (pounds/year)

Feed-to-pollutant conversion factor = conversion of feed inputs into pollutant loadings (i.e., TSS, BOD, TN, TP) in pounds of pollutant per pound of feed

A summary of the raw waste load estimates is presented in Table 10.3–4.

Table 10.3–4. Raw Waste Loads by Category

System	*Original Species*	*Ownership*	*Number*	*Range (lb)*			
				BOD	*TN*	*TP*	*TSS*
Flow-through	Salmon	Commercial & Non-commercial	13	39,270–412,468	3,086–32,408	561–5,892	28,050–294,620
Flow-through	Striped Bass-Tilapia-Catfish-Other	Commercial & Non-commercial	10	21,840–90,776	1,716–7,132	312–1,297	15,600–64,840
Flow-through	Trout	Commercial	13	14,945–262,500	1,174–20,625	214–3,750	10,675–187,500
Flow-through	Trout	Non-commercial	28	8,400–260,470	660–20,466	120–3,721	6,000–186,050
Recirculating	Striped Bass-Salmon-Shrimp-Tilapia-Other	Commercial & Non-commercial	7	46,200–2,522,345	3,630–198,184	660–36,034	33,000–1,801,675

10.4 Unit Load Reduction Modules

EPA evaluated several solids control strategies that are in use or could be used at flow-through, recirculating, and net pen facilities. These management strategies include:

- Feed management practices to achieve optimal feeding and prevent wasted feed. (Section 10.4.1).
- Active feed monitoring to ensure that feed offered to aquatic animals in net pen systems is consumed and not wasted (Section 10.4.2).

EPA developed unit load reduction modules that calculate the pollutant removal associated with a particular technology or practice for a CAAP facility. Each unit load reduction module contains a description of the technology or practice and the pollutant-specific removal efficiencies of the system component.

EPA used pollutant removal efficiencies for each of the TSS removal technologies and practices to determine pollutant load reductions that could be expected when a technology or practice is in place. These pollutant removal efficiencies were developed from a combination of data that were collected in the literature, facility monitoring data, and at EPA sampling events. By calculating load reduction efficiencies, EPA was able to directly estimate load reductions, without having to estimate loads from effluent concentrations and flow rates. EPA also compared its calculated estimates of loads and effluent concentrations for TSS with available monitoring and sampling data as a quality check (see Section 10.6 and Hochheimer and Escobar, 2004a; Hochheimer and Escobar, 2004b for details).

10.4.1 Feed Management

Feed management is a practice that was considered for all operations.

10.4.1.1 Description of Technology or Practice

Feed management recognizes the importance of effective, environmentally sound use of feed. System operators should continually evaluate their feeding practices to ensure that feed placed in the production system is consumed at the highest rate possible. Observing feeding behavior and noting the presence of excess feed can be used to adjust feeding rates to ensure minimal excess (USEPA, 2002c).

An added advantage of this practice is that proper feed management decreases the costs associated with the use of excess feed that is never consumed by the cultured species. Excess feed distributed to the production system increases the oxygen demand of the culture water and increases the solids loading to the treatment system. More important, solids from the excess feed usually settle and are naturally processed along with feces from the aquatic animals. In net pen operations, excess feed and feces accumulate under net pens, and if there is inadequate flushing, this accumulation can overwhelm the natural benthic processes and results in increased benthic degradation.

The primary operational factors associated with proper feed management are development of precise feeding regimes based on the weight of the cultured species and constant observation of feeding activities to ensure that the feed offered is consumed. Feed management is a practice required in net pen facility permits issued in EPA Regions 1 and 10 (USEPA, 2002c; USEPA, 2002d) and in Idaho and Washington flow-through system production facilities.

10.4.1.2 Pollutant Removals: All Systems

Pollutant removals associated with feed management result from better feed utilization and less wasted feed that is uneaten. Section 10.3.2 provides a detailed discussion on a variety of activities that facilities do to optimize feed utilization. Data are also presented in Table 10.3−1 that show ranges of feed conversion ratios (FCRs) for different facility groups (i.e., system type-species-ownership type) of CAAP facilities. EPA used this FCR data to estimate potential pollutant reductions at facilities with FCRs in the upper parts of the ranges for a facility group. It is important to reiterate that EPA used FCR values only as a means to estimate potential pollutant reductions, not as industry targets or regulatory requirements. EPA recognizes that it is possible for an individual facility to have greater than average FCRs for many reasons, even though the facility is practicing very efficient feed management. For example, a facility that has sub-optimal temperatures (either too high or too low) may have greater FCRs than a comparable facility with optimal, steady-state temperatures.

EPA evaluated feed management as a regulatory option for facilities that provided information on the detailed industry survey. The procedure EPA used involved facility-specific FCRs compared to a low FCR, which was estimated as the 25^{th} percentile FCR value for the facility group. Many facilities provided sufficient data in their detailed industry survey responses to enable EPA to calculate an actual facility-specific FCR. Some facilities were not able to provide sufficient information to enable EPA to estimate a facility-specific FCR, so EPA developed a methodology for estimating one. EPA used a randomly assigned FCR (based on a uniform distribution for the range of reported FCRs in a facility group) as the facility estimate. If the facility's FCR (either randomly assigned or actual) was greater than 75% of the inter-quartile range and were not currently meeting the regulatory limits for their type of discharge configuration, then EPA assumed that the facility could benefit from feed management practices and would incur costs and pollutant load reductions. More details about this methodology are presented in Hochheimer and Escobar (2004c). EPA estimated the amount of feed conserved as:

$$\text{Feed conserved} = \text{Feed used for year 2001} * \left(1 - \frac{\text{Target FCR}}{\text{Actual or estimated FCR}}\right)$$

Where:

Target FCR = the FCR obtained with implementation of a feed management program

Actual FCR = the FCR as calculated based on information reported by the facility

Estimated FCR = the FCR estimated for a facility if the facility did not provide sufficient data to calculate one

Feed used for year 2001 = pounds of feed reported by the facility in the detailed survey or estimated by EPA (see Table 10.3–2)

EPA estimated pollutant load reductions using values presented in Table 10.3–3 and the equation:

Specific Pollutant Load Reduction = Feed conserved * Specific Pollutant Reduction Factor

Where:

Feed conserved = pounds of feed reduced at the facility by feed management practices

Specific Pollutant Reduction Factor = pounds of pollutant (i.e., TSS, TN, TP, BOD) reduced/pound of feed reduced

10.4.2 Active Feed Monitoring

Active feed monitoring was proposed as a management practice for all net pen facilities. Real-time feed monitoring is a proven technology that includes video monitoring, digital scanning sonar, upwelling systems, used by all of the facility operators who responded to the detailed survey to produce Atlantic salmon in net pen systems. Some type of remote monitoring equipment is operated during feeding to monitor for uneaten feed pellets as they pass through the bottom of the net. Active feed monitoring can also include monitoring of sediment of sediment quality beneath the pens, monitoring the benthic community beneath the pens, capture of waste feed and feces, or the adoption of good husbandry practices, subject to the permitting authority's approval. For the final rule, net pen facilities must develop practices to minimize the accumulation of uneaten food beneath the pens using active feed monitoring and management practices.

10.4.2.1 Description of Technology or Practice

The goal of active feed monitoring is to further reduce pollutant loadings associated with feeding activities. A variety of technologies could be used, including video cameras with human or computer interfaces to detect passing feed pellets, an acoustic or digital scanning sonar, or a simple air lift pump with its intake located at the bottom of the net. One example of a real-time monitoring system used a video monitor at the surface that is connected to an underwater video camera. An employee watches the monitor for feed pellets passing by the video camera and then stops feeding activity when a predetermined number of pellets (typically only two or three) pass the camera. EPA observed this technology at several Maine facilities during site visits (Tetra Tech, 2002b; Tetra Tech, 2002c).

10.4.2.2 Pollutant Removals: All Systems

EPA estimated that pollutant reductions associated with active feed monitoring could be about 5% or more for all pollutants. Since all of the in-scope net pen facilities that responded to the detailed industry survey indicated that they had a form of active feed management in place, EPA did not estimate any feed reductions for this technology as a result of the final regulation.

10.4.3 Drug Reporting and Material Storage

The drug reporting requirement is estimated to be equal for all species and culture systems and based on facility-specific drug usage.

10.4.3.1 Description of Technology or Practice

The purpose of the drug reporting requirement is to enable the permitting authority to become aware of the potential for releases of INAD and extralabel drugs under specific circumstances. The regulation also requires proper material storage including spill containment for all drugs or pesticides stored at the facility. EPA evaluated spill prevention training and chemical containment storage systems as ways facilities can meet the regulatory requirements.

10.4.3.2 Pollutant Removals: All Systems

Pollutant reductions for BOD, TN, TP, and TSS may occur as a result of implementation of a drug reporting/material containment requirement. Containment systems and spill clean-up procedures may help to reduce the discharge of materials (e.g., feed, drugs and pesticides) only. EPA did not estimate load reductions from this technology/practice.

10.4.4 Structural Integrity of the Containment System

All flow-through, recirculating, and net pen facilities are required to maintain the structural integrity of their production systems and wastewater treatment systems.

10.4.4.1 Description of Technology or Practice

Facilities can use regular inspections to ensure that critical structural components are in proper working order and will not fail under typical operating conditions. Adherence to this general requirement should prevent the release of materials including culture animals and collected biosolids.

10.4.4.2 Pollutant Removals: All Systems

The maintenance of the structural integrity of the containment system is to ensure proper operation to prevent failure and thus, a release of materials as a result of failure.

10.5 FACILITY GROUPINGS

EPA defined facility-specific models for flow-through and recirculating systems and evaluated facility groups that were based on system type, species, and ownership.

EPA analyzed each facility separately to determine the production systems used, species produced, and any other unique characteristics. Although facilities were all different, they could be grouped into several categories. Table 10.5−1 shows in-scope facility groupings by system type for those facilities analyzed in the detailed survey sample (unweighted) and the corresponding estimate for the in-scope national population (weighted[5]). Table 10.5−2 illustrates the in-scope sample and national estimates grouped by ownership. Table 10.5−3 shows the facilities grouped by location, which was defined by EPA region. Table 10.4−4 groups in-scope facilities by the species identified in the screener survey that was used to categorize the facility in the strata for the sample selection. Table 10.5−5

[5] The number of facilities in each of the weighted groupings may not sum to 240 because of rounding error.

shows the facilities grouped by the combination of system type-species-ownership. This grouping was used in many of the comparative analyses, such as those done for FCR.

Table 10.5–1. Facility Groupings by System Type

System Type	*Weighted*		*Unweighted*	
	Number	*%*	*Number*	*%*
Flow-through	208	87	64	81
Recirculating	14	6	7	9
Net Pens	19	8	8	10
Total	240		79	

Table 10.5–2. Facility Groupings by Ownership

Ownership	*Weighted*		*Unweighted*	
	Number	*%*	*Number*	*%*
Non-commercial	139	58	43	54
Commercial	101	42	36	46
Total	240		79	

Non-Commercial	*Number*	*% of Total*	*Number*	*% of Total*
Federal	33	14	10	13
Army Corps	3	1	1	1
State	103	42	32	40

Table 10.5–3. Facility Groupings by Location

EPA Region	*Weighted*		*Unweighted*
	Number	*%*	*Number*
EPA Region 1	34	13	12
EPA Region 2	3	1	<5
EPA Region 3	14	6	5
EPA Region 4	35	16	10
EPA Region 5	14	6	<5
EPA Region 6	6	3	<5
EPA Region 7	4	2	<5
EPA Region 8	21	9	7
EPA Region 9	48	20	16
EPA Region 10	61	24	21
Total	240		79

Table 10.5–4. Facility Groupings by Sampled Species

Species	*Weighted*		*Unweighted*
	Number	*%*	*Number*
Catfish-Other Finfish-Shrimp	8	3	5
Trout	150	62	42
Salmon	64	27	21
Striped Bass	8	3	5
Tilapia	11	5	6
Total	240		79

Table 10.5–5. Facility Groupings by System-Ownership-Species

Flow-through Systems

Production	Species	Owner	Number of Facilities
>100,000	Salmon	Commercial & Non-commercial	13
>100,000	Striped Bass-Tilapia-Catfish-Other	Commercial & Non-commercial	10
>100,000	Trout	Commercial	13
>100,000	Trout	Non-commercial	28
		Total	64

Recirculating Systems

Production	Species	Owner	Number of Facilities
>100,000	Striped Bass-Salmon-Shrimp-Tilapia-Other	Commercial & Non-commercial	7
		Total	7

Net Pen Systems

Production	Species	Owner	Number of Facilities
>100,000	Salmon-Trout	Commercial	8
		Total	8

EPA performed pollutants loadings analyses on 71 flow-through and recirculating systems. Each facility was analyzed individually to determine baseline configurations and baseline pollutant loads for TSS, BOD, TN, and TP. Table 10.5–6 summarizes the baseline loads that were estimated for each facility. EPA used the removal efficiency data for each treatment unit described in Section 10.4 to determine estimates for baseline loads. EPA checked these estimates with monitoring data when possible to verify the estimates (see Hochheimer and Escobar 2004d for more information).

Table 10.5–6. Baseline Loads by Category

System	Original Species	Ownership	Number	Range (lb)			
				BOD	TN	TP	TSS
Flow-through	Salmon	Commercial & Non-commercial	13	3,641–40,360	1,765–24,926	196–3,848	994–96,600
Flow-through	Striped Bass-Tilapia-Catfish-Other	Commercial & Non-commercial	10	2,342–21,981	1,706–6,669	296–1,157	8,120–34,732
Flow-through	Trout	Commercial	13	430–45,005	505–18,758	49–2,896	933–71,113
Flow-through	Trout	Non-commercial	28	504–205,513	604–18,726	98–3,029	2,760–146,795

System	Original Species	Ownership	Number	Range (lb)			
				BOD	TN	TP	TSS
Recirculating	Striped Bass-Salmon-Shrimp-Tilapia-Other	Commercial & Non-commercial	7	2,772–228,900	3,321–90,669	537–14,666	15,180–331,508

10.6 LOAD REDUCTIONS AT REGULATORY OPTIONS

EPA's regulatory requirements for flow-through and recirculating systems include:

- Practices to control solids
- Facilities must maintain the structural integrity of production and wastewater treatment units. (No pollutant load reductions were estimated.)

EPA used its analysis of baseline conditions at each in-scope facility that responded to the detailed survey to estimate baseline discharge loads (see Table 10.5–1). EPA then applied a combination of treatment technologies and management practices to each facility as appropriate. Individual facility pollutant load reductions were scaled up to national pollutant load reductions by applying the appropriate weighting factor to the estimates for the individual facility and then summing across the facilities in the facility groups. Table 10.6–1 shows estimates of load reductions by facility group.

Table 10.6–1. Estimated Pollutant Load After Implementation for In-Scope CAAP Facilities

System	Original Species	Ownership	Number	Range (lb)			
				BOD	TN	TP	TSS
Flow- through	Salmon	Commercial & Non-commercial	13	3,502–40,360	1,765–24,926	196–3,848	994–95,968
Flow-through	Striped Bass-Tilapia-Catfish-Other	Commercial & Non-commercial	10	2,342–21,981	1,596–6,669	277–1,157	8,120–34,732
Flow-through	Trout	Commercial	13	430–35,145	504–18,758	49–2,896	933–62,100
Flow-through	Trout	Non-commercial	28	504–205,513	604–16,147	98–2,936	2,760–146,795
Recirculating	Striped Bass-Salmon-Shrimp-Tilapia-Other	Commercial & Non-commercial	7	2,772–169,661	3,321–57,874	537–9,361	15,180–264,500

10.7 OTHER POLLUTANT LOADS

Metals may be present in CAAP effluents from a variety of sources. Some metals are present in feed (as feed additives), occur in sanitation products, or may result from deterioration of CAAP machinery and equipment. EPA has observed that many of the treatment systems used within the CAAP industry provide substantial reductions of most metals. Many of the metals present are readily adsorbed to solids and can be adequately controlled by controlling solids.

Most of the metals appear to be originating from the feed ingredients. Trace amounts of metals are added to feed in the form of mineral packs to ensure that the essential dietary nutrients are provided for the cultured aquatic animals. Examples of metals added as feed supplements include copper, zinc, manganese, and iron (Snowdon, 2003).

Estimated metals load reductions from in-scope facilities implementing the final rule are summarized in the table below. These load reductions were estimated as a function of TSS loads, using data obtained from four of the sampling episodes (Clear Springs–Box Canyon Facility, (Tetra Tech, 2001a); Harrietta Hatchery (Tetra Tech, 2002a), and Fins Technology (Tetra Tech, 2001b) and Huntsdale Fish Culture Station (Tetra Tech, 2003b)) performed for the proposed rule. For this analysis, EPA first assumed that non-detected sampled had half the concentration of the detection limit. From the sampling data, EPA calculated net TSS and metals concentrations at different points in the facilities. EPA then calculated metal to TSS ratios (in milligrams of metal/kilogram of TSS), based on net concentrations calculated above, and removed negative and zero ratios from the sample. Finally, basic sample distribution statistics were calculated to derive the relationship between TSS and each metal.

Estimated load reductions of PCBs from in-scope facilities were calculated as a percentage of TSS load reductions. Since the main source of PCBs at CAAP facilities is through fish feed, a conversion factor was calculated to estimate the amount of PCBs discharged per pound of TSS. EPA assumed that 90% of food fed was eaten, and that 90% of food eaten would be assimilated by the fish. By combining the amount of food materials excreted by fish (10% of feed consumed) with the 10% of food uneaten, EPA was able to partition the PCBs among fish flesh and aqueous and solid fractions. EPA estimated that 2 micrograms/gram[6] of feed would be contaminated with PCBs, and that 21% this load would be contained in the discharged TSS. Estimated loads of PCBs from CAAP facilities under this rule are presented below in Table 10.7−1.

EPA estimated the load of oxytetracycline discharged from in-scope CAAP facilities using data from EPA's Detailed Survey of the CAAP Industry and peer reviewed scientific literature. EPA first determined facility specific amounts of oxytetracycline used by each CAAP facility. For those facilities that reported using oxytetracycline, EPA evaluated their responses to the detailed survey to determine the amount, by weight, of medicated feed containing oxytetracycline and the concentration of the drug in the feed. EPA applied this conversion factor to the amount of oxytetracycline used at an individual

[6] 2 micrograms/gram feed is the FDA limit on PCB concentrations in fish feed.

facility coupled with the estimated load of TSS reduced by the regulation to estimate the facility level discharge of oxytetracycline in the solids. The facility level estimates were then multiplied by the appropriate weighting factors and summed across all facilities to determine the national estimate of pounds of oxytetracycline reduced from discharges as a result of the regulation.

Table 10.7–1. Metals and Other Material Load Reductions Associated with TSS Reductions at In-Scope CAAP Facilities

Pollutant	*Total (lb)*	*Pollutant*	*Total (lb)*
TSS	553,495	Mercury	0.03
Aluminum	395.84	Molybdenum	1.40
Antimony	0.25	Nickel	4.31
Arsenic	0.42	Selenium	1.48
Barium	49.63	Silver	0.11
Beryllium	–	Thallium	0.12
Boron	16.52	Tin	0.78
Cadmium	0.13	Titanium	5.40
Chromium	3.20	Vanadium	2.28
Cobalt	0.83	Yttrium	0.28
Copper	44.57	Zinc	457.60
Iron	1,298.57	PCBs	0.04
Lead	1.21	Oxytetracycline	1,030
Manganese	372.78		

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