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.

SECTION 11

INCREMENTAL CAPITAL AND OPERATING AND MAINTENANCE COSTS FOR THE PROPOSED REGULATION

This section describes EPA's methodology for estimating engineering compliance costs associated with implementing the technology options proposed for the meat and poultry products (MPP) industry. EPA evaluated costs for each class of meat and poultry facilities, including meat, poultry, and combined meat-poultry (mixed) facilities. This section provides description of industry-wide compliance costs to achieve the proposed technology options.

11.1 OVERVIEW OF METHODOLOGY

EPA subdivided the entire MPP industry into 19 groupings and 4 size classes. EPA used these groupings and size classifications to develop 76 model facilities (19 groupings × 4 size classes) to represent the broad range of potential MPP facilities in current operation. The Computer Assisted Procedure for Design and Evaluation of Wastewater Treatment Systems (CAPDET) (Hydromantis, 2001), a computerized cost model, was used for developing the construction and annual operating cost of a treatment unit for each model facility. The construction cost was used to determine the capital cost of a treatment unit. The model facility costs were multiplied by the number of facilities that require the upgrade to provide the incremental costs for each set of model facilities. For selected technology options, EPA estimated retrofit costs based on each set of model facility costs. Each set of model facility category costs and the retrofit costs were combined separately to determine costs by regulatory subcategory (e.g., A through D, F through I, J, K, and L). Details of the method of cost estimating are presented in Section 11.9.

11.2 IDENTIFICATION OF TECHNOLOGY OPTIONS

EPA is proposing effluent limitations guidelines and standards based on a combination of processes and treatment technologies but is not requiring their use. Rather, the processes and technologies used to treat MPP wastewaters are left to the discretion of individual MPP facilities.

After promulgating the final rule, EPA will require compliance with the numerical limitations and standards and not require MPP facilities to use specific processes or technologies. The proposed technology options evaluated for existing direct dischargers (BPT/BCT/BAT), existing indirect dischargers (PSES), new direct dischargers (NSPS), and new indirect dischargers (PSNS) were based on an analysis of technology-in-place (TIP), according to data supplied in the MPP detailed surveys. A summary of the treatment units for the proposed technology options is shown in Table 11-1 and in Figures 11-1 through11-9. Note that Technology Option 5 is applicable to poultry facilities only.

Table 11-1. Proposed Technology Options for the MPP Industry

	Technology Options								
	Direct Discharger					Indirect Discharger			
Treatment Units	**1**	**2**	**3**	**4**	**5[a]**	**1**	**2**	**3**	**4**
Screen	X	X	X	X	X	X	X	X	X
Dissolved air flotation (DAF)	X	X	X	X	X	X	X	X	X
Equalization tank						X	X	X	X
Anaerobic lagoon	X	X	X	X	X				
Biological treatment with nitrification	X[b]	X	X	X	X		X	X	X
Biological treatment with nitrification and denitrification			X	X	X			X	X
Biological treatment with nitrification and denitrification and phosphorous removal				X	X				X
Filter					X				
Ultraviolet (UV) disinfection	X	X	X	X	X				

X: treatment unit is required for that option.
[a] EPA only considered Direct Option 5 for poultry facilities only.
[b] Direct Option 1 uses a less optimized form of nitrification. (See Section 11.8.4.)

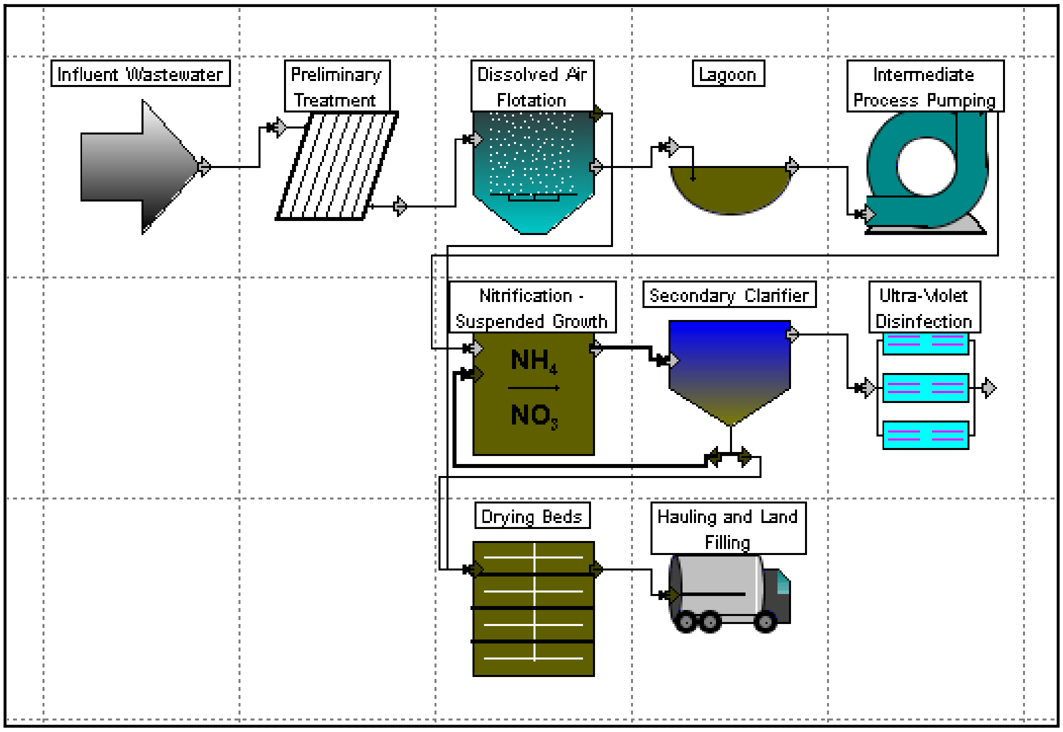

Figure 11-1. Treatment Unit Schematic for Direct Technology Option 1 (assuming incomplete nitrification).

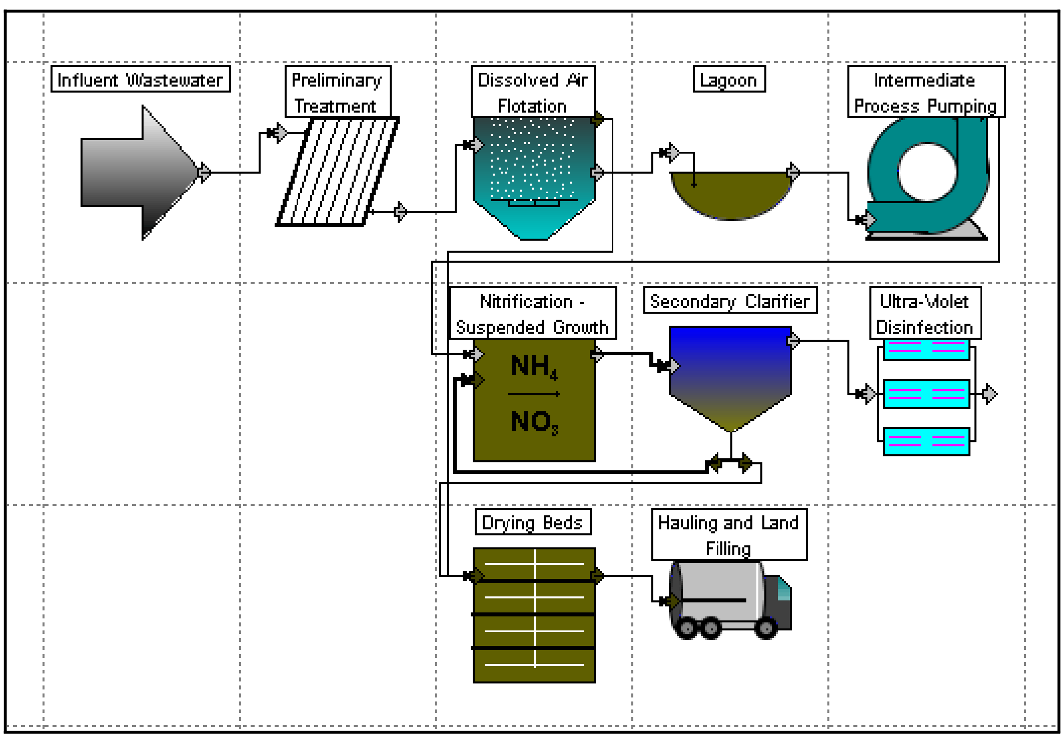

Figure 11-2. Treatment Unit Schematic for Direct Technology Option 2.

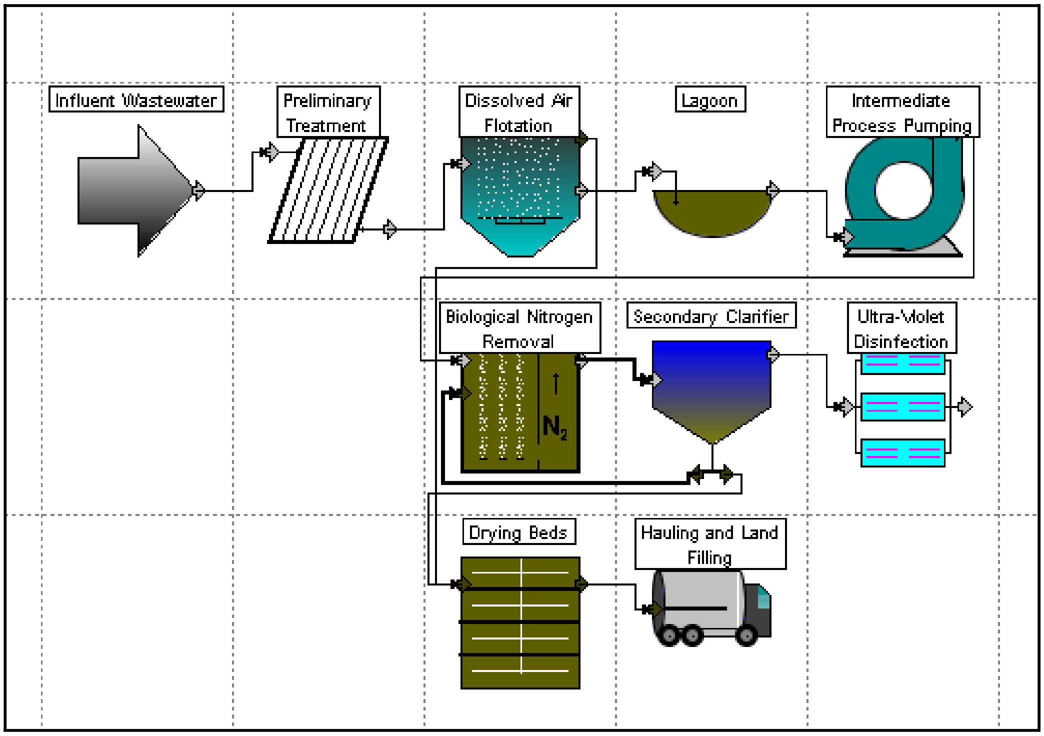

Figure 11-3. Treatment Unit Schematic for Direct Technology Option 3.

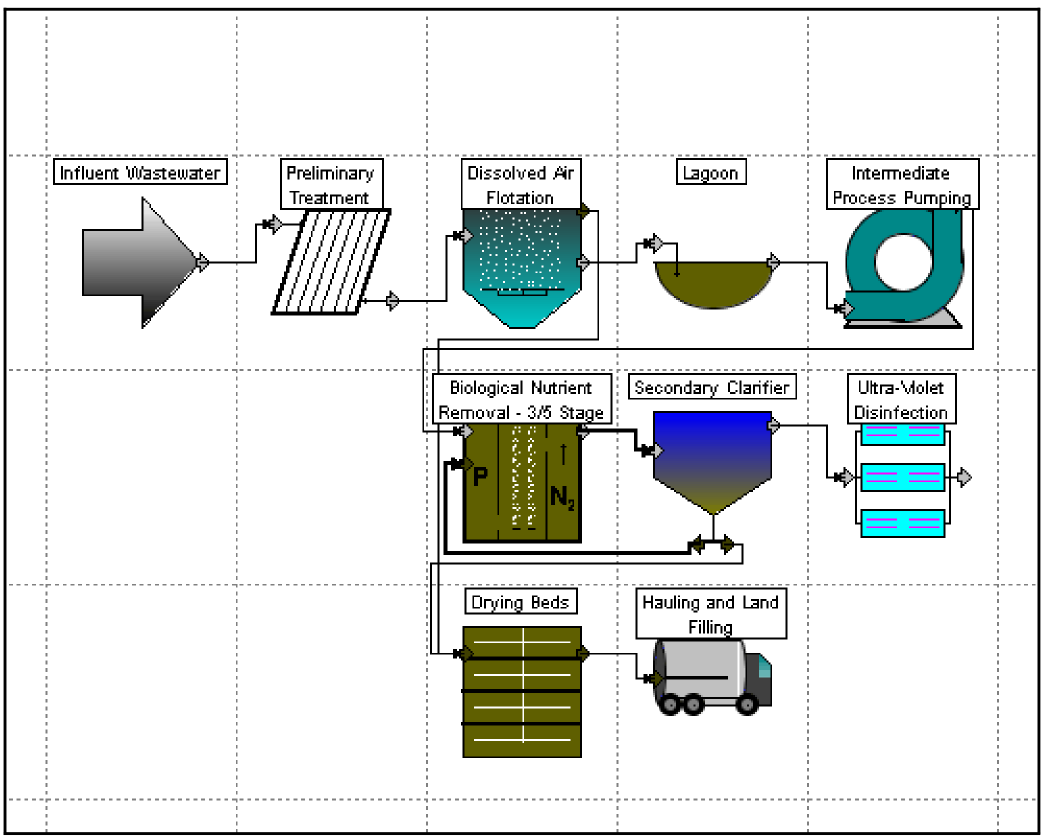

Figure 11-4. Treatment Unit Schematic for Direct Technology Option 4.

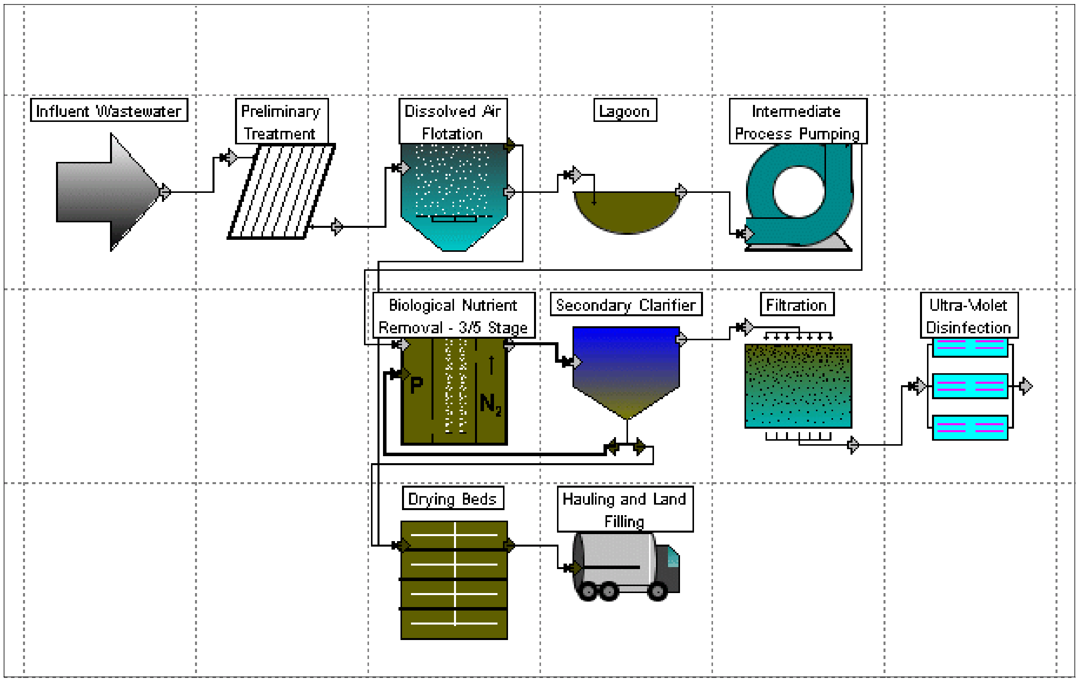

Figure 11-5. Treatment Unit Schematic for Direct Technology Option 5 (Poultry Only).

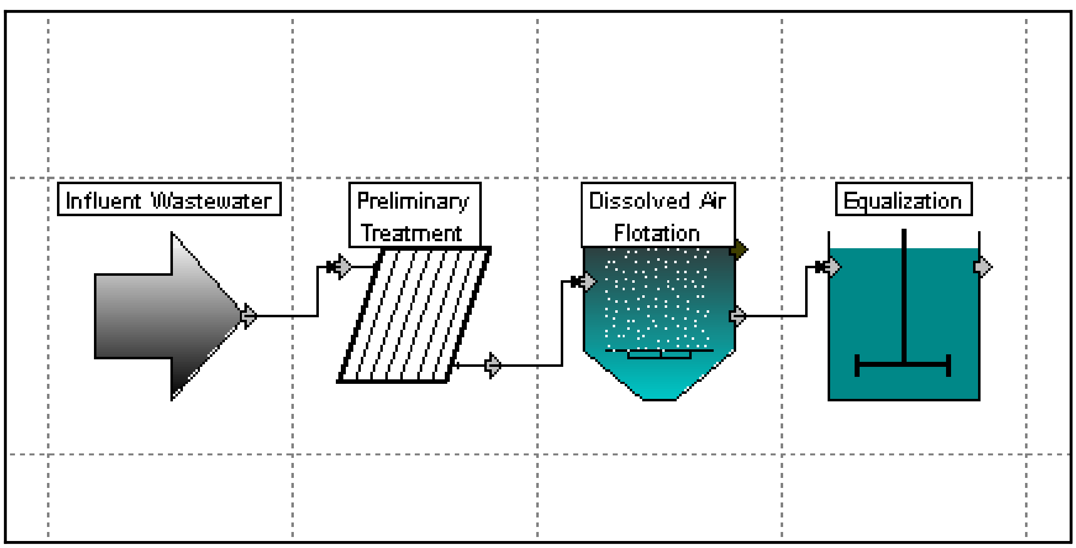

Figure 11-6. Treatment Unit Schematic for Indirect Technology Option 1.

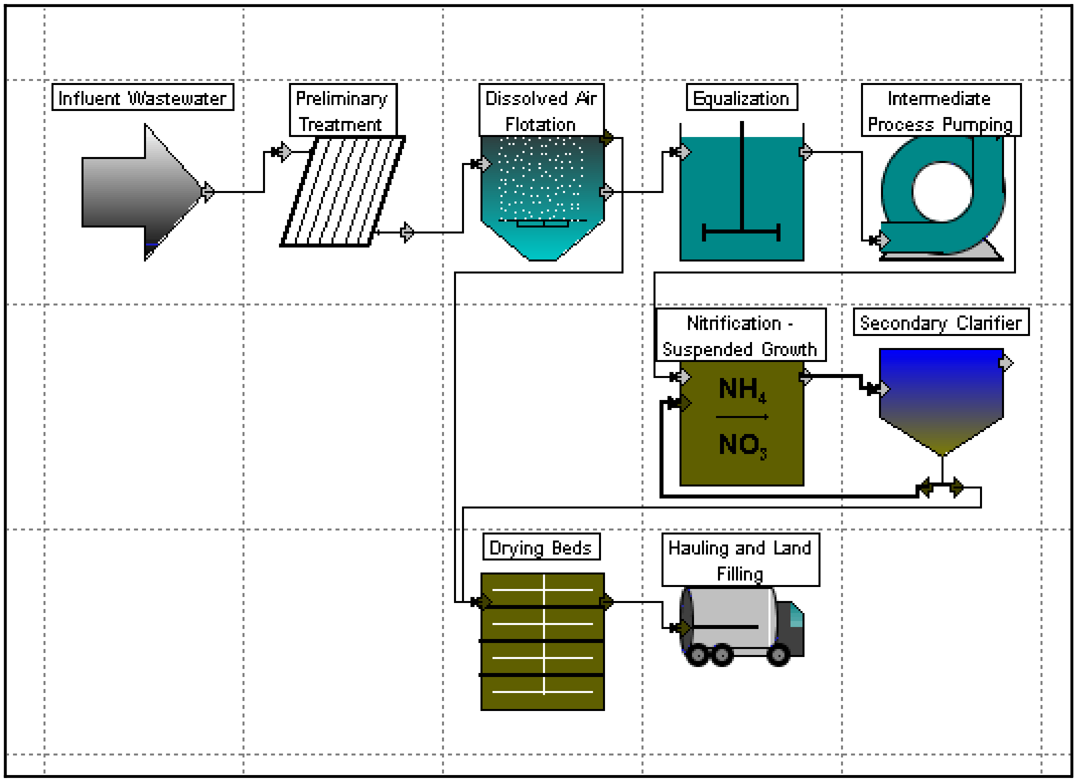

Figure 11-7. Treatment Unit Schematic for Indirect Technology Option 2.

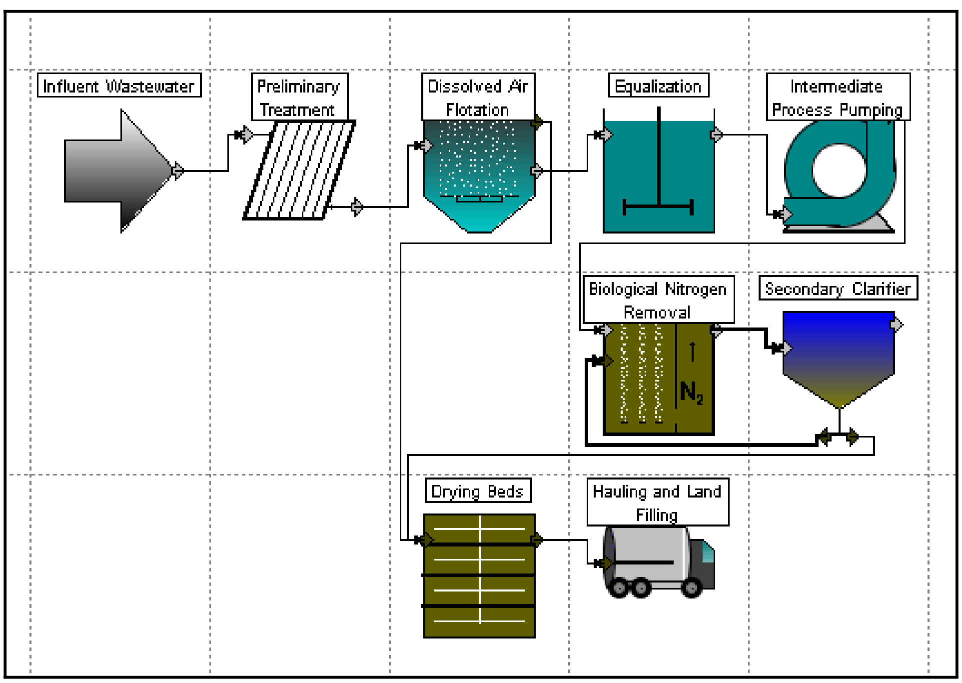

Figure 11-8. Treatment Unit Schematic for Indirect Technology Option 3.

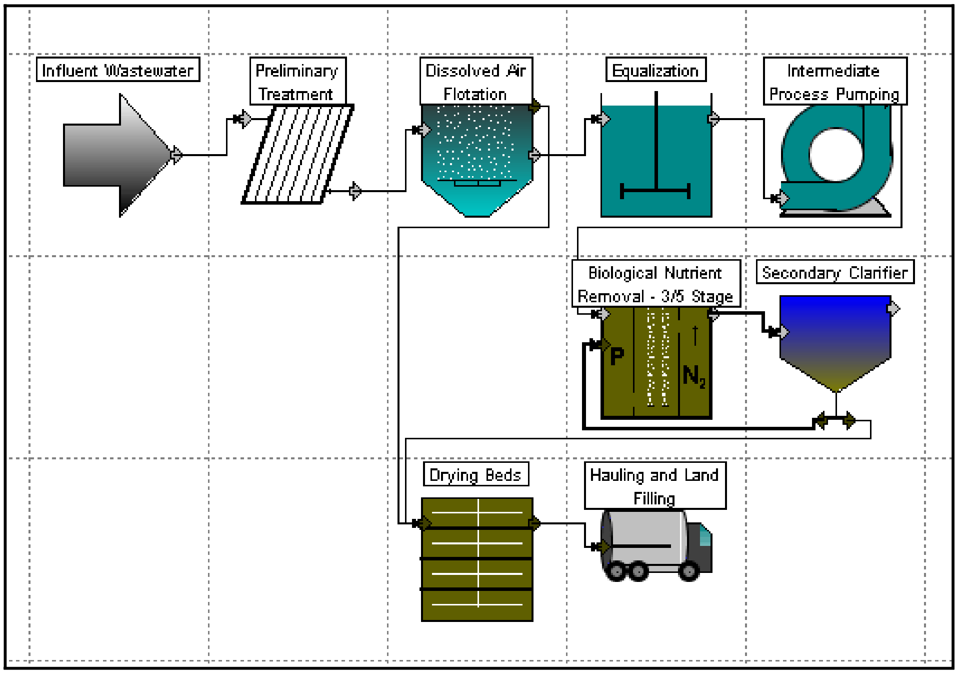

Figure 11-9. Treatment Unit Schematic for Indirect Technology Option 4.

11.3 DEVELOPMENT OF MPP MODEL FACILITIES

EPA used the MPP screener survey results to develop MPP model. These model facilities were used to estimate compliance costs and were also used in other analyses (e.g., pollutant reductions by treatment technology, economic impacts, non-water quality environmental impacts). To develop the MPP model facilities, EPA first separated MPP facilities based on the type of animal processed (e.g., meat, poultry, or both meat and poultry). To ensure that all MPP facilities identified in the MPP screener survey were accounted for, and that variations in raw wastewater characteristics are considered, EPA classified all MPP operations as first processing (e.g., slaughtering, carcass preparation, and quartering), further processing (e.g., deboning, cooking, sausage making), or rendering (wet or dry) and all possible combinations of these processes. These separations and classifications produced 19 different groupings, shown in Table 11-2.

Table 11-2. Definition of 19 MPP Facility Groupings

Number	Product Type	Model Facility Grouping Code	Process(es) Performed			Production Values Used to Define Size Classifications (in 1,000 lbs)			
			First Processing	Further Processing	Rendering	Small	Medium	Large	Very Large
1	Meat	R1	X			< 50,000	< 500,000	< 1,000,000	≥ 1,000,000
2	Meat	R2		X		< 50,000	< 3,000,000	< 6,000,000	≥ 6,000,000
3	Meat	R12	X	X		< 50,000	< 1,750,000	< 3,500,000	≥ 3,500,000
4	Meat	R13	X		X	< 60,000	< 600,000	< 1,200,000	≥ 1,200,000
5	Meat	R23		X	X	< 60,000	< 3,100,000	< 6,200,000	≥ 6,200,000
6	Meat	R123	X	X	X	< 60,000	< 1,850,000	< 3,700,000	≥ 3,700,000
7	Poultry	P1	X			< 10,000	< 150,000	< 300,000	≥ 300,000
8	Poultry	P2		X		< 7,000	< 125,000	< 250,000	≥ 250,000
9	Poultry	P12	X	X		< 8,000	< 137,000	< 275,000	≥ 275,000
10	Poultry	P13	X		X	< 20,000	< 250,000	< 500,000	≥ 500,000
11	Poultry	P23		X	X	< 17,000	< 225,000	< 450,000	≥ 450,000
12	Poultry	P123	X	X	X	< 18,000	< 238,000	< 475,000	≥ 475,000
13	Mixed[a]	M1	X			< 30,000	< 300,000	< 650,000	≥ 650,000
14	Mixed[a]	M2		X		< 30,000	< 1,500,000	< 3,000,000	≥ 3,000,000
15	Mixed[a]	M12	X	X		< 30,000	< 1,000,000	< 2,000,000	≥ 2,000,000
16	Mixed[a]	M13	X		X	< 40,000	< 400,000	< 850,000	≥ 850,000
17	Mixed[a]	M23		X	X	< 40,000	< 1,600,000	< 3,200,000	≥ 3,200,000
18	Mixed[a]	M123	X	X	X	< 40,000	< 1,100,000	< 2,200,000	≥ 2,200,000
19	Meat and/or Poultry	Render			X	< 10,000	< 100,000	< 200,000	≥ 200,000

[a] Meat and Poultry.

EPA then further separated each of the 19 groupings into four size classes (small, medium, large, and very large) based on total annual production data from the MPP screener survey to develop 76 model facilities (19 groupings × 4 size classes). The resultant model facilities allow EPA to consider MPP facility variations in (1) facility raw wastewater characteristics, as determined by the source animal distinction (e.g., meat or poultry) and processes performed (e.g., first processing, further processing; and rendering), and (2) facility size, which can support estimation of wastewater volumes generated and thus the size of required treatment units. EPA used these 76 model facilities to more accurately estimate costs, loadings, non-water quality environmental impacts, and economic impacts of the proposed limitations and standards on the MPP industry.

11.4 SELECTION OF A COST MODEL

EPA investigated various sources to collect cost information for the technology options considered. The sources include vendor quotations, literature, the wastewater cost (W/W Cost) computer model (W/W Cost, 1998), and the CAPDET computer model (Hydromantis, 2001). EPA did not use vendor quotations or literature to derive cost curves for treatment units because of a lack of detailed information. The W/W Cost model was also not used because of model limitations, particularly the fact that the model does not have the costs for all the treatment units considered in the technology options (e.g., denitrification). CAPDET was selected for estimating the compliance costs for the proposed MPP regulation because it is user-friendly and has a database that contains the latest costs (year 2000) of all the treatment units considered in the MPP technology options. More important, based on a comparison to actual costs for MPP facilities, CAPDET predicted the actual costs of MPP wastewater treatment plants reasonably well (see Section 11.11).

The CAPDET software was originally developed based on the need for a method of accurate and rapid preliminary design and cost estimating of wastewater treatment plant construction projects. The U.S. Army Corps of Engineers developed the software for EPA with the specific intent of assisting personnel responsible for wastewater treatment planning in the evaluation of wastewater treatment alternatives, based primarily on life cycle costs and degree of treatment provided. The major emphasis with CAPDET has been the development of accurate planning-level cost estimates for unit processes. The model was designed to provide the planning-level estimates based on knowledge of the basic system formulations and the use of cost curves. The software calculates the design of each unit process, based on the influent to the process, and then costs the design. This two-step approach gives the user the option to review the produced design and modify it. Typical design defaults have been used for each unit process to increase the acceptability of the calculated designs and make the software easier to use for planners that require planning-level cost estimates for a new facility or an upgrade to an existing facility.

Two basic methods are typically used for planning-level cost estimating. Parametric cost estimating is based on a statistical approach (i.e., statistical analysis of the cost of facilities of similar size and characteristics at other locations). A modification of this statistical approach is the development of standard designs for various flows and formulation of a cost based on engineering quantities. The second method identifies cost elements to which input unit prices are applied (i.e., cubic yards of concrete in a clarifier are quantified). To this number an input cost value for reinforced concrete in place is applied to determine construction costs. CAPDET combines both parametric and unit costing techniques for estimating total project costs.

Costs associated with construction of a wastewater treatment facility are divided into two categories: (1) unit process costs and (2) other direct and indirect costs. Unit process costs are those associated with a specific treatment process, such as a clarifier. Battery limits are drawn such that the clarifier is an individual functioning unit. Cost element estimating is used to determine the costs of the unit process within these battery limits. Other direct and indirect costs include those cost items required to create a functional treatment facility. These costs are derived parametrically from EPA-developed cost curves based on bid data.

11.5 DESCRIPTION OF COST COMPONENTS

Cost estimation has two components: (1) capital costs and (2) operation and maintenance costs. The capital cost is the initial investment a facility makes to build a treatment unit (or series of treatment units). The operation and maintenance costs are annual costs incurred to maintain and run that treatment unit (or series of treatment units).

11.5.1 Capital Costs

The basis of capital cost estimating is to identify all costs associated with wastewater treatment facility construction. These costs, once identified, can be categorized into two categories: (1) unit process construction costs and (2) other direct and indirect costs. The sum of the two costs provides the total capital costs. Often other direct and indirect costs are expressed as a percentage of the construction costs to determine the capital cost. A similar approach is followed to estimate the capital costs of the treatment units for the proposed regulation. The construction cost of treatment units obtained from CAPDET model runs is multiplied by a factor to determine the capital cost.

11.5.1.1 Construction Cost

The construction cost of a unit process is the cost to construct and install a treatment unit, including its associated housing, piping, and electric work. The costs are defined within battery limits, which are established to be the physical dimensions of the unit process plus 5 feet. The major cost items for construction of any unit process can be generally categorized as follows:

- Concrete or steel tanks and structures
- Installed equipment
- Building and housing
- Piping and insulation
- Electrical works, control systems, and other facilities

Structural Components

The costs of the structural component comprise the costs of reinforced concrete, earthwork, structures, and piping. The construction of earthen basins (such as anaerobic lagoons) is usually accomplished with equal cut-and-fill quantities. In other words, excavated material is used in embankments so that borrowing of dirt from outside is not necessary. The procedure is applicable only when soil and groundwater conditions are ideal, which the CAPDET model assumes to simplify costing procedures. The unit cost input consists of dollars per cubic yard of earthwork assuming equal cut-and-fill.

The costs of reinforced concrete structures are estimated as the sum of costs of concrete slabs and concrete walls because of the significant difference in costs between the two types of in-place structures. The unit cost inputs for both type of structures in the CAPDET model are in dollars per cubic yard (Hydromantis, 2001).

Equipment and Installation Costs

Equipment for the wastewater treatment system may constitute one of the largest items of identifiable fixable capital costs. Accurate estimation depends on up-to-date equipment cost data. With a limited number of unit cost input entries, it is very difficult to maintain a reliable cost database. The following description outlines a procedure that produces an accurate estimate within these limitations. The installed equipment cost is considered in three components: the purchase cost of the equipment, installation labor cost, and other minor costs such as electrical work, minor piping, foundations, painting, and the like.

The purchase cost of process equipment is a function of size or capacity. To minimize the number of cost inputs required, a standard unit of a particular size (or capacity) is selected and the purchase cost of all other units of that type is expressed as a fraction or multiple of the standard unit purchase cost. The exact form of the cost-versus-size relationship and the selection of the standard sizes for each major equipment item were determined from a review of manufacturers' information and available literature. In most cases, these size-cost relationships are relatively unaffected by inflation and other cost changes.

Two options are available by which the purchase cost of equipment can be escalated to account for inflation. The first option is for the user to obtain from equipment manufacturers the current cost of the standard size equipment at the treatment plant site. The purchase cost of any other size item of like equipment is then automatically escalated by the cost versus size relationships described above. The second option is to escalate the purchase costs by the use of cost indices (Hydromantis, 2001). Only one input is required for this process, the Marshall and Swift Equipment Cost Index. The 1977 and 2000 purchase prices of the standard size equipment are stored in the CAPDET model and are updated automatically if the cost index is input into the program. The latter of the two methods requires fewer input values. If the model user inputs a cost for equipment, the index is not used to update the new costs.

Man-hour requirements for installation are dependent on the type and size of equipment. The relationships between man-hour requirements for installation and equipment size and type have been established and are presented in the designs for each unit process. The installation cost is estimated by multiplying the man-hour requirements by the input labor rates. In many cases, data concerning manpower requirements for equipment installation were found to be incomplete or nonexistent. In such cases, the model uses a percentage of purchase price factor to calculate the cost of equipment installation. These factors, in general, were obtained from equipment manufacturers and published sources.

The other minor costs for each type of equipment may include costs of piping, steel, instruments, electrical components, insulation, painting, insurance, taxes, and so forth. These items are estimated as a percentage of the purchase costs. The percentage values will vary with the type and size of equipment. These percentage values were established based on design experience, engineering judgment, manufacturers' inputs, and previously published literature (Hydromantis, 2001).

Costs for Building and Housing

Buildings are essential in certain unit processes for protection against weather or maintenance of a requisite environment. The building requirements are related to the equipment to be housed and are estimated as square footage of floor space. Building costs are estimated by multiplying the square footage of floor space required by the unit cost per square foot (Hydromantis, 2001).

Costs for Piping System

Piping costs are evaluated independently. Estimating process piping costs presents the greatest challenge for the cost engineer. Estimating costs from detailed drawings is an arduous, time-consuming task much beyond the scope of CAPDET. Evaluation on any other basis might produce widely varying results. To estimate the cost of the "major piping system," a combination of two well-established estimating methods used by the chemical industries is employed. The costs of material are estimated by the use of the Dickson "N" method, and the field erection cost is estimated by the cost of "joints" method. The R.A. Dickson "N" method uses a technique to estimate purchase price of piping material similar to the one proposed to estimate equipment costs. Relationships are developed between the cost ratios, designated as N factors, and sizes of pipe material (Hydromantis, 2001).

With these factors stored in CAPDET for cast iron pipe, steel pipe, fittings, and valves, the user inputs only a limited number of unit costs of the reference components. The field erection costs for the piping system can be estimated by use of the cost-per-joint method. The unit of work measurement is the joint (two for couplings and valves, three for tees, etc.). Because joints require the bulk of piping labor for erection, the costs of handling, hanging pipe placement, and insulation are estimated as a fraction of the cost of makeup joints. The man-hours of field erection per joint for various pipe sizes and materials, as well as the fraction for placing and insulating, are evaluated in the quantities calculations. The field erection costs of the piping system are estimated based on the labor requirements and unit labor price inputs. The total piping system costs are the sum of the following items: (1) piping material costs, (2) field erection costs, and (3) other minor costs as a percentage of total piping costs.

In many cases it is impractical, at the planning level, to identify piping quantities and sizes. In such cases, a percentage of other construction cost factors is used to estimate piping cost. The method used is specific for each process (Hydromantis 2001).

11.5.1.2 Total Capital Costs

The construction cost of wastewater treatment facilities involves not only the cost of the construction of unit processes but also other direct and indirect costs incurred in creating a functional facility. Piping and pumping, and instrumentation and controls are examples of direct costs; engineering and contingency are examples of indirect costs. The total capital cost is the sum of the construction cost and other direct and indirect costs. Based on the cost information obtained from the cost document for the centralized waste treatment industry (USEPA, 1998), the other direct and indirect costs are estimated to be 69 percent of the construction cost of the treatment units. Direct and indirect costs as percentage of construction cost are provided in Table 11-3. (See Attachment 11-1 in Appendix D for details.) The capital cost for a treatment unit is obtained by multiplying the construction cost by 1.69 to estimate the total capital cost of the treatment unit.

Table 11-3. Cost Factors Used to Estimate Capital Costs

Cost Item	Cost Type	Cost Factor (Percent of Construction Cost)
Construction cost	Direct	100
Piping	Direct	17
Instrumentation and controls	Direct	13
Engineering	Indirect	19.5
Contingency	Indirect	19.5
Total capital cost		169

For details, see Attachment 11-1 in Appendix D.

11.5.2 Operation and Maintenance Costs

The operation and maintenance costs of a wastewater treatment unit process can be divided into several major categories: energy, operation labor, maintenance labor, chemical costs, operation and maintenance material and supply costs, and sludge disposal costs. The techniques and methods used in CAPDET for estimating operation and maintenance costs are presented below (Hydromantis, 2001).

11.5.2.1 Energy

Energy costs are derived from the calculated use of electric power, fuel oil, or natural gas. The quantities calculations generate the quantities of energy use, whereas the cost calculations apply user input unit prices to calculate the unit process energy cost. The total energy cost of the treatment facility is simply the sum of the energy costs for the unit processes.

The cost of electric power is by far the predominant energy cost for most processes. The procedure for calculating electric power cost is presented below. For some processes energy cost may involve natural gas and fuel oil. Because natural gas and fuel oil are consumed in relatively few processes, the costs of these fuels are tabulated as a material cost. For costing these fuels EPA use techniques similar to those used to calculate electric power costs.

Electric power consumption is estimated for each unit process and is part of the output data from the quantities calculations of each process. The power consumption for the treatment facility is simply the sum of the power consumption for the unit processes. The power consumption is converted to costs by multiplying the power consumption (in kilowatt-hours per year) by the unit price input for electric power costs (in dollars per kilowatt hour). Electric power rates vary according to location, peak demand, and level of consumption. EPA used the CAPDET default national cost of $0.08 per kilowatt-hour.

11.5.2.2 Labor Costs

The cost of labor can be divided into four categories: operation, maintenance, administrative and general, and laboratory. Recommended staffing for the different levels of manpower required for each of the four labor groups was established by using several publications on staffing of wastewater treatment facilities. Based on staffing charts in the literature, equations were developed to estimate an average labor rate for each labor group as a function of Operator II labor rate. The user can input the Operator II labor rate or accept the default value. The labor cost in each group is then calculated using the labor rate and the man-hours. EPA used the CAPDET default labor rates.

Operation labor and maintenance labor are applied to the unit processes specified in the treatment alternatives. The man-hours required over a year’s time for operation labor and maintenance labor are calculated for each unit process. The total man-hours requirement is the sum of the requirement for each unit process in the treatment facility. However, administrative and general labor, as well as laboratory labor, is computed for the treatment facility as a whole. The man-hours required for administrative and general labor and for laboratory labor are determined from equations that involve average flow to the treatment plant.

11.5.2.3 Operation and Maintenance Material and Supply Costs

Operation and maintenance material and supply costs are calculated for each unit process. Typically, these costs are calculated as a percentage of the unit construction costs. The total operation and maintenance material and supply costs for the entire treatment facility are the sum of the costs for each unit process used in the treatment facility.

11.5.2.4 Chemical Costs

Four different chemicals are typically used at treatment facilities: lime, alum, ferric chloride, and polymers. Quantities of each chemical required by the treatment processes are calculated in the quantities calculations. These quantities are based on CAPDET's calculations to achieve desired removals or effluent concentrations from input (influent) concentrations. The cost of a chemical is determined by multiplying the amount required by the unit cost of the chemical. The total annual chemical costs for the facility are simply the sum of the five different chemicals used in the various processes.

11.5.2.5 Sludge Disposal Costs

The sludge generated by biological treatment units and DAF units is assumed to be dried and dewatered in sludge dewatering devices before being hauled off-site for land disposal. Therefore, for DAF and biological treatment systems, an additional annual cost of sludge disposal was added. CAPDET assumes sludge is dewatered in drying beds and sent to disposal at 50 percent solids content. A sludge disposal cost of $2.3/ton (Parker, 1998) was used for hauling of the dried sludge leaving the sludge dryer.

11.5.2.6 Total Operation and Maintenance

The total annual operation and maintenance cost is the sum of the energy costs, the labor costs, the operation and maintenance material and supply costs, the chemical costs, and the sludge disposal costs.

11.6 DESCRIPTION OF THE TREATMENT UNITS AND SELECTED DESIGN SPECIFICATIONS

For model runs, the cost modules in CAPDET are selected based on the treatment units required for the technology options shown previously in Table 11-1. This section describes the treatment units selected for the model runs. Descriptions of the treatment units, based on the technical document in CAPDET, are presented below (Hydromantis, 2001).

11.6.1 Preliminary Treatment

Preliminary treatment comprises two processes: screening and grit removal. Because most of the available cost information combines these processes and the costs of these treatment units are relatively small, cost estimates are parametric. Inaccuracy in estimating the cost of the preliminary treatment introduces only a small error in the total facility cost.

Screening devices are used to remove large objects that otherwise might damage pumps and other equipment, obstruct pipelines, and interfere with the normal operation of the treatment facilities. Bar screens are commonly used in the wastewater treatment facilities. Bar screens consist of vertical or inclined bars spaced at equal intervals across the channel where wastewater flows. The quantity of material removed by bar screening depends on the size of the bar spacings. These devices may be cleaned manually or mechanically. The design of bar screens is based on average and peak wastewater flow.

Grit removal is classified as a protective or a preventive measure. The process does not contribute materially to the reduction in the pollutant load applied to the wastewater treatment facility. Grit chambers are designed to remove grit, which can include sand, gravel, cinder, and other inorganic abrasive matter. Grit causes wear on pumps, fills pump sumps and sludge hoppers, clogs pipes and channels, and occupies valuable space in sludge digestion tanks. Grit removal, therefore, reduces the costs of maintaining mechanical equipment and eliminates operational difficulties caused by grit. Grit removal is recommended for small and large treatment facilities. Bar screens are usually installed ahead of grit chambers to remove large objects. The design of screens and grit chambers depends on the type selected, the type of grit removal equipment, the specifications of the selected grit removal equipment, and the quantity and quality of the grit to be handled. This process is part of preliminary treatment. Default design values in CAPDET were used to develop costs for preliminary treatment. A 15-year life expectancy was selected.

11.6.2 Dissolved Air Flotation

Flotation is a solid-liquid separation process. Separation is induced by introducing fine gas bubbles (usually air) into the system. The gas-solid aggregate has an overall bulk density less than the density of the liquid; thus, these aggregates rise to the surface of the fluid. Once the solid particles have floated to the surface, they can be collected by a skimming operation. In wastewater treatment, flotation is used as a clarifying process to remove suspended solids and as a thickening process to concentrate various types of sludges. However, the process generally is used for clarifying of certain industrial wastes and for concentrating waste-activated sludge.

Dissolved air flotation (DAF) involves air being dissolved in the wastewater under elevated pressures and later released at atmospheric pressure. The principal components of a dissolved air-pressure flotation system are a pressurizing pump, air injection facilities, a retention tank, a back pressure regulating device, and a flotation unit. The primary variables for flotation design are pressure, recycle ratio, feed solid concentration, detention period, air-to-solid ratio, use of polymers, and solids and hydraulic loadings. CAPDET sizes a circular DAF system with a concrete structure. Specific information on design specifications for DAF units was not available in the MPP detailed surveys. Therefore, the default design values in CAPDET were used to develop costs for dissolved air flotation. A 15-year life expectancy was selected.

11.6.3 Equalization

Equalization is used to dampen variable waste flows so that the treatment facility receives a relatively constant flow. It has been shown that many treatment processes operate better if extreme fluctuations in hydraulic and organic loadings are eliminated. Equalization basins are usually aerated to prevent the settling of solids and to prevent anaerobic conditions from developing.

The equalization basin volume is based on the magnitude and frequency of the variations in hydraulic and organic load. The basin volume required for equalizing dry weather diurnal flows is calculated based on two-hour flows for 24 consecutive hours. However, if the two-hour flow data are not available, the desired volume of the basin is based on the median flow (see Table 11-6). The program can be used for equalization of flows other than dry weather diurnal flows by inputting the required basin volume. Cost of equipment is calculated from current cost values in the selected database updated using the appropriate current cost indices. Default design values in CAPDET were used to develop costs including the assumption that the basin is aerated. A 15-year life expectancy was selected.

11.6.4 Lagoon

Lagoons have been extensively used for municipal and industrial wastewater treatment, where sufficient land area is available. According to the MPP detailed surveys reviewed for the proposed rulemaking, almost 30 percent of MPP facilities use a lagoon as part of their treatment system. Some of the reasons for the popularity of lagoons are that they (1) have operational stability with fluctuating loads, (2) usually require relatively unskilled operators, (3) incur low operational costs, and (4) involve low construction costs. Lagoons can be anaerobic, aerobic, or facultative.

Anaerobic lagoons are anaerobic throughout their depth, except for a very shallow upper layer. These lagoons are constructed deep to ensure anaerobic conditions and to conserve heat. Typically they are from 8 to 20 feet deep. Reductions of more than 65 percent of the influent BOD_5 are common with anaerobic lagoons.

For the model runs that included lagoons, an unlined anaerobic lagoon was selected with a BOD loading rate of 350 pounds per acre per day. A 12-foot lagoon depth and 15-year life expectancy were selected. Other parameters used to develop costs of an anaerobic lagoon were left at the default values provided by CAPDET.

11.6.5 Intermediate Pumping

Several locations in a treatment facility may require pumping. Pumping is typically required at points in the treatment train that create relatively high head losses or where a relatively consistent flow is desired for optimum performance (e.g., pumping wastewater from an anaerobic lagoon to a biological treatment system). The wastewater at this point is relatively clean and free from large solids, so that more efficient pumps can be used for these processes than for raw waste pumping. Default design values in CAPDET were used to develop costs for intermediate pumping stations. A 15-year life expectancy was selected.

11.6.6 Nitrification—Suspended Growth

Nitrogen in wastewater is present in several forms including organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. The prevalent forms in untreated MPP wastewater are organic nitrogen and ammonia nitrogen. Organic nitrogen exists in both soluble and particulate forms.

Nitrification is the process that converts organic and ammonia nitrogen to nitrate nitrogen. Nitrification may be coupled with denitrification, which reduces nitrate to nitrogen gas and removes the nitrogen from the water.

Suspended growth nitrification systems are similar in design to carbon oxidation-activated sludge systems. The biological growth is suspended in an aeration basin. Mechanical or diffused aerators provide oxygen for nitrification and provide mixing that keeps the solids in suspension. The mixed liquor is then clarified to remove suspended solids and concentrate the sludge for recycle. The solids retention time in a nitrification system is longer than that in a carbon oxidation system given the slower growth rate of the nitrifiers compared to heterotrophic bacteria. The plug flow suspended growth system is considered in CAPDET. Default design values in CAPDET were used to develop costs of a nitrification system. A 15-year life expectancy was selected. As described further in Section 11.9.2, there are situations where new unit processes may not be required to achieve full nitrification. To account for the ability of facilities to upgrade existing nitrification-suspended growth systems, EPA estimated retrofit costs.

11.6.7 Biological Nitrogen Removal

Biological nitrogen removal encompasses both nitrification and denitrification. Nitrification is the process that converts organic and ammonia nitrogen to nitrate nitrogen. Nitrification may be coupled with denitrification, which reduces nitrate to nitrogen gas and removes the nitrogen from the water. Experience has shown that significant biological nitrogen removal activity does not occur in strictly aerobic systems. Rather, such activity is achieved by incorporating an unaerated zone into the process design. For denitrification, an anoxic stage (nitrate present, no oxygen) is included. The reactor configuration typically includes an anaerobic/unaerated stage ahead of an aerobic reactor. These reactors are followed by a secondary clarifier used to concentrate the sludge and return it to the unaerated stage.

Denitrification is a two-step biological process. Nitrate is converted to nitrite, which in turn is reduced to nitrogen gas. This two-step process is termed “dissimilation.” A broad range of bacteria, including *pseudomonas*, *micrococcus*, *achromobacter* and *bacillus*, can accomplish denitrification. These bacteria can use either nitrate or oxygen to oxidize organic material. Because the use of oxygen is more energetically favorable than using nitrate, denitrification must be conducted in the absence of oxygen (anoxic condition) to ensure that nitrate, rather than oxygen, is used in the oxidation of the organic material. For denitrification to occur, a carbon source must be available for oxidation. Carbonaceous material in the raw wastewater is often used as a carbon source. However, if the carbonaceous material in the wastewater is not available, an external carbon source may have to be added to the denitrification system. Default design values in CAPDET were used for the design parameters to develop costs for biological nitrogen removal. A 15-year life expectancy was selected.

11.6.8 Biological Nutrient Removal—3/5 Stage

Biological nutrient removal (BNR) encompasses both nitrogen removal and excess biological phosphorus removal. Excess biological phosphorus removal is a biologically mediated process used within activated sludge systems to achieve phosphorus removal from wastewater. The process involves cultivating certain microorganisms within the mixed community. These microorganisms, termed polyphosphate accumulating organisms (PAOs), have the ability to take up more phosphorus than they require for growth. The net effect of this uptake is a reduction of phosphorus concentration in wastewater to a level that can be less than 1 mg/L.

Experience has shown that significant BNR activity does not occur in strictly aerobic systems. Rather, BNR behavior is achieved by incorporating an unaerated zone into the process design. For denitrification, an anoxic stage (nitrate present, no oxygen) is included, and for phosphorus removal, an anaerobic stage (neither nitrate nor oxygen present) must be included in the reactor configuration. For a description of the nitrification and denitrification stages, refer to Section 11.6.7.

The three-stage BNR configuration includes an anaerobic stage, followed by an anoxic stage followed by an aerobic stage. One internal recycle is used to recycle nitrate from the aerobic stage to the anoxic stage and a return activated sludge (RAS) recycle is used to recycle thickened sludge from the clarifier to the anaerobic stage.

The five-stage configuration (also termed a “modified Bardenpho”) is similar to the three-stage configuration in that the first three reactors are similar and one internal recycle recycles nitrate to the anoxic stage. However, to increase the nutrient removal capacity, two additional stages are placed after the aerobic stage and before the clarifier. The first of these stages is anoxic for more denitrification, and the second is aerobic for effluent polishing. The five-stage configuration was selected to develop costs for this process. Default design values in CAPDET were used to develop costs for the BNR process. A 15-year life expectancy was selected. It should be noted that due to limitations of the CAPDET model, EPA could not adjust for the fact that treatment in an anaerobic lagoon precedes the BNR process. This limitation most likely results in overestimating the cost for the BNR process.

11.6.9 Secondary Clarification

Secondary clarifiers are commonly used in conjunction with biological wastewater treatment systems to remove settleable solids. They produce an effluent low in suspended solids and an underflow of sufficient concentration to maintain a sufficient population of active microbial mass in the tank of biological activity. The secondary clarifiers are, therefore, designed to provide clarification, as well as thickening. The design of clarifiers is based on the solids loading rate, in addition to being governed by the overflow rate and detention time. The design calculation considers the peak incoming wastewater flow; the return sludge withdrawal usually takes place at a point very near the inlet to the tank. The performance of the final clarifiers is affected by the method of sludge withdrawal. The preferred sludge collection mechanism is a vacuum- or suction-type draw-off. Default design values in CAPDET were used to develop costs for secondary clarifiers. A 15-year life expectancy was selected. It should be noted that due to limitations of the CAPDET model, EPA could not adjust for the fact that treatment is an anaerobic lagoon precedes the BNR process. This limitation most likely results in overestimating the cost for the BNR process.

11.6.10 Filtration

Filtration is the removal of suspended solids (and bacteria) through a porous medium. The increasing concern for abatement of water pollution and the requirements for high-quality effluents from wastewater treatment facilities have resulted in the rapid and wide acceptance of filtration in wastewater treatment. Filtration is being used to remove biological floc from secondary effluents and phosphate precipitates from phosphate removal processes, and as a tertiary wastewater treatment operation to prepare effluents for reuse in water reuse, industry, agriculture, and recreation.

Granular media used in filtration include sand, coal, crushed anthracite, diatomaceous earth, perlite, and powdered, activated carbon. Sand filters have been most commonly. However, mixed dual-media and multi-media filters are more effective and easier and less expensive to operate than sand filters for the treatment of wastewaters. In the mixed dual-media and multi-media filters, two or three materials of different specific gravities and sizes are selected to ensure intermixing between the various media at the interfaces. Sand and anthracite are typically used for dual-media filters, while garnet is added for multi-media filters.

The design of filters depends on the influent wastewater characteristics, process and hydraulic loadings; method and intensity of cleaning; nature, size, and depth of the filtering material; and the required quality of the final effluent. Various sizes and types of filtration units are available in the market. For smaller installations, the package units usually are selected. For larger installations, concrete wall constructions are used for containing the filter units. A parametric cost curve is used for the package-type filtration units. The construction costs for the larger concrete wall, rectangular cell, and filtration systems are estimated based on equipment and material costs. Default design values in CAPDET were used to develop costs. A 15-year life expectancy was selected.

11.6.11 Drying Beds

Sludge drying beds are a common method for dewatering digested sludge, especially in small plants. Drying beds are usually constructed using 4 to 9 inches of sand over 8 to 18 inches of graded gravel. The beds are usually divided into at least three sections for operational purposes. An underdrain system, usually of vitrified clay pipes spaced 9 to 20 feet apart, is used to remove water.

The design of sludge beds is influenced by many factors, such as weather conditions, sludge characteristics, land value, proximity of residences, and use of sludge conditioning aids. Default design values in CAPDET were used to develop costs. Sludge produced in this process was assumed to contain 50 percent solids. A 15-year life expectancy was selected.

11.6.12 Disinfection

Disinfection is the selective destruction of pathogenic organisms; sterilization is the complete destruction of all microorganisms. Disinfection used in water and wastewater treatment has resulted in the control and reduction of waterborne diseases.

Disinfection may be accomplished through the use of chemical agents, physical agents, mechanical means, and radiation. In wastewater treatment the most commonly used disinfectant is chlorine; however, other halogens, ozone, and ultraviolet radiation have been used.

Ultraviolet (UV) disinfection has been used to disinfect wastewater for some time and is often the preferred disinfection method. UV disinfection has the following advantages over chemical methods: (1) no residual toxicity to aquatic communities; (2) more effective than chlorine in inactivating harmful viruses, spores, and cysts (e.g., *Cryptosporidium*); (3) improved safety; and (4) no production of harmful trihalomethanes and other chlorinated by-products.

The major disadvantage is cost, although this is improving as additional technology is brought to market. In addition, the UV sources must be cleaned regularly to maintain effective disinfection. High operational energy costs may also be a concern. EPA assumed that MPP facilities would use UV disinfection. Although this assumption may overestimate disinfection costs (as compared, for example, to chlorination), EPA feels that UV disinfection provides more environmental benefits than other options. Default design values in CAPDET were used to develop costs, and 15-year life expectancy was selected.

11.7 CAPDET MODEL INPUT

The input parameters required to run the CAPDET model consist of the influent pollutant concentrations, target effluent pollutant concentrations, wastewater flow, and design specifications of the treatment units. This section presents a discussion of the influent concentrations, effluent concentrations, and wastewater flow. The design specifications of the treatment units are discussed in Section 11.6.

11.7.1 Influent Concentrations

EPA obtained the influent concentrations from the 1-day, 3-day, and 5-day MPP sampling episodes. Data from the sampling locations that represent influent concentrations of the wastewater treatment system were selected. These sampling points were grouped based on the type of MPP operation shown in Table 11-2 in Section 11.3. For sampling points representing the same type of influent wastewater from multiple facilities, an average of the concentrations was taken. EPA reviewed and discarded those data that were questionable, based on engineering judgment. For example, BOD values that were reported higher than COD values were removed; total Kjedahl nitrogen values lower than ammonia values were removed. If data were not available, EPA derived data from similar operating facilities with similar wastewater characteristics.

Table 11-4 shows the influent concentrations used to run the CAPDET model. Default values provided in CAPDET were selected for the parameters for which no sampling value was available. These included percent volatile solids, cations, anions, nondegradable fraction of volatile suspended solids (VSS), and temperature. Soluble COD value was calculated assuming that the ratio of soluble BOD to BOD is same as the ratio of the soluble COD to COD. Because in most instances wastewater would be exposed to the atmosphere (i.e., exposed to oxygen), it was assumed that all nitrite would be converted to nitrate. Therefore, the nitrite concentration in the influent wastewater was assumed to be practically zero, and the nitrate concentration was set equal to the nitrate/nitrite concentration obtained from sampling episodes. The settleable solids value was obtained from the total suspended solids (TSS) concentration by using the following equation developed from data for domestic wastewater (Metcalf and Eddy, 1991):

Settleable solids = 0.0178 * TSS - 1.8031, where
TSS = total suspended solids concentration (mg/L).

11.7.2 Effluent Concentrations

The effluent concentrations were obtained from the 3-day and 5-day MPP sampling episodes performed by EPA and from MPP detailed survey responses. EPA identified best performing meat, poultry, rendering, and mixed facilities representing the technology options based on effluent concentrations and the TIP. If data were not available, EPA derived data from similar operating facilities with similar wastewater characteristics. Table 11-5 shows the long-term the effluent concentrations used for running the CAPDET model.[1] The model did not require any effluent concentrations for Technology Option 1 for indirect dischargers because performance is based solely on percent removals of influent concentrations. The costs for

[1] It should be noted that for purposes of estimating costs, EPA extracted data from the sampling episodes and MPP detailed surveys prior to completion of pollutant load reduction. As a result, the values used to represent desired effluent concentrations for purposes of generating costs were slightly different from the long-term averages used to generate expected pollutant load reductions.

Table 11-4. Influent Concentrations Used as Model Input

Model Facility Grouping Code	BOD_5	Soluble BOD_5	COD	Soluble COD	TSS	TKN	Total P[a]	NH_3-N	O&G[b]	NO_3-N	pH
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	s.u.
R1	1,126	563	2,252	1,126	1,051	128	9	43	394	0.00	7.00
R2	1,492	1,150	2,630	2,027	363	24	82	15	163	2.13	8.99
R12	2,941	1,245	5,917	2,505	1,590	164	51	127	386	5.38	7.46
R13	4,209	1,223	15,204	4,418	3,532	78	54	43	406	0.01	7.42
R23	2,941	1,245	5,917	2,505	1,590	164	51	127	386	5.38	7.46
R123	2,941	1,245	5,917	2,505	1,590	164	51	127	386	5.38	7.46
P1	1,175	279	2,164	514	654	47	9	7	724	3.70	6.74
P2	1,760	660	5,000	1,875	1,295	161	72	6	424	0.38	6.60
P12	1,270	391	3,364	1,035	767	121	21	7	252	0.49	6.66
P13	2,000	780	5,000	1,951	1,220	132	26	11	619	1.24	6.60
P23	2,000	780	5,000	1,951	1,220	132	26	11	619	1.24	6.60
P123	2,000	780	5,000	1,951	1,220	132	26	11	619	1.24	6.60
M2	1,670	732	3,445	1,511	1,226	127	100	30	557	1.25	8.99
M23	1,670	732	3,445	1,511	1,226	127	100	30	557	1.25	8.99
Render	4,432	2,824	6,980	4,447	954	124	26	120	160	9.81	7.41

Note: Model facility groupings for which EPA screener survey did not identify any facilities are not shown.
[a] Total phosphorus.
[b] Oil and grease (HEM).

Table 11-5. Target Effluent Concentrations Used as Model Input

Meat Type	Discharge Type	Option	Soluble BOD5 mg/L	TSS mg/L	Total P[a] mg/L	Total Coliform cfu/100 mL	TKN mg/L	NH_3N[b] mg/L	NH_3N /TKN Ratio
Poultry	Direct	2	NR	8.60	NR	125	NR	0.44	NR
		3	1.53	8.27	NR	125	2.80	NR	0.17
		4	4.8	5.60	0.47	2	1.19	NR	NR
		5	3.00	5.50	0.41	2	1.29	NR	NR
	Indirect	2	NR	6.00	NR	NR	NR	0.60	NR
		3	2.96	6.00	NR	NR	3.57	NR	0.17
		4	4.80	5.60	0.47	NR	1.19	NR	NR
Meat	Direct	2	NR	21.67	NR	125	NR	0.57	NR
		3	1.53	8.27	NR	125	2.80	NR	0.17
		4	4.80	5.60	0.47	2	1.19	NR	NR
	Indirect	2	NR	34.60	NR	NR	NR	3.32	NR
		3	5.20	34.60	NR	NR	4.63	NR	0.72
		4	4.80	5.60	0.47	NR	1.19	NR	NR
Mixed	Direct	2	NR	7.88	NR	125	NR	0.38	NR
		3	1.53	8.27	NR	125	2.80	NR	0.17
		4	4.80	5.60	0.47	2	1.19	NR	NR
	Indirect	2	NR	34.60	NR	NR	NR	3.32	NR
		3	5.20	34.60	NR	NR	4.63	NR	0.72
		4	4.8	5.60	0.47	NR	1.19	NR	NR
Render	Direct	2	NR	21.67	NR	125	NR	0.57	NR
		3	1.53	8.27	NR	125	2.80	NR	0.17
		4	4.8	5.6	0.47	2	1.19	NR	NR
	Indirect	2	NR	34.60	NR	NR	NR	3.32	NR
		3	5.20	34.60	NR	NR	4.63	NR	0.72
		4	4.80	5.6	0.47	NR	1.19	NR	NR

NR: input not required to run that option.
[a] Total phosphorus.
[b] Concentrations during summer; concentrations during winter are 2.5 (default value) times summer concentration.

Technology Option 1 for direct dischargers were obtained from the costs of Technology Option 2. Therefore, Technology Option 1 for direct dischargers did not require any effluent concentrations.

11.7.3 Flow

Based on statistical analysis of the data in the MPP screener survey EPA developed 76 model facilities. (See Section 11.3.) The wastewater flow for each model facility, hereafter referred to as model facility flow, is equal to the median wastewater flow of the corresponding facilities identified in the MPP screener survey. Table 11-6 shows the model facility flows for 76 model facilities used in CAPDET model runs.

CAPDET requires average flow, maximum flow, and minimum flow of the treatment system to be costed as input to run the model. For each model facility, the average flow was taken equal to the respective model facility flow shown in Table 11-6. Since most facilities operate 5 days a week, the average daily flow (gallons/day) for Option 1 for indirect dischargers was calculated by dividing the flows (gallons/year) as reported in the screener surveys by 260 days/year. (Note: Option 1 for indirect discharges has equalization at the end of the treatment system.) All other options include some sort of biological treatment following equalization; therefore, a constant flow over 365 days a year was assumed for biological treatment for Indirect Options 2, 3, and 4. The treatment units for those options were costed on an average daily flow (gallons/day) obtained by dividing the flows (gallons/year) by 365 days/year. The maximum flow and the minimum flows were taken equal to 125 percent and 75 percent of the average flow, respectively.

11.8 OTHER COST MODELING PARAMETERS

In addition the costs provided by CAPDET, other cost modeling parameters were used to obtain industry-wide compliance costs. A description of other cost modeling parameters is provided below.

Table 11-6. Model Facility Median Flows for 76 Model Facility Categories

Model Facility Grouping Code	Flow (gallons/year)			
	Small	Medium	Large	Very Large
R1	120,000	7,164,858	N/A	N/A
R12	150,000	114,000,000	N/A	N/A
R13	366,300	163,800,000	242,207,998	745,000,000
R123	300,000	547,500,000	888,329,000	N/A
R2	100,000	23,580,000	4,507,584	2,588,000
R23	18,900	150,992,000	N/A	N/A
P1	4,169,000	188,005,312	230,124,007	501,764,107
P12	90,000	90,040,000	234,375,494	418,113,000
P13	N/A	110,463,705	413,250,000	442,000,000
P123	N/A	122,845,544	730,000,000	722,693,232
P2	199,100	22,321,000	112,887,720	8,000,000
P23	910,000	12,696,150	221,000,000	N/A
Render	36,500,000	8,925,000	23,400,000	46,081,200
M2	150,000	65,000,000	N/A	N/A
M23	663,000	N/A	N/A	N/A

Note: Model facility groupings for which EPA screener survey did not identify any facilities are not shown.
N/A: Not applicable because the EPA screener survey did not identify any facilities in this model facility classification.

11.8.1 Number of Facilities

Based on statistical analysis of the data in the MPP Screener Survey, EPA developed national estimates for the direct and indirect discharging facilities representing the 76 model facilities. Table 11-7 shows the national estimates by model facility category. These estimates do not include the 65 certainty select facilities because those facilities were not included in the MPP screener survey. EPA determined the incremental costs of the 65 certainty select facilities separately, based on the model facility category costs and the number of facilities.

Table 11-7. Number of Facilities in 19 MPP Facility Groupings by Size

Model Facility Grouping Code	Direct dischargers				Indirect dischargers			
	Small	Medium	Large	Very Large	Small	Medium	Large	Very Large
R1	17	6	0	0	265	0	0	0
R12	0	0	0	0	674	28	0	0
R13	17	17	7	12	12	7	3	5
R123	25	17	7	0	50	12	5	0
R2	43	10	1	1	2,489	160	4	4
R23	0	4	0	0	32	7	0	0
P1	0	17	25	7	19	32	48	12
P12	0	6	2	8	20	11	4	14
P13	0	7	8	2	0	2	2	1
P123	0	2	3	1	0	3	7	2
P2	0	10	1	2	272	133	4	18
P23	0	0	0	0	4	9	6	0
Render	6	7	6	8	17	26	21	28
M2	9	5	0	0	707	97	0	0
M23	0	0	0	0	4	0	0	0

Note: Model facility groupings for which EPA screener survey did not identify any facilities are not shown.

11.8.2 Frequency of Occurrence

EPA developed 76 model facilities, as discussed in Section 11.3. EPA considered only the direct and the indirect discharging facilities because those types of facilities will be affected by the proposed regulation. Because the wastewater in a direct discharging facility generally undergoes more treatment before discharge than that of an indirect discharging facility, the model facility categories were further grouped by the type of discharge. Because of the limited number of responses in the MPP detailed survey, the Agency grouped the medium, large, and very large direct and indirect facilities into two “non-small” facility groups for estimating current TIP.

EPA evaluated the wastewater treatment systems of all the direct and indirect discharging facilities in the MPP detailed survey. To determine the wastewater treatment upgrades necessary for the facilities to be in compliance with the proposed regulation, the Agency compared the existing TIP of the facilities with those of the technology options (Table 11-1). Based on the comparison, EPA determined the frequency of occurrence of treatment units for each of the model facility categories. Frequency of occurrence of a treatment unit is defined as the ratio of the number of facilities that have the treatment unit in place (or other treatment units that can perform the same function) to the total number of facilities in that category. The treatment units considered are those which are listed for the technology options in Table 11-1. As previously stated, EPA applied the same frequency of occurrence distribution across medium, large, and very large facilities for each of the two “non-small” facility groups. That is, the same frequency of occurrence distribution for each treatment unit was applied to all non-small indirect dischargers and the same frequency of occurrence distribution for each treatment unit was applied to all non-small direct dischargers. The frequency of occurrence of treatment units for each model facility is available in Attachment 11-2 in Appendix D. Facilities that do not have a treatment unit incur costs to upgrade to achieve the performance of the proposed technology options.

11.8.3 Number of Treatment Units Required

Because frequency of occurrence represents the fraction of facilities that have the treatment unit in place, “[1- frequency of occurrence]” represents the fraction of facilities that require the treatment unit for the technology option considered. Therefore, the number of facilities in a model facility category that require a treatment unit is given by

Number of facilities that require the treatment unit = $(1\text{-FO}) \times N$, where

FO = frequency of occurrence of a treatment unit and

N = national estimate of the number of facilities in the model facility category.

11.8.4 Performance Cost

EPA estimated the incremental cost for each technology option by comparing the existing TIP of a facility identified in the MPP detailed survey with that of the proposed technology option, costed for the additional treatment units needed to meet the technology option. Therefore, a facility identified by the MPP detailed survey that has a TIP similar to a technology treatment option does not accrue any additional cost for that technology option. It is expected that the facilities with a TIP comparable to an option should be able to meet the proposed effluent limits of that option. In reality, however, some of these facilities with TIP may not be able to meet the proposed effluent limits because of inadequate operational practices. Therefore, to calculate the cost of improving the performance, EPA assumed a 10 percent increase in the total annual costs of all the facilities with TIP as performance cost. The performance cost may include cost for improving operation of the treatment plant, changing sludge retention time, altering dissolved oxygen content of wastewater in the tanks, mixing, monitoring, automation, and other costs that would improve the performance of the plant to achieve the desired effluent concentration.

Performance cost is also used to determine the costs for Technology Option 1 from the costs of Technology Option 2. Although Technology Option 1 contains the same treatment units as Technology Option 2 (see Table 11-1), the effluent quality of Technology Option 1 is inferior to that of Technology Option 2 because of limited nitrification. However, a facility with Technology Option 1 might achieve the effluent quality of Technology Option 2 by improving the operational practices (e.g., changing solids retention time, blowing more air to the aeration basin etc.). Therefore, the costs for Technology Option 1 for direct dischargers are determined to be equal to the costs of Technology Option 2, without the performance cost.

11.9 DERIVATION OF COST ESTIMATES

EPA determined compliance costs for the proposed options using the results of the CAPDET model runs and other cost modeling parameters (Section 11.8). For Technology Option 3 and Option 4 EPA also determined the compliance costs by retrofitting the existing treatment systems. This section discusses the method used to calculate the compliance costs with and without consideration of retrofit costs. Table 11-8 shows by size and discharge type the technology options that are costed for the proposed regulation.

Table 11-8. Technology Options by Size and Discharge Type Costed for the Proposed Regulation

Discharge Type	Technology Option	Non-Small Facilities		Small Facilities	
		Direct	Indirect	Direct	Indirect
Direct	1			X	
	2	X		X	
	3	X		X	
	3 (with retrofit costs)	X		X	
	4	X			
	4 (with retrofit costs)	X			
	5 (poultry only)	X			
Indirect	1		X		X
	2		X		X
	3		X		X
	3 (with retrofit costs)		X		
	4		X		X
	4 (with retrofit costs)		X		

X: Category is costed for that option.

EPA used the model facility approach to determine the incremental costs for the proposed rule. CAPDET was used for developing construction cost and annual operating and maintenance costs of treatment units for the model facility flow. The capital cost of a treatment unit was calculated using the construction cost obtained from CAPDET. The costs of a treatment unit times the number of facilities that require the upgrade yielded the incremental costs for each set of model facilities. The number of facilities that require upgrade is equal to the product of the "[1- frequency of occurrence]" of the treatment unit and the total number of facilities in the model facility category (see Section 11.8.3). As described in Section 11.9.2, retrofit costs for the applicable technology options were developed from the set of model facility costs. The model facility costs and the retrofit costs were combined separately to determine costs by regulatory subcategory.

The step-by-step method for calculating the incremental industry-wide cost is summarized below:

- Use the MPP screener survey data to establish production levels for each of the 76 model facilities.

- Use the MPP screener survey data to identify the median wastewater flow (model facility flow), and to estimate the number of MPP facilities nationally represented by each of the 76 model facilities.

- Use the MPP detailed survey data to determine frequency of occurrence for treatment units in each of the 76 model facilities.

- Develop construction costs and annual costs of treatment units from CAPDET using model facility wastewater flows and typical influent and effluent pollutant concentrations.

- Estimate capital costs of treatment units from construction costs (see Section 11.5).

- Estimate capital and annual costs on a national basis for each regulatory option of the 76 model facilities using capital and annual costs of treatment units, frequency of occurrence, and national estimate of MPP facilities for each of the 76 model facilities.

- Estimate the regulatory cost for each subcategory based on the model facility costs.

11.9.1 Model Facility Costs Without Consideration To Retrofit Costs

As discussed in Section 11.3, EPA developed 76 model facilities to represent the broad range of MPP facilities in current operation. Running the CAPDET model was the first step in calculating the incremental compliance costs. For each model facility, a process schematic representing the technology options (see Table 11-1) was developed in CAPDET. A preliminary treatment module in CAPDET that consisted of screen and grit removal was selected to represent the screens. The biological treatment units costed in CAPDET were nitrification module (under suspended growth) for Option 2, biological nitrogen removal module (under biological nutrient removal) for Option 3, and biological nutrient removal module with 3/5 stage (under biological nutrient removal) for Option 4 and Option 5. The biological treatment system consisted of the biological treatment units, clarifiers, pumps, blowers, and sludge drying beds.

Section 11.6 discusses the selected design specifications for the treatment units. The required input influent and effluent concentrations of the pollutants and the model facility flow used for the model runs are explained in Section 11.7.

With a given set of concentrations and flow, CAPDET calculates the construction cost and the annual operation costs of individual treatment units, as well as the total annual cost of the treatment scheme. The total annual cost of the treatment scheme is the sum of the annual operating costs of the treatment units and the labor costs for administrative and laboratory work (see Section 11.5.2). Because labor costs for administrative and laboratory work are available for the entire treatment system, the costs were proportioned to individual treatment units, based on the individual operation costs generated by CAPDET. Therefore, the annual operation cost of a treatment unit is the sum of the individual annual costs generated by CAPDET and the proportional costs of administrative and laboratory labor. For DAF and biological treatment systems, an additional annual cost of sludge disposal was added. A sludge disposal cost of $2.3/ton (Parker, 1998) was used as the cost for hauling of the dried sludge leaving the sludge dryer.

The construction cost of a treatment unit was obtained as an output of the CAPDET model runs. As discussed in Section 11.5.1, the capital cost of the treatment unit is obtained by multiplying the construction cost by 1.69. The model runs were performed using the 2000 cost database provided in CAPDET. The costs were adjusted to 1999 dollars using the *Engineering News* index (ENR, 2001). Once the capital and annual operating costs associated with treatment units were determined, the incremental capital and annual costs by model facility category were obtained by multiplying the treatment unit costs by the number of treatment units required for the technology option (see Section 11.8.3).

The national estimate of the number of facilities in the model facility category shown in Table 11-7 does not include the 65 certainty select facilities. EPA determined the incremental costs of the 65 certainty select facilities, based on the model facility category costs and the number of facilities. These costs were added to obtain the total industry-wide costs for non-small facilities.

Costs by model facility category are provided in Attachment 11-3 in Appendix D. Costs for Technology Option 1 for direct dischargers were developed for small direct discharging facilities only. Since Technology Option 1 for direct dischargers is the same as Technology Option 2 with limited nitrification, the costs for Technology Option 1 for direct dischargers are equal to the costs of Technology Option 2 without the performance cost. Costs for Technology Option 5 for direct dischargers were developed for poultry facilities only.

11.9.2 Model Facility Category Costs With Consideration to Retrofit Costs

EPA observed that many operations with some sort of treatment already in place may be able to upgrade the existing treatment process rather than construct an entirely new structure. The method of cost calculation described earlier in Section 11.9.1 assumes that even if a facility had a nitrification system in place, it would incur a cost of a new nitrification and denitrification (N+DN) system for Technology Option 3 and a new nitrification/denitrification with phosphorus removal (N+DN+DP) for Technology Option 4. These represent an upper bound of the cost because in reality the nitrification system can be retrofitted to a N+DN system, which may be retrofitted to a N+DN+DP system. Therefore, for Technology Options 3 and 4 two types of capital costs are calculated: upper bound costs and retrofit costs.

In light of the ability to retrofit nitrification to accomplish both nitrification and denitrification or to upgrade nitrification/denitrification to accomplish nitrification/denitrification with phosphorus removal, EPA solicited information related to retrofit costs from several technical experts for use in estimating compliance costs for the MPP industry. EPA contacted two experts in MPP wastewater treatment design and biological nutrient removal wastewater treatment systems (Tetra Tech, 2001).

Based on the input from these two experts, Table 11-9 presents the retrofit costs (as a percent of the cost of a nitrification system) as those needed to (1) upgrade a nitrification system to a N+DN system and (2) upgrade a nitrification system to a N+DN+DP system. As shown, each expert provided a range of estimates, which were relatively close to each other. The experts also noted that the upgrades might be as complicated as partitioning existing aeration tanks and/or adding additional tanks and accessories (generally reflected by the upper end of the range) or as simple as operational changes, such as switching air flow to the aeration basin on and off periodically (generally reflected by the lower end of the range).

Table 11-9. Estimated Retrofit Costs (As Percent of Nitrification Costs) to Upgrade a Nitrification System

Scenario	Estimate 1	Estimate 2
Nitrification to N+DN	25%–50%	15%–40%
Nitrification to N+DN+DP	50%–75%	25%–65%

Source: Tetra Tech, 2001.

Although the estimates provided by the two experts are very close, the arithmetic average of the midpoint of the range of the percentages they provided was used as the basis for incorporating retrofit costs into the MPP industry compliance cost estimates. In summary, it is estimated that to upgrade a nitrification system to a N+DN system, a facility would incur 33 percent of the capital cost of a nitrification system. To upgrade a nitrification system to a N+DN+DP system, a facility would incur 54 percent of the capital cost of a nitrification system. Therefore, retrofit costs were calculated for only Technology Options 3 and 4.

For the direct discharger technology options, nitrification costs were not available to calculate potential retrofit costs. (All direct dischargers were assumed to be performing biological treatment with nitrification, based on results from the MPP detailed survey.) Therefore, capital costs from the nitrification/denitrification technology option (Technology Option 3) were used as a surrogate for the nitrification costs. Because in most cases the Technology Option 3 costs would be expected to be lower than nitrification costs (generally because less oxygen is required and less control is needed for alkalinity), the retrofit percentages of 33 percent and 54 percent were increased. Specifically, based on professional judgment, it was assumed that to upgrade a nitrification system to a N+DN system, a facility would incur 45 percent of the capital cost of a greenfield nitrification/denitrification system and to upgrade a nitrification system to a N+DN+DP system, a facility would incur 65 percent of the capital cost of a greenfield nitrification/ denitrification system. As described in Section 11.11, these assumptions were reasonable when compared to actual costs at several MPP facilities.

For the indirect discharger regulatory options, it was assumed that there would be no real retrofit opportunities for the technology option requiring nitrification (Technology Option 2) because very few indirect dischargers possess the tanks and/or equipment for nitrification. However, based on the input from the experts there would be opportunities for retrofitting when moving to the nitrification/denitrification technology option (Technology Option 3) and the nitrification, denitrification, and phosphorus removal technology option (Technology Option 4). For these two technology options, the retrofit average percentages (33 percent and 54 percent) were used to adjust the compliance costs for only the fraction of those facilities that have the opportunity to retrofit.

11.10 ESTIMATED COSTS

The costs generated by the method outlined in Section 11.9 were used to calculate the compliance cost by regulatory category. This section presents the estimated costs for the proposed regulation.

11.10.1 Model Facility Costs

The model facility costs obtained by the method outlined in Section 11.9 are shown in the table provided in Attachment 11-3 of Appendix D. As shown in Table 11-7, results from the

EPA screener survey indicate that there are no MPP facilities for some model facilities (e.g., there are no reported MPP direct or indirect facilities for the "R1-Very Large" model facility). The costs for those categories are zero. Because all non-small facilities that discharge directly to surface waters currently have biological treatment with nitrification (based on data provided as part of the MPP detailed survey), the costs for Technology Option 2 were minimal. Costs for Technology Option 5 for direct dischargers were developed for poultry facilities only, while costs for Technology Option 1 for direct dischargers were developed for small direct discharging facilities only.

11.10.2 Regulatory Subcategory Costs

EPA developed a regulatory subcategory scheme for the proposed rule, based on various combinations of the 76 model facility category costs. There are 10 regulatory groupings, which are defined in Table 11-10.

Table 11-10. Definition of 10 MPP Regulatory Groupings

40 CFR Part 432 Subcategory	Facility Size[1]	Facility Type	Model Facility Grouping Code[a]
A, B, C, D	M, L, VL	Meat first processors	R1, R12, R13, R123
	S	Meat first processors	R1, R12, R13, R123
F, G, H, I	M, L, VL	Meat further processors	R2, R23, 0.61*M2[c]
	S[b]	Meat further processors	R2, R23, 0.59*M2[c], 0.5*M23[c]
J	M, L, VL	Independent renderers	Render
	S	Independent renderers	Render
K	M, L, VL	Poultry first processors	P1, P12, P13, P123
	S	Poultry first processors	P1, P12, P13, P123
L	M, L, VL	Poultry further processors	P2, P23, 0.39*M2[c]
	S	Poultry further processors	P2, P23, 0.41*M2[c], 0.5*M23[c]

[a] The following abbreviations apply: S = small, M = medium, L = large, VL = very large, R = meat facilities, P = poultry facilities, M = facilities producing both meat and poultry products, 1 = first processors, 2 = further processors, and 3 = meat or poultry facilities performing on-site rendering.

[b] This group of small meat further processors includes all meat facilities that annually produce fewer than 50 million pounds of finished product and all facilities currently covered under Subpart E (Small Processors).

[c] Costs of mixed meat are allocated to similar operations in the meat and poultry subcategory.

The 76 model facility costs are combined according to Table 11-10 to generate the costs by regulatory subcategory. For mixed (performing both meat and poultry) meat operations, the MPP screener survey identified only medium-sized facilities performing further processing (model facility code = M2) and small facilities performing further processing, and further processing and rendering (model facility codes = M2 and M23). EPA allocated the costs for mixed meat operations into the meat further processors regulatory grouping (40 CFR Part 432, Subcategories F through I) and poultry further processors regulatory grouping (40 CFR Part 432, Subcategory L) based on total annual production. EPA allocated the costs equally between the two groupings if production data were not available. Tables 11-11 to 11-14 show the costs by regulatory subcategory for non-small and small facilities.

11.11 COMPARISON OF MODEL PREDICTED COST WITH ACTUAL COST

Table 11-15 compares the costs (construction, capital, annual) provided by the facilities in the MPP detailed survey and the costs predicted by CAPDET. The costs are adjusted to 1999 dollars with the *Engineering News* cost index (ENR, 2001). As discussed in Section 11.5.1.2, the capital cost of a treatment unit is obtained by multiplying its construction cost by 1.69. The model runs were performed with the actual flows for these specific facilities provided in the MPP detailed survey by the facilities. However, the influent and the effluent concentrations of all the required pollutants were not available; therefore, the model runs were made with typical concentrations described in Section 11.7. For disinfection, the model runs were based on a UV disinfection system because the system was used to estimate the model facility category costs, as discussed in Section 11.9.

The percent difference in construction/capital cost varied between −34 percent and +44 percent, with the exception of one facility where the percent difference was +166 percent. [Note: Positive percentage differences indicate that the CAPDET model costs were higher than the actual costs and vice versa.] The percent difference in actual and model-predicted construction/capital costs for 6 out of 11 facilities is around 20 percent or lower. The percent difference in annual costs varied between −49 percent and 218 percent. The facility that has a difference of 218 percent uses chlorine for disinfection but was costed for a UV disinfection

Table 11-11. Incremental Capital, Retrofit, and Annual Costs of Non-small Direct Discharging Facilities

Tech. Option	Cost Type	Meat		Poultry		Rendering	65 Certainty Select Facilities	Total Costs
		A-D	F-I	K	L	J		
2	Capital	$8,246,826	$151,167	$1,484,907	$154,729	$0	$803,010	$10,840,639
	Annual	$8,341,357	$358,916	$4,319,010	$263,420	$512,217	$1,103,594	$14,898,514
3	Capital	$274,636,709	$2,466,851	$221,276,114	$12,148,868	$24,235,794	$42,781,147	$577,545,483
	Annual	$26,093,418	$380,659	$21,409,816	$1,446,099	$2,813,796	$4,171,503	$56,315,291
	Retrofit	$123,586,519	$1,110,083	$99,574,251	$5,466,990	$10,906,107	$19,251,516	$259,895,467
4	Capital	$567,299,659	$32,064,579	$292,840,006	$19,180,890	$27,388,270	$75,101,872	$1,013,875,276
	Annual	$49,288,019	$3,104,328	$25,768,368	$1,978,115	$2,949,043	$6,647,030	$89,734,903
	Retrofit	$178,513,861	$1,603,453	$143,829,474	$7,896,764	$15,753,266	$27,807,745	$375,404,564
5	Capital	N/A	N/A	$327,080,644	$17,719,557	N/A	$27,584,016	$372,384,217
	Annual	N/A	N/A	$26,630,326	$1,695,960	N/A	$2,266,103	$30,592,389

N/A: Not applicable because Direct Option 5 applies to poultry facilities only.

Table 11-12. Incremental Capital, Retrofit, and Annual Costs of Non-small Indirect Discharging Facilities

Tech. Option	Cost Type	Meat		Poultry		Rendering	65 Certainty Select Facilities	Total Costs
		A-D	F-I	K	L	J		
1	Capital	$32,125,587	$61,732,331	$42,407,911	$50,931,088	$3,497,420	$15,255,547	$205,949,884
	Annual	$3,134,010	$10,888,392	$5,560,401	$8,752,574	$862,033	$2,335,793	$31,533,203
2	Capital	$624,536,780	$388,978,549	$771,398,217	$375,177,189	$82,708,839	$179,423,966	$2,422,223,540
	Annual	$74,314,195	$53,466,015	$93,495,543	$57,932,593	$12,803,252	$23,360,928	$315,372,526
3	Capital	$460,188,220	$460,188,220	$637,073,223	$319,733,512	$121,046,542	$151,856,489	$2,050,062,606
	Annual	$40,491,298	$40,491,298	$55,838,473	$35,269,247	$13,057,455	$14,727,639	$198,823,125
	Retrofit	$374,210,631	$374,210,631	$575,708,468	$316,967,007	$78,857,861	$136,174,413	$1,838,354,575
4	Capital	$602,773,174	$602,773,174	$670,720,969	$444,047,365	$130,924,926	$190,219,346	$2,567,961,174
	Annual	$47,996,617	$47,996,617	$55,543,183	$40,216,343	$13,224,592	$16,246,718	$219,330,692
	Retrofit	$473,484,033	$473,484,033	$625,628,025	$442,131,680	$92,106,957	$172,749,802	$2,332,122,332

Table 11-13. Incremental Capital, Retrofit, and Annual Costs of Small Direct Discharging Facilities

Technology Option	Cost Type	Meat		Poultry		Rendering	Total Costs
		A-D	E-I	K	L	J	
1	Capital	$209,270	$137,394	$0	$22,523	$0	$369,187
	Annual	$7,002	$4,547	$0	$738	$0	$12,287
2	Capital	$209,270	$137,394	$0	$22,523	$0	$369,187
	Annual	$486,666	$273,721	$0	$26,343	$172,632	$959,362
3	Capital	$14,646,645	$1,452,166	$0	$682,701	$8,192,232	$24,973,744
	Annual	$2,752,231	$421,892	$0	$134,053	$909,610	$4,217,786
	Retrofit	$6,590,990	$653,475	$0	$307,215	$3,686,504	$11,238,185

Note: Zero costs ($0) indicate that no MPP facilities were identified from the MPP Screener Survey for this regulatory grouping.

Table 11-14. Incremental Capital and Annual Costs of Small Indirect Discharging Facilities for the Various TechnologyOptions

Technology Option	Cost Type	Meat		Poultry		Rendering	Total Costs
		A-D	E-I	K	L	J	
1	Capital	$119,827,472	$482,868,533	$4,546,294	$103,388,978	$2,796,848	$713,428,125
	Annual	$17,343,753	$70,665,654	$936,533	$16,386,885	$513,318	$105,846,143
2	Capital	$584,635,684	$1,559,329,895	$22,583,519	$376,667,269	$43,635,312	$2,586,851,679
	Annual	$100,720,499	$271,961,694	$3,641,817	$61,675,081	$6,030,492	$444,029,583
3	Capital	$592,231,249	$1,863,181,201	$26,520,704	$378,133,257	$36,320,992	$2,896,387,403
	Annual	$90,024,749	$281,660,364	$3,821,424	$54,803,074	$3,752,576	$434,062,187
4	Capital	$722,696,546	$2,207,175,158	$31,865,901	$446,101,763	$39,443,676	$3,447,283,044
	Annual	$96,489,992	$296,249,096	$4,032,023	$57,581,328	$3,717,570	$458,070,009

Table 11-15. Comparison of CAPDET Model Prediction of Capital (and Construction) and Annual Costs with Actual Costs

Facility Code	Treatment Units[a]	CAPDET Cost Model Prediction: Construction/ Capital Cost ($ 1999)	CAPDET Cost Model Prediction: Annual Cost ($ 1999)	Actual Cost: Construction/ Capital Cost ($ 1999)	Actual Cost: Annual Cost ($ 1999)	Percent Difference[c] (%): Construction/ Capital	Percent Difference[c] (%): Annual
3	E+S+D		52399		50,000		+5
1502	S+E+D+L+E+N+D N+U+SD		527,713		1,032,000		-49
1762	S+D	404,195[2]		374,091[2]		+8	
4558	D	464,171		460,644		+1	
	E+N+DN+DP	2,992,424		2,676,968		+12	
	D+E+N+DN+DP+U	4,677,927	308,746	3,252,461	97,179	+44	+218
4787	E+D	151,549[b]	53,665	128,118[b]	46,940	+18	+14
6519	E+D+E+N+DN+U+ SD		684,696		690,000		-1
7012	S+E+D+L		529,836		280,000		+89
7041	S+D	3,194,882		1,200,000		+166	
	N+DN	7,910667		5,600,000		+41	
	S+D+L+N+DN+U		1,479,012		1,555,813		-5
7995	S+E+D+N+DN+SD	5,760,829	775,041	4,873,287	545,419	+18	+42
	D	334,069[b]		276,915[b]		+21	
	E+N+DN	2,339,460[b]		1,743,810[b]		+34	
8842	S+D+E	297,103	63,056	448,225	113,093	-34	-44

[a] S = screen, D = dissolved air floatation, E = equalization basin, N = nitrfication, N+DN = nitrification and denitrification, N+DN+DP = nitrification and dentrification and phosphorous removal, U = ultraviolet disinfection, SD = sludge dryer.
[b] Construction cost.
[c] Percent difference = (CAPDET cost - actual cost) x 100/actual cost.

system, which might have contributed to a higher model-predicted cost. The percent difference in actual and model-predicted annual costs for four out of nine facilities is within +/-15 percent. Therefore, EPA concludes that, in most cases, the model is able to predict the actual cost with reasonable accuracy. The difference in actual and predicted cost estimates may be attributed to approximate cost estimates provided by the facilities, engineering judgments used in the selection of the model parameters, and/or use of typical concentrations instead of the actual design concentrations. However, note that in most cases the predicted cost is higher than the actual costs. This indicates that the costs estimated by EPA for the options are unlikely to underestimate actual costs that a facility would incur to achieve the technology treatment option. Therefore, the economic impact of these costs should not be underestimated

As described previously in Section 11.9.2, all nitrification systems can be retrofitted to N+DN and N+DN+DP systems, and the capital costs incurred for such an upgrade are approximately 33 percent and 54 percent of the cost of a nitrification system. Based on engineering judgment, EPA refined the factors to be 45 percent and 65 percent of the cost of a greenfield N+DN system, respectively. Therefore, the retrofit cost to upgrade an N+DN system to an N+DN+DP system is approximately 20 percent (= 65 percent − 45 percent) of the cost of an N+DN system. Estimated retrofit capital costs of N+DN and N+DN+DP by model facility category for non-small direct discharging facilities are shown in Table 11-16 and Table 11-18, respectively (taken from Table A-4 of Appendix A). These estimated costs were compared with the retrofit costs for N+DN and N+DN+DP available in the literature. Table 11-17 and Table 11-19 show the retrofit costs available in the literature for several wastewater treatment plants that may be upgraded to N+DN and N+DN+DP systems respectively. If the initial investment cost is available, then the percent increase in the cost to upgrade was calculated and compared. If the initial investment cost of the treatment plants (up to nitrification) was not available, a normalized parameter of retrofit cost/MGD was used for the basis of comparison. Retrofit capital costs divided by the flow provided the retrofit costs per unit flow.

As shown in Table 11-16, the estimated retrofit costs for N+DN systems ranged from $1.3 million/MGD to $43 million/MGD with a mean and a median of $6.5 million/MGD and $3.2 million/MGD, respectively (based on $ 1999). The cost per MGD estimated is compared with the retrofit cost per MGD available in the literature. The retrofit cost per MGD (based on 1999 $) as reported in Table 11-17 varied between $12,000/MGD and $3.7 million/MGD with a mean and a median of $650,000/MGD and $300,000/MGD. Thus, comparing the mean and the median, it can be said that the estimated retrofit costs are almost 10 times higher than the costs reported in the literature. As discussed in Section 11.8.4, depending on the type of upgrade required, retrofit costs might vary from 15 percent to 50 percent of the cost of the nitrification

Table 11-16. Retrofit Capital Costs of Nitrification/Denitrification by Category for the Proposed Regulation

Model Facility Grouping Code	Size	Retrofit Capital Costs[a] ($ 1999)	N+DN Frequency Factor[b]	Number of Facilities[c]	Flow[d] (MGD)	Retrofit Capital Cost ($ 1999/MGD)
R2	Medium	98,815	0.98	10	0.065	7,601,158
R13	Medium	28,083,452	0.14	17	0.449	4,278,158
R23	Medium	118,769	0.98	4	0.414	3,586,005
R123	Medium	1,370,040	0.98	17	1.5	2,686,354
R2	Large	6,498	0.98	1	0.012	27,075,000
R13	Large	15,839,177	0.14	7	0.664	3,962,489
R123	Large	957,706	0.98	7	2.43	2,815,126
R2	Very large	6,022	0.98	1	0.007	43,016,786
R13	Very large	77,336,143	0.14	12	2.04	3,673,437
P1	Medium	12,695,217	0.23	17	0.515	1,883,186
P2	Medium	3,582,590	0.20	10	0.061	7,341,373
P12	Medium	3,395,017	0.25	6	0.247	3,054,447
P13	Medium	4,608,071	0.33	7	0.303	3,242,677
P123	Medium	2,081,694	0.00	2	0.337	3,088,567
P1	Large	21,222,194	0.23	25	0.63	1,749,923
P2	Large	788,937	0.20	1	0.309	3,191,492
P12	Large	1,966,867	0.25	2	0.642	2,042,437
P13	Large	13,232,186	0.33	8	1.13	2,184,683
P123	Large	11,611,084	0	3	2	1,935,181
P1	Very large	9,805,491	0.23	7	1.37	1,327,884
P2	Very large	532,854	0.2	2	0.022	15,137,898
P12	Very large	11,624,854	0.25	8	1.15	1,684,761
P13	Very large	3,478,687	0.33	2	1.21	2,145,484
P123	Very large	3,852,889	0	1	1.98	1,945,903
M2	Medium	1,442,589	0.59	5	0.178	3,953,381
Render	Medium	2,488,431	0	7	0.024	14,812,088
Render	Large	2,943,171	0	6	0.064	7,664,509
Render	Very large	5,474,505	0	8	0.126	5,431,057
Mean						**6,518,266**
Median						**3,217,084**

[a] From Table D-3 in Attachment 11-3 in Appendix D.
[b] From Table D-1 in Appendix D.
[c] From Table 11-7.
[d] Derived from Table 11-6.

Table 11-17. Wastewater Treatment Plants Evaluated for Biological Nitrogen Removal

State	Treatment Plant	Estimated Retrofit Capital Cost (million $ 1999)	Design Flow (MGD)	Estimated Retrofit Capital Cost/Flow ($ 1999/MGD)
Pennsylvania	Altoona City (E)	1.23	9	136,667
	Altoona City (W)	1.233	13.5	91,333
	Chambersburg	6.347	4.5	1,410,444
	Greater Hazleton	7.84	8.9	880,899
	Hanover	0.06	4.5	13,333
	Harrisburg	25.448	30	848,267
	Lancaster	1.077	29.7	36,263
	Lebanon	4.039	8	504,875
	Scranton	2.815	16	175,938
	State College	0.78	6	130,000
	Susquehanna	1.619	12	134,917
	Throop	3.32	7	474,286
	Williamsport (C)	6.339	7.2	880,417
	Williamsport (W)	5.246	4.5	1,165,778
	Wyoming Valley	0.763	32	23,844
	York City	1.78	26	68,462
Maryland	Brunswick	0.39	0.7	557,143
	Chestertown	1.35	0.9	1,500,000
	Crisfield	1.949	1	1,949,000
	Elkton	1.97	2.7	729,630
	Federalsburg	1.525	0.75	2,033,333
	Georges Creek	1.663	0.6	2,771,667
	Indian Head	0.532	0.49	1,085,714
	Mattawoman	4.25	15	283,333
	Winebrenner	1.48	0.6	2,466,667
New York	Binghampton	13.057	25	522,280
	Endicott	6.656	8	832,000
Virginia	Arlington	0.56	30	18,667
	Colonial Beach	0.09	2	45,000
	Dahlgren	0.03	0.325	92,308
	Dale Services #1	0.22	3	73,333
	Dale Services #8	0.22	3	73,333
	Fishersville	0.79	2	395,000
	Front Royal	0.05	4	12,500
	Harrisonburg	4.688	16	293,000
	H.L.Mooney	0.49	18	27,222
	Leesburg	2.77	4.85	571,134

State	Treatment Plant	Estimated Retrofit Capital Cost (million $ 1999)	Design Flow (MGD)	Estimated Retrofit Capital Cost/Flow ($ 1999/MGD)
	Lower Potomac	20.8	67	310,448
	Middle River/Verona	0.15	4.5	33,333
	Occoquan	0.51	6.25	81,600
	Parkins Mill	0.097	2	48,500
	Purcellville	1.3	1	1,300,000
	Rocco Foods	4.48	1.2	3,733,333
	Strasburg	0.12	0.975	123,077
	Stuarts Draft	1.24	1.4	885,714
	Waynesboro	3.5	4	875,000
	Woodstock	0.07	1	70,000
Mean				**654,659**
Median				**310,448**

Source: Randall et al., 1991.

system. To account for all kinds of upgrading, an upper bound percentage (45 percent of the cost of a nitrification and denitrification system) was used for retrofit cost estimation. This approach resulted in higher cost estimates. However, it should be noted that the range of estimated retrofit cost per MGD and those reported in literature overlap. This indicates that few of the facilities reported in the literature may actually incur greater than or equal to 45 percent of the cost of an N+DN system.

The costs to upgrade an N+DN system to an N+DN+DP system for the two treatment plants shown in Table 11-19 are 8 percent and 12 percent of the cost of the N+DN system. This cost is below the selected percentage of 20 percent used by EPA to estimate the retrofit costs of N+DN+DP from N+DN systems. Considering the fact that the cost of upgrading to an N+DN+DP system varies from facility to facility, the Agency believes that the selected 20 percent increase in cost is a reasonable estimate. The model-predicted cost and the cost available in the literature were also compared based on cost per MGD. The retrofit costs were calculated assuming the cost to upgrade from nitrification to an N+DN+DP system is 65 percent of the cost of an N+DN system (see Section 11.8.4). The estimated retrofit costs for upgrade from nitrification to N+DN+DP systems ranged from $77,000/MGD to $21 million/MGD (based on

Table 11-18. Retrofit Capital Costs Of Nitrification/Denitrification/Phosphorous Removal

Model Facility Grouping Code	Size	Retrofit Capital Costs[a] ($ 1999)	N+DN+DP Frequency Factor[b]	Number of Facilities[c]	Flow[d] (MGD)	Retrofit Capital Cost ($ 1999/MGD)
R2	Medium	142,733	0	10	0.065	219,589
R13	Medium	40,564,987	0	17	0.449	5,314,422
R23	Medium	171,555	0	4	0.414	103,596
R123	Medium	1,978,947	0	17	1.5	77,606
R2	Large	9,386	0	1	0.012	782,167
R13	Large	22,878,812	0	7	0.664	4,922,292
R123	Large	1,383,353	0	7	2.43	81,326
R2	Very large	8,699	0	1	0.007	1,242,707
R13	Very large	111,707,762	0	12	2.04	4,563,226
P1	Medium	18,337,536	0.08	17	0.515	2,276,654
P2	Medium	5,174,852	0.07	10	0.061	9,121,897
P12	Medium	4,903,914	0	6	0.247	3,308,984
P13	Medium	6,656,102	0.22	7	0.303	4,023,321
P123	Medium	3,006,892	0	2	0.337	4,461,263
P1	Large	30,654,281	0.08	25	0.63	2,115,547
P2	Large	1,139,575	0.07	1	0.309	3,965,534
P12	Large	2,841,030	0	2	0.642	2,212,640
P13	Large	19,113,158	0.22	8	1.13	2,710,625
P123	Large	16,771,565	0	3	2	2,795,261
P1	Very large	14,163,487	0.08	7	1.37	1,605,328
P2	Very large	769,678	0.07	2	0.022	18,809,335
P12	Very large	16,791,455	0	8	1.15	1,825,158
P13	Very large	5,024,770	0.22	2	1.21	2,661,989
P123	Very large	5,565,284	0	1	1.98	2,810,749
M2	Medium	2,083,739	0.04	5	0.178	2,438,834
Render	Medium	3,594,400	0	7	0.024	21,395,238
Render	Large	4,251,248	0	6	0.064	11,070,957
Render	Very large	7,907,619	0	8	0.126	7,844,860
Mean						**4,455,754**
Median						**2,752,943**

[a] From Table D-3 in Attachment 11-3 in Appendix D.
[b] From Table D-3 in Appendix D.
[c] From Table 11-7.
[d] derived from Table 11-6.

Table 11-19. Wastewater Treatment Plants Evaluated for Biological Phosphorus Removal

State	Treatment Plant	Design Flow (MGD)	Retrofit Capital Cost from AS to N+DN (1999 million $)	Retrofit Capital Cost from AS to N+DN+DP (1999 million $)	Retrofit Capital Cost from AS to N+DN+DP/ Flow (1999 $/MGD)	Percent Increase in Cost from N+DN to N+DN+DP
Virginia	Leesburg	4.85	2.77	2.98	614,433	7.6%
	Occoquan	6.25	0.51	0.57	91,200	11.8%

AS = activated sludge process.
Source: Randall et al., 1999.

$ 1999) with a mean and a median of $4.5 million/MGD and $2.7 million/MGD, respectively. The cost per MGD estimated was compared with the retrofit cost per MGD available in the literature. The retrofit cost per MGD as reported in Table 11-19 are $600,000/MGD and $91,000/MGD (based on $ 1999). These values reported in the literature are within the spectrum of the estimated costs of $77,000/MGD and $21 million/MGD, although on the lower end. As discussed in Section 11.9.2, depending on the type of upgrade required, retrofit costs might vary from 25 percent to 75 percent of the cost of the nitrification system. However, to account for all kinds of upgrades, an upper bound percentage (65 percent of the cost of a N+DN system) was used for retrofit cost estimation. This might have resulted in higher EPA cost estimates.

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